

D90^{Plus}

Line Distance Protection System



Instruction Manual

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D90^{Plus} Line Distance Protection System Instruction Manual for version 1.9x.

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D90^{Plus} Line Distance Protection System

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D90^{Plus} Line Distance Protection System

Chapter 1: Introduction

This chapter outlines safety and technical support information for the D90^{Plus} Line Distance Protection SystemTM.

Safety symbols and definitions

Before attempting to install or use the device, review all safety indicators in this document to help prevent injury, equipment damage, or downtime.

The following safety and equipment symbols are used in this document.



Indicates a hazardous situation which, if not avoided, will result in death or serious injury.



Indicates a hazardous situation which, if not avoided, could result in death or serious injury.



Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.



Indicates practices not related to personal injury.

For further assistance

For product support, contact the information and call center as follows:

GE Grid Solutions
650 Markland Street
Markham, Ontario
Canada L6C 0M1
Worldwide telephone: +1 905 927 7070
Europe/Middle East/Africa telephone: +34 94 485 88 54
North America toll-free: 1 800 547 8629
Fax: +1 905 927 5098

Worldwide e-mail: multilin.tech@ge.com
Europe e-mail: multilin.tech.euro@ge.com
Website: <http://gegridsolutions.com/multilin>

D90^{Plus} Line Distance Protection System

Chapter 2: Product description

This chapter outlines the product, order codes, and specifications.

Product description

Designed for superior performance and ease-of-use, the D90^{Plus} is a single platform solution for protecting transmission lines from medium voltage (MV) to extra high voltage (EHV) and cables of various voltage levels. It allows transmission limits to be maintained or even increased while respecting the transient stability limits of the power system.

The scalable platform consists of protection, control, automation, monitoring, communication, digital fault recorder, and security functionality. This incremental scaling allows advanced customization to suit specific user requirements. The convergent platform integrates multiple devices, eliminating external devices and reducing the footprint of relay panels, resulting in reduced wiring, commissioning, and capital costs. The unique sub-cycle distance algorithm can trip in less than one power system cycle for source impedance ratios (SIR) up to 30.

The key benefits of the D90^{Plus} are

- Secure subcycle protection ensures trip times less than one cycle
- Reliable and secure protection on lines equipped with series compensation
- Superior phase selection algorithm ensures secure high speed single-pole tripping
- Simplified programmable automation controller eliminates the need for substation programmable logic controller
- Configurable alarm annunciator eliminates the need for separate annunciator panel
- Intuitive and easy-to-use large front panel color display with preconfigured information on metering, fault records, event records, and separate control screen for bay control
- High-end fault and disturbance recording, including internal relay operating signals, eliminating the need for redundant recording devices
- Reduced installation space requirements through compact design
- True convergence of protection, metering, automation, bay control functions, multiple input and output options, and extensive communications capability
- Built-in phasor measurement unit streaming synchrophasors as per IEEE C7.118

Firmware architecture

The D90^{Plus} is a sub-cycle distance protection and advanced automation controller that is organized into six functions.

- Protection
- Automation
- Metering
- Digital fault recorder (DFR)
- Equipment manager
- Front panel interface

These functions operate independently from one another. Each function has its own configuration settings and generates its own output signals. All functions share the hardware and the communications facilities within the device.

The protection function contains the necessary elements required to detect faults in the power system and send tripping signals to isolate the fault. This is the primary sub-system for many users. The protection function also has its own dedicated FlexLogic engine that runs at the same scan rate as the protection (16 times per power system cycle). Protection FlexLogic is used to create custom logic schemes for protection purposes.

The automation function is divided into two major sub-groupings: control schemes and automation logic. Control schemes are hard-coded general purpose schemes responsible for automatic control within the substation. These include breaker and disconnect switch control, interlocking, and synchrocheck. Automation logic is intended for development of custom or advanced automatic schemes where the user requires a level of functionality beyond that provided in the hard-coded schemes. Automation logic generally requires a lower execution rate than protection logic but with expanded functionality and lines of logic.

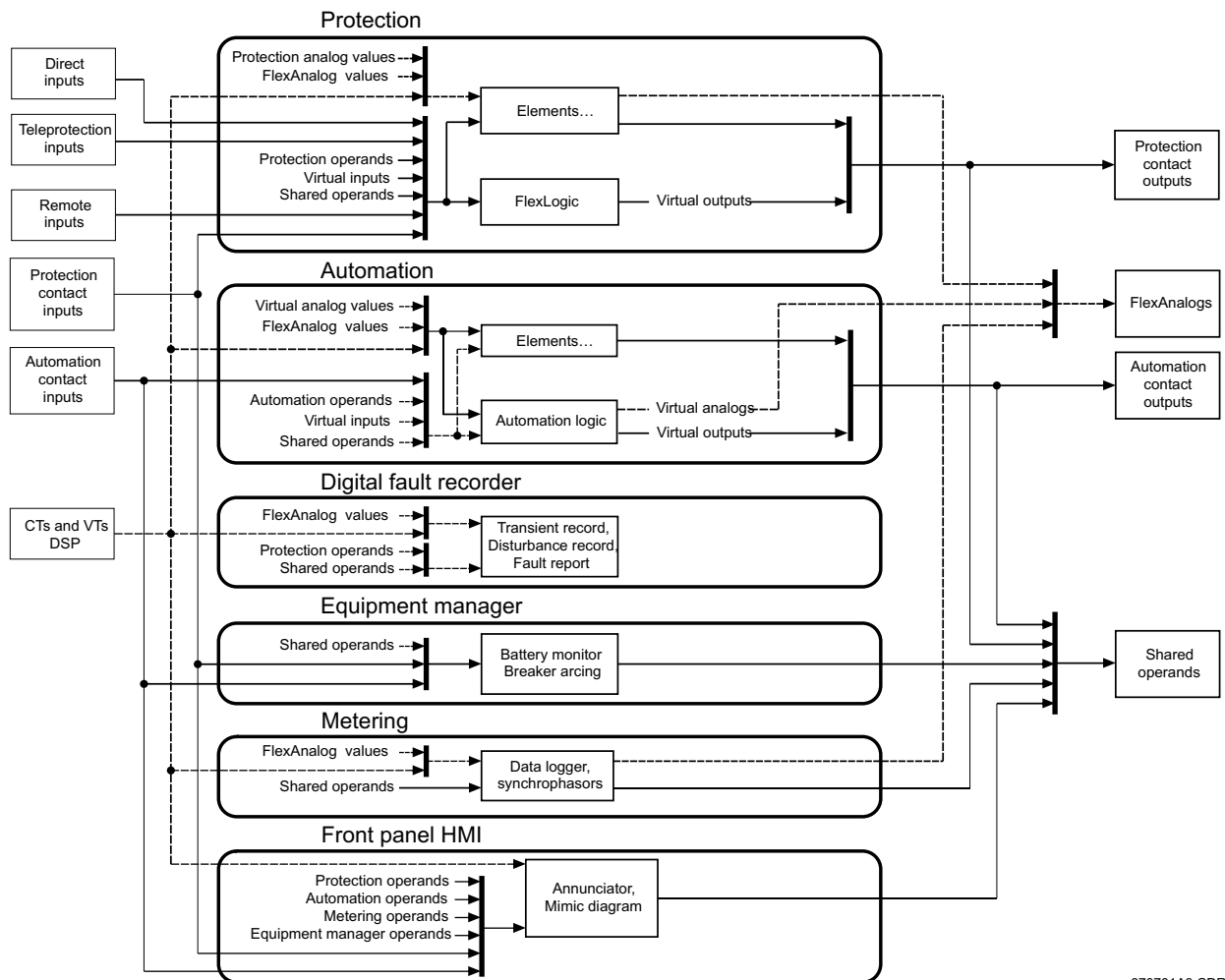
The metering function generates a range of real-time power system measurements, including voltage, current, frequency, complex power, and energy. It also incorporates a data logger that provides historical recording of selected metering quantities and includes statistical (maximum, minimum, and average) and alarm capabilities. The metering function also provides synchrophasor capabilities in accordance with IEEE C37.118-2005.

The digital fault recorder (DFR) function incorporates transient recorder, disturbance recorder, and fault report capabilities. The transient recorder is intended to capture short events, such as a fault at a high sampling rate (up to 256 samples per cycle). The disturbance recorder captures longer events, such as a power swing at a lower sampling rate. The channel assignments and triggering of these features can be independently configured. The fault report facility provides a comprehensive record of the key measurements associated with an event, including fault type, fault location, pre-fault and post-fault quantities, and clearing time.

The equipment manager function monitors important parameters of the station battery under normal operation and can be used to detect incipient failures.

Despite their logical separation, signals can be exchanged among these functions. For instance, it is useful for the digital fault recorder to record the output of protection functions. Consequently, a pre-determined set of signals is available as inputs to each function. The figure illustrates these signals.

Figure 1: Functional architecture



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The D90^{Plus} also includes shared operand functionality. Output signals from the various functions can be assigned as shared operands available to all functions. These signals can then be assigned as inputs within other functions.

For example, assume that the **PHASE TOC1 OP** protection FlexLogic operand is required as a signal within the automation function. This signal is then assigned as a shared operand. As such, the **PHASE TOC1 OP** operand subsequently becomes available to the automation function by appearing in the list of available operands.

Hardware architecture

The unit is a microprocessor-based device. It has a modular design, its chassis containing discrete modules that interface over a common bus. Each module has a specific purpose. Several modules are required for basic operation of the device, while others are optional.

The power supply module receives AC or DC power from an external supply and produces conditioned 12 V DC power for all modules in the chassis. The power supply also generates 48 V DC power for external contact wetting. The output contact indicating a critical failure of the unit also resides on this module.

The AC module measures AC currents and voltages derived from CTs and VTs. These signals are sampled and digitized and sent over the device's bus to the CPU module for further processing. A version is available that accepts nominal 5 A current and another that accepts nominal 1 A current.

Input and output modules monitor digital (on and off) signals from external devices (field contacts or other IEDs), control external devices such as breakers, and send digital signals to other devices. Input and output modules are subdivided into protection inputs and outputs and automation inputs and outputs, with several variations of each type.

The CPU module contains the firmware for the D90^{Plus}. The firmware contains the algorithms required for the various functions provided by the device. The CPU receives analog and digital data from the AC and input/output modules. The CPU processes the data and resulting control actions are sent back to the input-output modules. The CPU has one rear Ethernet port that is used for configuration and record retrieval and one rear RS485 port supporting the Modbus and DNP protocols. The CPU also contains the IRIG-B port required for clock synchronization.

The communications module is required for communicating with external devices over Ethernet using the trivial file transfer protocol (TFTP), HTTP, Parallel Redundancy Protocol (PTP), IEC 61850, DNP 3.0, or IEC60870-5-104 protocol. This module is also required for peer-to-peer GSSE/GOOSE messaging. This module contains its own microprocessor that is dedicated to handling communications tasks. It also contains two redundant Ethernet ports. Each port supports 100Base-FX over multi-mode fiber and 10/100Base-TX over twisted pair, with auto-negotiation. These ports can additionally be configured for single IP or dual IP redundancy.



The D90^{Plus} requires one power supply module, one CPU module, one AC module, and at least one protection input/output module. Communications modules are optional.

The front panel interface consists of an annunciator display, a main display, and an EnerVista USB port. The annunciator display collects alarm indications from the D90^{Plus} internal functions and presents them using a standard annunciator format. Alarms and their corresponding messages are entirely user-configurable. The main display allows the user to view metering data collected by the D90^{Plus}. It also provides access to the control functions via dedicated control pushbuttons. The USB port allows the user to interface with the D90^{Plus} using the EnerVista software running on a computer.

Figure 2: D90^{Plus} block diagram

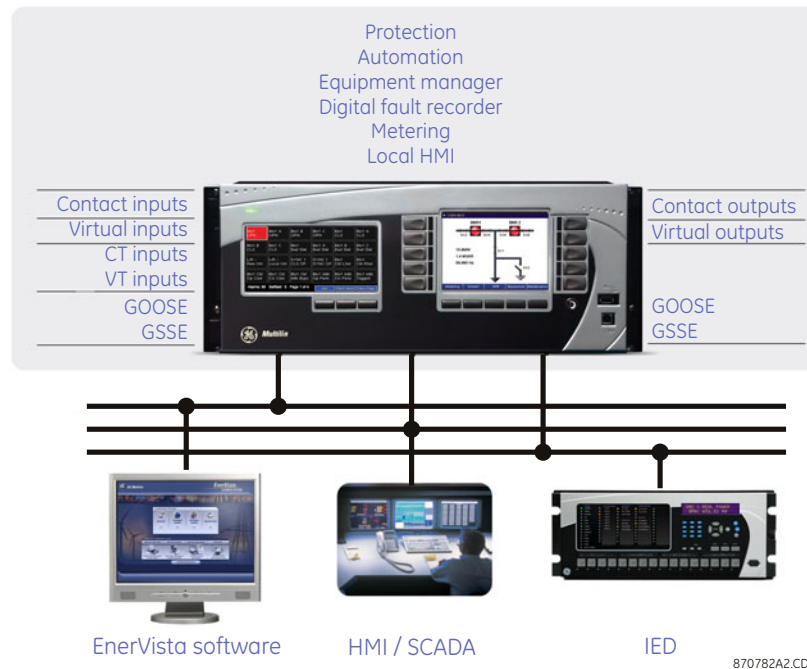
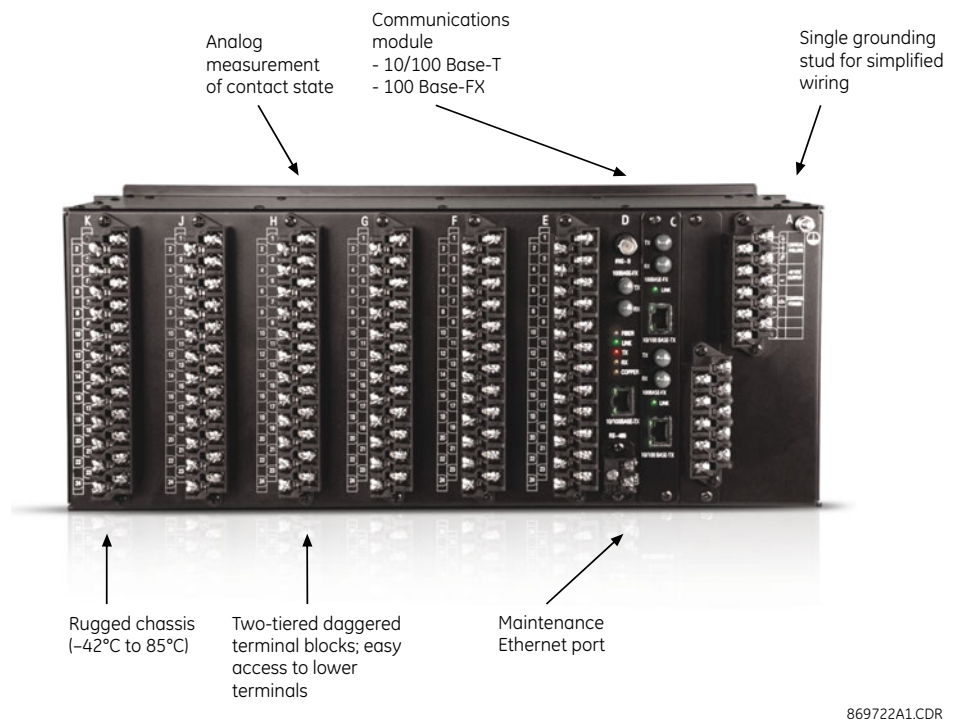


Figure 3: D90^{Plus} hardware overview

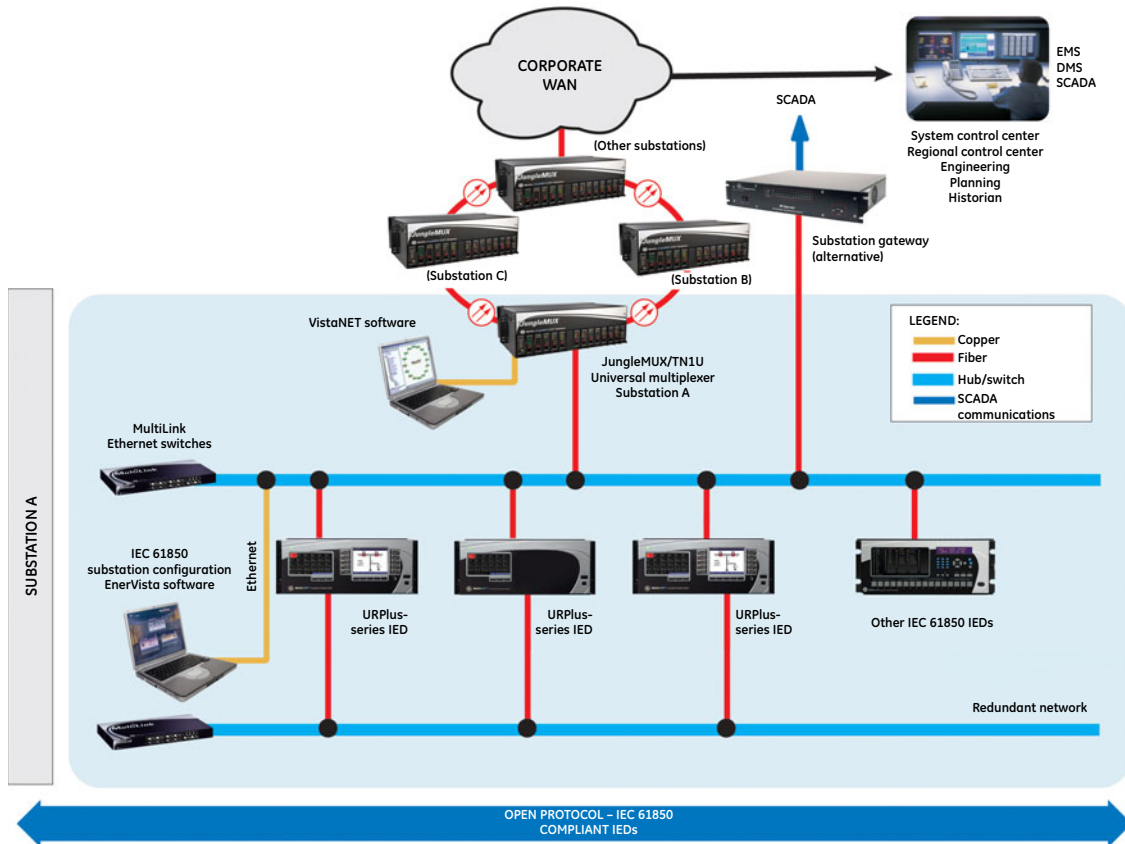


An option of the D90^{Plus} is support for the Parallel Redundancy Protocol (PRP) of IEC 62439-3 (clause 4, 2012). The PRP allows high availability in substation automation networks. It applies to networks based on Ethernet technology (ISO/IEC 8802-3).

Communications overview

The EnerVista UR^{Plus} Setup software can communicate with the relay through three ports: the front panel USB port, the rear Ethernet port, and the rear RS485 port. Both rear ports are located in slot D.

Figure 4: Communications overview



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To communicate through the D90^{Plus} rear RS485 port from a computer's RS232 port, the GE Multilin RS232/RS485 converter box is required. This device (catalog number F485) connects to the computer using a straight-through serial cable. A shielded twisted-pair (20, 22, or 24 AWG) connects the F485 converter to the D90^{Plus} rear communications port. The converter terminals (+, -, GND) are connected to the D90^{Plus} communication module (+, -, COM) terminals. Terminate the line with a 120 Ω, 1 nF R-C network.

Communications via Ethernet requires a connection to an Ethernet network using a standard copper or fiber cable. The Ethernet port can also connect directly to a computer using a cross-over cable.

To communicate via the faceplate USB port, use a standard USB serial cable. No converter box is required.

For additional information, refer to:

[Main processor module](#) on page 44.

Front panel interface

Information is displayed on the D90^{Plus} front panel through two display panels. One serves as a digital annunciator and the other reflects display and control functions. The panels provide easy access and visualization of device information, ranging from the large display

of metered values, such as voltage, current, demand, energy, and sequence components, to a comprehensive display of fault reports, sequence of events, and transient recorded waveforms. The front panel interface also displays device health information with critical and non-critical alarm status. The panels allow access to comprehensive information without having to navigate through conventional displays and keypads.

Annunciator

The D90^{Plus} provides an embedded, configurable color LCD annunciator on the front panel of the device, eliminating the need for LEDs and separate annunciators in the panel.

Any contact, direct input, remote input, or internally generated operand can be assigned to the annunciator. Up to 288 targets can be assigned. The display can be configured for 12, 24, or 48 alarms per page to a maximum of 24 pages. A separate self-test message page displays error messages about device health. This page also provides a graphical representation of the error messages, which assists in identifying and correcting problems.

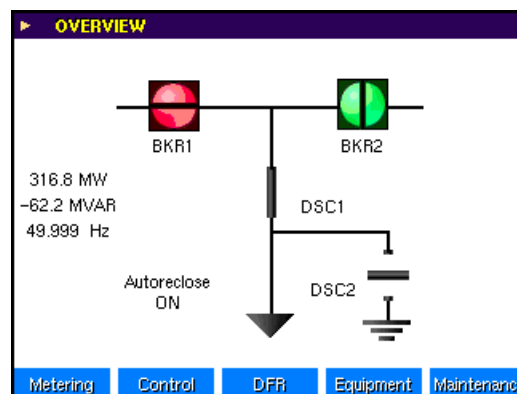
Figure 5: Typical annunciator display

Phase Distance Zone 1	Phase Distance Zone 2	Ground Distance Zone 1	Ground Distance Zone 2
Line Pickup	Pilot Scheme	Breaker 1 Failure	Breaker 2 Failure
Autoreclose Lockout	Fuse Failure	Setting Group 2 Active	Fault Report
Alarms: 6 Selftest: 1 Page 1 of 1			
Adv. Next Alarm Next Prop.			

Control functions

The front panel interface contains a mimic diagram that provides status and control for 2 breakers and up to 6 disconnect switches. Many different bay configurations can be realized through the setting of the device. Tagging of a device and substitution of device status can also be carried out through front panel. Status and control of the autoreclose function is also available through the mimic diagram.

Figure 6: Front panel control example



USB port

The front panel provides a USB 2.0 port for local connection to a computer.

Figure 7: Front panel USB connection



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Protection features

The D90^{Plus} is designed for superior performance and ease-of-use, providing a single platform solution for protecting transmission lines from medium voltage (MV) to extra high voltage (EHV) and cables of various voltage levels. The scalable platform consists of protection, control, automation, monitoring, communication, digital fault recorder (DFR) and security functionality. The incremental scaling allows customization in building the device to suit specific requirements. The convergent platform integrates multiple devices, eliminating external devices, and reduces the footprint of relay panels, resulting in reduced wiring, commissioning, and capital costs.

Distance protection

The core of the D90^{Plus} relay is the subcycle distance function providing a high degree of sensitivity and selectivity for all types of faults. The distance function features five zones of phase distance and ground distance protection, providing the user the utmost flexibility of making each zone directional, non directional, or reverse. This allows customization to a variety of applications, including primary line protection, backup protection for busbars, and backup protection for generators, transformers, and reactors. The D90^{Plus} can be applied to power systems with different earthing conditions, lines with in-zone transformers or tapped transformer feeders and overhead lines with series compensation. Each zone element for the phase and ground distance can be set to the quadrilateral or mho characteristic with the flexibility of designing different characteristic shapes to suit for different power system conditions.

The advanced comparator based distance elements provide utmost security, sensitivity, and selectivity for different types of faults. Superior digital filtering techniques provide secure and optimum reach accuracy even under worst-case CVT transients without compromising the operating time. Secure direction detection is achieved by using positive sequence memory voltage polarization providing reliable directionality for worst-case close-in faults. The D90^{Plus} employs a well-proven algorithm for phase selection, which provides fast, secure, and reliable faulted phase identification for single pole tripping and proper fault distance calculation for a variety of power system conditions. An additional voltage monitoring function provides extra security to the distance element, which can be used to block the distance elements under voltage transformer fuse failure conditions.

For additional information, refer to:

[Distance elements](#) on page 185

[Distance elements](#) on page 1

Application to series-compensated lines

The D90^{PLUS} provides enhanced stability and security by employing an adaptive distance reach control to cope with the overreaching and sub-synchronous oscillations when applied to, or in the vicinity of, series compensated lines. For directional integrity, the relay uses memory voltage polarization, and a multi-input comparator is used to deal with current inversion issues in series compensated lines.

For additional information, refer to:

[Series compensated line protection application guidelines](#) on page 225

[Series compensated lines](#) on page 649

In-zone transformer compensation

Phase distance elements in the D90^{PLUS} can be used to detect faults through different types of three-phase wye or delta transformers, allowing application of the D90^{PLUS} for backup protection on generators. VTs and CTs can be installed independently of each other on either side of the power transformer. The relay automatically compensates for transformer connections, to guarantee accurate reach for any type of fault.

For additional information, refer to:

[Phase distance](#) on page 188

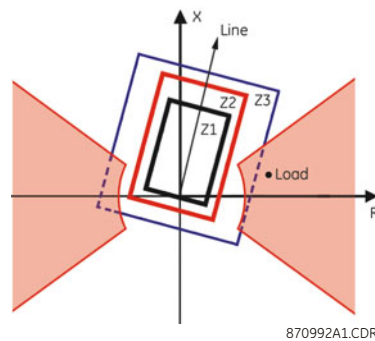
[Phase distance applied to power transformers](#) on page 642

Load encroachment

The reliable load encroachment feature offers excellent discrimination between keep loading conditions and fault conditions especially for long lines under heavy loads by supervising the distance elements or any overcurrent element. This prevents unwarranted tripping under heavy line load conditions and enables optimum operation of the line while meeting regulatory requirements for the loading.

The figure illustrates distance quadrilateral characteristics supervised by the load encroachment function.

Figure 8: Load encroachment characteristic example



For additional information, refer to:

[Load encroachment](#) on page 218

Fault locator

The integrated fault locator provides the distance to the fault in kilometers or miles.

For additional information, refer to:

[Fault report](#) on page 506

Communication aided (pilot) schemes

The D90^{Plus} supports different pilot scheme functions for fast fault clearance for any faults within the protected line. The following types of pilot-aided schemes are available:

- Direct under-reaching transfer trip (DUTT)
- Permissive under-reaching transfer trip (PUTT)
- Permissive over-reaching transfer trip (POTT)
- Hybrid permissive over-reaching transfer trip (hybrid POTT) with permissive echo and transient blocking logic
- Directional comparison blocking scheme
- Directional comparison unblocking scheme (DCUB)

All communication-aided schemes can be programmed for single-bit, two-bit, or four-bit communications. This allows transmission of phase selective information for reliable single-pole tripping if required.

For additional information, refer to:

[Pilot-aided schemes](#) on page 291

[Communications channels for pilot-aided schemes](#) on page 657

Power swing detection

Dynamic transients in the power system due to short-circuits, circuit switching, or load fluctuations can travel across the power network as power swings characterized by fluctuating currents and voltages. This can result in unwanted tripping since distance elements can respond to these power swings as faults. The D90^{Plus} power swing detection element provides both power swing blocking and out-of-step tripping functions. The element measures the positive sequence apparent impedance and traces its locus with respect to either a two or three step user-selectable mho or quadrilateral operating characteristics.

For additional information, refer to:

[Power swing detect](#) on page 209

Line pickup

The line pickup feature uses a combination of undercurrent and undervoltage to identify a line that has been de-energized (line end open). Three instantaneous overcurrent elements are used to identify a previously de-energized line that has been closed onto a fault.

For additional information, refer to:

[Line pickup](#) on page 181

Overvoltage and undervoltage protection

Long lines under lightly loaded conditions or no-load can experience acceptably voltages exceeding the rated per unit voltage level of the line. The phase overvoltage element of the D90^{Plus} can be used to initiate a local trip as well as a remote trip using direct transfer trip. The D90^{Plus} also provides additional voltage functions including neutral overvoltage, negative-sequence overvoltage, and phase undervoltage.

For additional information, refer to:

[Voltage elements](#) on page 264

Overfrequency and underfrequency protection

The multiple stages of underfrequency and overfrequency elements can be used to initiate load shedding or remedial action schemes or frequency-based load restoration schemes during lack of generation in the network or due to sudden load drops. When combined with the advanced automation capabilities of the D90^{Plus}, flexible special protection schemes can be built.

For additional information, refer to:

[Underfrequency](#) on page 360

[Overfrequency](#) on page 362

Overcurrent functions

The D90^{Plus} provides overcurrent functions for phase, neutral, and ground that can run in parallel with distance protection or can be programmed to provide primary protection under conditions when distance elements are blocked during fuse-failure conditions. Functions include

- Instantaneous and timed overcurrent elements for phase, neutral, ground, and negative-sequence protection
- Directional supervision is available for phase, neutral, and negative-sequence elements
- Time overcurrent elements can be set individually to use IEEE, IEC, or custom FlexCurves

For additional information, refer to:

[Current elements](#) on page 228

Autoreclose

The D90^{Plus} provides multi-shot autoreclosing for single-pole or three-pole autoreclose on all types of faults with independently programmable dead times for each shot. Autoreclosing also can be dynamically blocked by user-programmable logic. Four different autoreclose modes are available, enabling the user to select the reclosing mode of their practice.

For additional information, refer to:

[Autoreclose](#) on page 337

Breaker failure

The D90^{Plus} can be used to carry out fully independent breaker failure protection over the breakers associated with the line when connected to a substation with a breaker-and-a-half or ring bus arrangement. The D90^{Plus} provides the required current source inputs, digital inputs and outputs, and elements to perform two independent breaker failure functions.

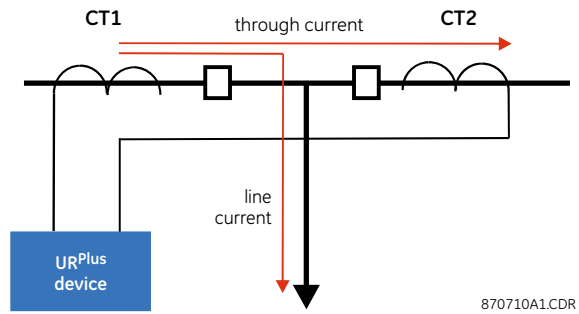
For additional information, refer to:

[Breaker failure](#) on page 275

Multi-breaker configurations

The D90^{Plus} supports multi-breaker busbar configurations, such as breaker-and-a-half and ring bus arrangements, providing dual breaker autoreclose, dual synchrocheck elements, and dual independent breaker failure elements.

Figure 9: Breaker-and-a-half configuration example



Single-pole tripping

The D90^{Plus} relay uses an advanced phase selection algorithm that provides fast and accurate fault type identification even under weak-infeed conditions. The pilot schemes for single pole tripping offer an option to send the permissive/blocking signal using one, two or four bits of information. This allows more information sharing between the terminal relays and improves the accuracy of single-pole tripping on cross-country faults. A built-in trip function coordinates actions of the key elements of the single-pole tripping package.

Automation features

A separate automation engine with powerful Boolean and math functions allows the user to easily engineer custom automation schemes. This includes advanced interlocking schemes, remedial action schemes, and advanced load shedding schemes.

Execution of the automation logic is independent of protection elements and protection logic. The automation capability is segmented into seven independent modules to simplify implementation and testing of complex schemes in which each module is independently editable and password protected. While building and compiling these modules, intelligent error detection automatically notifies the user of errors, such as overflows, type mismatch, division by zero, and square root of a negative number, allowing the user to achieve maximum optimization. The programming interface complies with the global standard IEC 61131 for industrial control programming and also allows for embedded comments. Easy to use online and offline debugging and simulation tools provide extensive testing capabilities of complex schemes. This includes forcing of input variables, simulation of analog values and visualization of live logic states and live analog values.

Synchrocheck and breaker control, disconnect switch control, and local/remote breaker control are available as hard-coded schemes as part of the D90^{Plus} automation capabilities.

For additional information, refer to:

[Automation specifications](#) on page 1

[Automation](#) on page 429

Synchronism check

The synchrocheck elements typically are used at locations where the two parts of the system are interconnected through at least one other point in the system, which are to be joined by the closure of one or more circuit breakers. The D90^{Plus} provides the required voltage source inputs, digital inputs and outputs, and elements to monitor differences in voltage magnitudes, phase angles, and frequencies to perform synchronism check across two breakers. The D90^{Plus} can be used to carry out full independent control over the breakers associated to the line when connected to a substation with a breaker-and-a-half or ring bus arrangement.

For additional information, refer to:

[Synchrocheck](#) on page 450

Scalable hardware

The D90^{Plus} is available with a multitude of input and output configurations to suit the most demanding application needs. The expandable modular design allows for easy configuration and future upgrades. Types of digital outputs include trip-rated form-A and solid-state (SSR) relays available with optional circuit continuity monitoring and current detection to verify continuity and health of the associated circuitry.

Equipment manager features

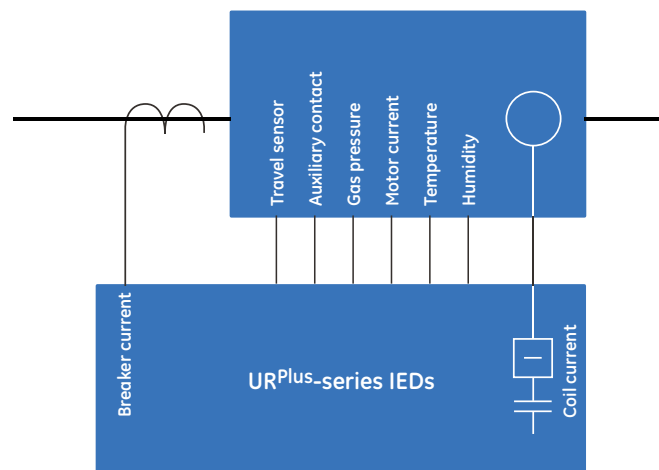
Critical assets, such as circuit breakers and the station battery, are monitored with the D90^{Plus}. The D90^{Plus} processes the interrupted current of the breaker, the auxiliary contact status of the breakers, spring compressor operating time and frequency, compressor motor current, SF6 pressure stages and the circuit breaker trip and close coil monitoring to alert the operator of an impending circuit breaker problem. Up to two breakers, associated trip, close coils and station battery can be monitored in real time. These features are available through the front panel interface in real time, allowing operating personnel to detect any abnormality and take corrective action. A comprehensive equipment-monitoring feature of D90^{Plus} reduces the downtime of your assets and improves the availability of the power system.



NOTE

Only the battery monitor and breaker arcing current features are supported in the current version of the D90^{Plus}.

Figure 10: Circuit breaker monitoring example



870785A2.CDR

For additional information, refer to:

[Equipment manager](#) on page 493

Metering and monitoring features

Voltage, current, and power metering are built into the protection platform as a standard feature. Current parameters are available as total waveform RMS magnitude, or as fundamental frequency only RMS magnitude and angle (phasor).

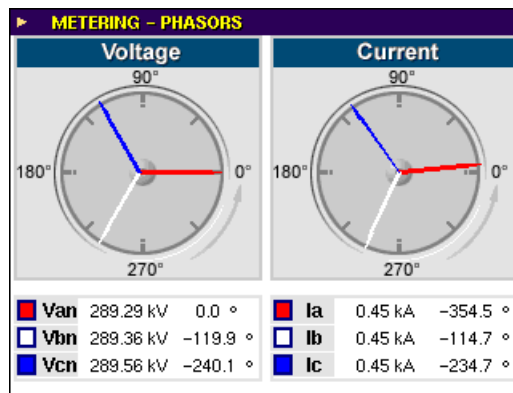
Measured values include

- Voltage phasors

- Voltage symmetrical components
- Current phasors
- Current symmetrical components
- Current true one-cycle RMS values
- Active, reactive, and apparent power
- Power factor (all power values per phase and total)
- Four-quadrant energy
- Frequency
- Synchrophasors
- Data logger

The measured signals are available for larger local display in the color LCD, accessible remotely using communications.

Figure 11: Phasors display example



Energy metering

The metered values for real, reactive, and apparent power, as well as power factor, are displayed via the front panel interface or through the EnerVista UR^{PLUS} Setup software.

Phasors

The metered values and phasor representations for phase current, ground current, phase voltage, and auxiliary voltage are displayed on the front panel and in the EnerVista UR^{PLUS} Setup software.

Sequence components metering

The metered values and phasor representations for negative-sequence current and voltage, positive-sequence current and voltage, and zero-sequence current and voltage are displayed on the front panel and in the EnerVista UR^{PLUS} Setup software.

Digital fault recorder features

The data acquisition and computing platform of the D90^{PLUS} provides high-resolution recording of power system parameters, replacing the need for an expensive stand-alone digital fault recorder (DFR), resulting in capital cost savings. The digital fault recorder features a high-resolution transient recorder (fast scan), a long-term disturbance recorder (slow scan), and a longer sequence of events with up to 8,000 events. The internal clock used for time-tagging events can be synchronized with an IRIG-B signal or via the SNTP protocol over the Ethernet port. This precise time stamping allows the sequence of events to be determined throughout the system.

Figure 12: Typical front panel fault report display

DFR – FAULT REPORT – FAULT 43640					
Aug 08 2007 11:01:53.002147					
Cause of Trip:		TRIP 3-POLE		Type: BCG	
Location:		354.7		Shot Count:0	
Active Setting Group:		1			
Prefault					
Van	292.482 KV	360.1 °	Ia	370.874 A	10.6 °
Vbn	292.373 KV	240.0 °	Ib	373.163 A	250.6 °
Vcn	292.407 KV	120.0 °	Ic	372.009 A	131.3 °
Fault					
Van	286.431 KV	0.2 °	Ia	364.003 A	353.2 °
Vbn	250.418 KV	238.5 °	Ib	2.317 KA	166.7 °
Vcn	254.867 KV	124.9 °	Ic	2.070 KA	19.7 °
Duration: NA					
Prev Rcd		Next Rcd		Events	

Sequence of events recorder

The D90^{Plus} contains an advanced sequence of events recorder with the capability to record up to 8,000 events.

Event information can be accessed either through the front panel or the EnerVista Launchpad software. The very high sampling rate and large amount of storage capacity available for data recording in the D90^{Plus} can eliminate the need for installing costly stand-alone event recording equipment.

Fault reports and fault locator

The D90^{Plus} supports a fault report and associated fault location data. The fault report stores data pertinent to an event that is triggered and provides the distance to the fault location. A maximum of 15 records are stored in the nonvolatile memory providing a comprehensive summary of events associated with a fault.

Transient recorder

The transient recorder captures critical system data during a transient event. It is tailored to capture shorter duration events, such as faults at high resolution. The transient recorder can be programmed to sample at 256 samples per cycle. The D90^{Plus} can store up to 64 records in nonvolatile memory with up to one minute of storage capacity for all 16 analog channels and 128 digital channels. The transient recorder incorporates integrated triggering. Any monitored channel can be configured to trigger the recorder.

Disturbance recorder

Longer-term events are monitored by disturbance recorders and include voltage sag, swell, and overloading. Any configured analog or digital channel can trigger the disturbance recorder. The D90^{Plus} can store up to 64 records in nonvolatile memory with up to five minutes of storage capacity.

Communications features

The D90^{Plus} communications module is dedicated to processing the IEC 61850, DNP 3.0, and IEC 60870-5-104 protocols. This module provides redundant Ethernet ports, each with 10/100Base-TX and 100Base-FX connectors.

Modbus RTU and DNP 3.0 are also available as default protocols through the RS485 port or the CPU Ethernet ports (slot D).

AUXILIARY OVERVOLTAGE

Pickup level: 0.000 to 1.100 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy: $\pm 0.5\%$ of reading from 10 to 208 V
 Pickup delay: 0.00 to 600.00 seconds in steps of 0.01
 Reset delay: 0.00 to 600.00 seconds in steps of 0.01
 Timing accuracy: $\pm 3\%$ of operate time or ± 4 ms (whichever is greater)
 Operate time: <2 cycles at $1.10 \times$ pickup at 60 Hz

AUXILIARY UNDERVOLTAGE

Pickup level: 0.000 to 1.100 pu in steps of 0.001
 Dropout level: >102% of pickup
 Level accuracy: $\pm 0.5\%$ of reading from 10 to 208 V
 Curve shapes: GE IAV inverse, definite time
 Curve multiplier: 0.00 to 600.00 in steps of 0.01
 Timing accuracy: $\pm 3\%$ of operate time or ± 4 ms (whichever is greater)

BREAKER FAILURE

Mode: single-pole, three-pole
 Current supervision: phase current, neutral current
 Supervision pickup: 0.001 to 30.000 pu in steps of 0.001
 Supervision dropout: <98% of pickup
 Supervision accuracy at 0.1 to $2.0 \times CT$: $\pm 2\%$ of rated
 Supervision accuracy at $>2.0 \times CT$: $\pm 2.5\%$ of reading
 Time accuracy: $\pm 3\%$ or 4 ms (whichever is greater)

BREAKER FLASHOVER

Operating quantity: phase current, voltage, and voltage difference
 Pickup level voltage: 0.000 to 1.500 pu in steps of 0.001
 Dropout level voltage: 97 to 98% of pickup
 Pickup level current: 0.000 to 1.500 pu in steps of 0.001
 Dropout level current: 97 to 98% of pickup
 Level accuracy: $\pm 0.5\%$ or $\pm 0.1\%$ of rated (whichever is greater)
 Pickup delay: 0.000 to 65.535 seconds in steps of 0.001
 Time accuracy: $\pm 3\%$ or ± 42 ms (whichever is greater)
 Operate time: <42 ms at $1.10 \times$ pickup at 60 Hz

CONTACT INPUTS

Input rating: 300 V DC maximum
 On threshold: 70% of nominal voltage setting or 20 V (whichever is greater)
 Off threshold: 30% of nominal voltage setting or 15 V (whichever is greater)
 Bounce threshold: 50% of nominal voltage setting or 20 V (whichever is greater)
 AZ threshold: 80% of nominal voltage setting
 Overvoltage threshold: 130% of nominal voltage setting or 285 V maximum
 Maximum current: 10 mA during turn on, 0.5 mA steady-state
 Nominal voltage: 24 to 250 V
 Input impedance: active
 Recognition time: <1 ms
 Debounce timer: 1.50 to 16.00 ms in steps of 0.25
 Chatter detection timer: 1 to 100 seconds
 Chatter state changes: 10 to 100

DISTURBANCE DETECTOR (50DD)

Type: sensitive current disturbance detector
 Range: 0.004 to 0.04 pu (twice the current cut-off level threshold)

FLEXCURVEST™

Number: 4 (A through D)
 Reset points: 40 (0 through 1 of pickup)
 Operate points: 80 (1 through 20 of pickup)
 Time delay: 0 to 65535 ms in steps of 1

FLEXELEMENTS™

Elements: 16
 Operating signal: any analog actual value, or two values in differential mode
 Operating signal mode: signed or absolute value
 Operating mode: level, delta
 Comparator detection: over, under
 Pickup level: -90.000 to 90.000 pu in steps of 0.001
 Hysteresis: 0.1 to 50.0% in steps of 0.1
 Delta dt : 20 ms to 60 days
 Pickup delay: 0.000 to 65.535 seconds in steps of 0.001
 Dropout delay: 0.000 to 65.535 seconds in steps of 0.001

FLEXMATRIX

Principle: aggregates and conditions signals for tripping and auxiliary functions
 Timing accuracy: ± 1 ms

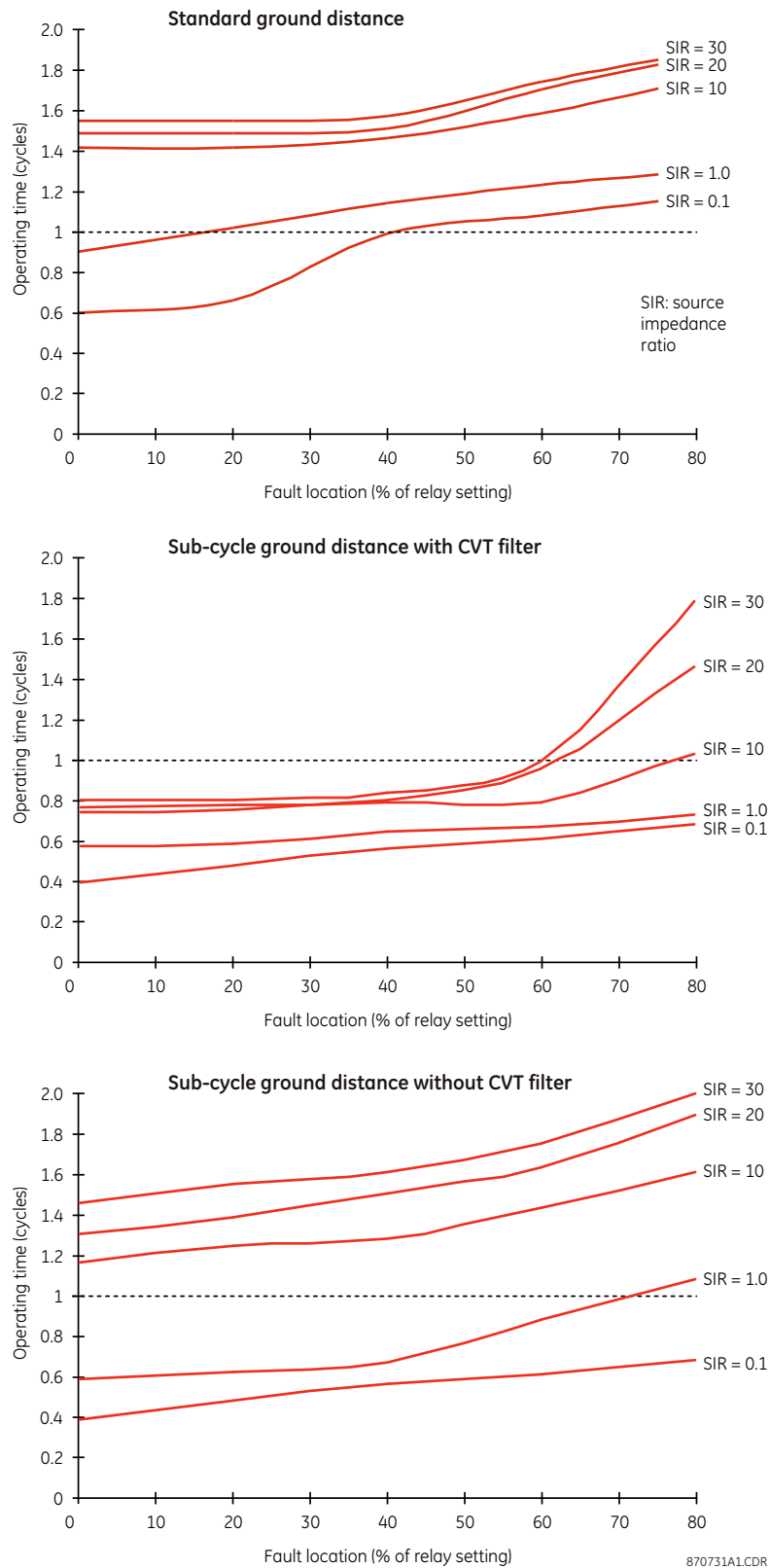
FLEX STATES

Number: up to 256 logical variables grouped under 16 Modbus addresses
 Programmability: any logical variable, contact, or virtual input

GROUND DISTANCE

Characteristic: mho (memory polarized or offset) or quad (memory polarized or non-directional), selectable individually per zone
 Reactance polarization: negative-sequence or zero-sequence current
 Non-homogeneity angle: -40 to 40° in steps of 1
 Zones: 5
 Directionality: forward, reverse, or non-directional per zone
 Reach (secondary ohms): 0.02 to 250.00 ohms in steps of 0.01
 Reach accuracy: $\pm 5\%$, including the effect of CVT transients up to an SIR of 30 for $V < 1.1 \times V_{\text{nominal}}$
 Distance characteristic angle: 30 to 90° in steps of 1
 Comparator limit angle: 30 to 90° in steps of 1
 Characteristic angle: 30 to 90° in steps of 1
 Limit angle: 30 to 90° in steps of 1
 Z0/Z1 magnitude: 0.00 to 10.00 in steps of 0.01
 Z0M/Z1 angle: -90 to 90° in steps of 1
 Z0M/Z1 magnitude: 0.00 to 7.00 in steps of 0.01
 Z0/Z1 angle: -90 to 90° in steps of 1
 Right and left blinder reach: 0.02 to 500.00 ohms in steps of 0.01
 Right and left blinder characteristic angle: 60 to 90° in steps of 1
 Time delay: 0.000 to 65.535 seconds in steps of 0.001
 Timing accuracy: $\pm 3\%$ or 4 ms (whichever is greater)
 Current supervision level: neutral current (3I₀)
 Current supervision pickup: 0.050 to 30.000 pu in steps of 0.001
 Memory duration: 5 to 25 cycles in steps of 1
 Voltage supervision pickup: 0 to 5.000 pu in steps of 0.001 (series compensation applications)
 Operation time: 1 to 1.5 cycles (typical)
 Reset time: 1 power cycle (typical)

Figure 14: Ground distance operating curves



GROUND INSTANTANEOUS OVERCURRENT

Pickup level:..... 0.000 to 30.000 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy at 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT:..... ±1.5% of reading
 Overreach: <2%
 Pickup delay:..... 0.00 to 600.00 seconds in steps of 0.01
 Reset delay: 0.00 to 600.00 seconds in steps of 0.01
 Operate time:..... <16 ms at 3 × pickup at 60 Hz
 Timing accuracy for operation at 1.5 × pickup:..... ±3% or ±4 ms (whichever is greater)

GROUND TIME OVERCURRENT

Current:..... phasor or RMS
 Pickup level:..... 0.000 to 30.000 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy at 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT:..... ±1.5% of reading
 Curve shapes:..... IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC (BS) A, IEC (BS) B, IEC (BS) C, IEC Short Inverse, IAC Inverse, IAC Short Inverse, IAC Very Inverse, IAC Extremely Inverse, I²t, FlexCurves™ (programmable), definite time (0.01 second base curve)
 Curve multiplier:..... 0.01 to 600.00 in steps of 0.01
 Reset type: instantaneous/timed (per IEEE)
 Timing accuracy for 1.03 to 20 × pickup: ±3.5% of operating time or ±1 cycle (whichever is greater)

LINE PICKUP

Phase instantaneous overcurrent: 0.000 to 30.000 pu in steps of 0.001
 Undervoltage pickup: 0.000 to 3.000 pu in steps of 0.001
 Overvoltage delay:..... 0.000 to 65.535 seconds in steps of 0.001

LOAD ENCROACHMENT

Responds to: positive-sequence quantities
 Minimum voltage:..... 0.000 to 3.000 pu in steps of 0.001
 Reach: 0.02 to 250.00 ohms in steps of 0.01 (secondary ohms)
 Impedance accuracy:..... ±5%
 Angle:..... 5 to 50° in steps of 1
 Angle accuracy:..... ±2°
 Pickup delay:..... 0.000 to 65.535 seconds in steps of 0.001
 Reset delay: 0.000 to 65.535 seconds in steps of 0.001
 Timing accuracy:..... ±3% or ±4 ms (whichever is greater)
 Operate time:..... <30 ms at 60 Hz

NEGATIVE-SEQUENCE DIRECTIONAL OVERCURRENT

Directionality:.....co-existing forward and reverse
 Polarizing:.....voltage
 Polarizing voltage:.....V₂
 Operating current:.....I₂
 Level sensing (zero-sequence):..... $|I_0| - K \times |I_1|$
 Level sensing (negative-sequence):..... $|I_2| - K \times |I_1|$
 Restraint, K:.....0.000 to 0.500 in steps of 0.001
 Characteristic angle:.....0 to 90° in steps of 1
 Limit angle:.....40 to 90° in steps of 1, independent for forward and reverse
 Angle accuracy:.....±2°
 Offset impedance:.....0.00 to 250.00 ohms in steps of 0.01
 Pickup level:.....0.05 to 30.00 pu in steps of 0.01
 Dropout level:.....<98%
 Operation time:.....<16 ms at 3 × pickup at 60 Hz

NEGATIVE-SEQUENCE INSTANTANEOUS OVERCURRENT

Pickup level:.....0.000 to 30.000 pu in steps of 0.001
 Dropout level:.....<98% of pickup
 Level accuracy at 0.1 to 2.0 × CT:.....±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT:.....±1.5% of reading
 Overreach:.....<2%
 Pickup delay:.....0.00 to 600.00 seconds in steps of 0.01
 Reset delay:.....0.00 to 600.00 seconds in steps of 0.01
 Operate time:.....<20 ms at 3 × pickup at 60 Hz
 Timing accuracy for operation at 1.5 × pickup:.....±3% or ±4 ms (whichever is greater)

NEGATIVE-SEQUENCE OVERVOLTAGE

Pickup level:.....0.000 to 1.250 pu in steps of 0.001
 Dropout level:.....<98% of pickup
 Level accuracy:.....±0.5% of reading from 10 to 208 V
 Pickup delay:.....0.00 to 600.00 seconds in steps of 0.01
 Reset delay:.....0.00 to 600.00 seconds in steps of 0.01
 Timing accuracy:.....±3% or ±20 ms (whichever is greater)
 Operate time:.....< 30 ms at 1.10 × pickup at 60 Hz

NEGATIVE-SEQUENCE TIME OVERCURRENT

Pickup level:.....0.000 to 30.000 pu in steps of 0.001
 Dropout level:.....<98% of pickup
 Level accuracy at 0.1 to 2.0 × CT:.....±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT:.....±1.5% of reading
 Curve shapes:.....IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC (BS) A, IEC (BS) B, IEC (BS) C, IEC Short Inverse, IAC Inverse, IAC Short Inverse, IAC Very Inverse, IAC Extremely Inverse, I²t, FlexCurves™ (programmable), definite time (0.01 second base curve)
 Curve multiplier:.....0.01 to 600.00 in steps of 0.01
 Reset type:.....instantaneous/timed (per IEEE) and linear
 Timing accuracy for 1.03 to 20 × pickup:.....±3.5% of operating time or ±1 cycle (whichever is greater)

NEUTRAL DIRECTIONAL OVERCURRENT

Directionality:	co-existing forward and reverse
Polarizing:	voltage, current, dual
Polarizing voltage:	V ₀ or VX
Polarizing current:	IG
Operating current:	I ₀
Level sensing:	$3 \times (I_0 - K \times I_1)$, IG; independent for forward and reverse
Restraint (K):	0.000 to 0.500 in steps of 0.001
Characteristic angle:	-90 to 90° in steps of 1
Limit angle:	40 to 90° in steps of 1, independent for forward and reverse
Angle accuracy:	±2°
Offset impedance:	0.00 to 250.00 ohms in steps of 0.01
Pickup level:	0.002 to 30.000 pu in steps of 0.01
Dropout level:	<98%
Operation time:	<16 ms at 3 × pickup at 60 Hz

NEUTRAL INSTANTANEOUS OVERCURRENT

Pickup level:	0.000 to 30.000 pu in steps of 0.001
Dropout level:	<98% of pickup
Level accuracy at 0.1 to 2.0 × CT:	±0.5% of reading or ±1% of rated (whichever is greater)
Level accuracy at >2.0 × CT:	±1.5% of reading
Overreach:	<2%
Pickup delay:	0.00 to 600.00 seconds in steps of 0.01
Reset delay:	0.00 to 600.00 seconds in steps of 0.01
Operate time:	<20 ms at 3 × pickup at 60 Hz
Timing accuracy for operation at 1.5 × pickup:	±3% or ±4 ms (whichever is greater)

NEUTRAL OVERVOLTAGE

Pickup level:	0.000 to 1.250 pu in steps of 0.001
Dropout level:	<98% of pickup
Level accuracy:	±0.5% of reading from 10 to 208 V
Pickup delay:	0.00 to 600.00 seconds in steps of 0.01 (definite time) or user-defined curve
Reset delay:	0.00 to 600.00 seconds in steps of 0.01
Timing accuracy:	±3% or ±20 ms (whichever is greater)
Operate time:	<3 cycles at 1.10 × pickup

NEUTRAL TIME OVERCURRENT

Current:	phasor or RMS
Pickup level:	0.000 to 30.000 pu in steps of 0.001
Dropout level:	<98% of pickup
Level accuracy at 0.1 to 2.0 × CT:	±0.5% of reading or ±1% of rated (whichever is greater)
Level accuracy at >2.0 × CT:	±1.5% of reading
Curve shapes:	IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC (BS) A, IEC (BS) B, IEC (BS) C, IEC Short Inverse, IAC Inverse, IAC Short Inverse, IAC Very Inverse, IAC Extremely Inverse, I ² t, FlexCurves™ (programmable), definite time (0.01 second base curve)
Curve multiplier:	0.01 to 600.00 in steps of 0.01
Reset type:	instantaneous/timed (per IEEE)
Timing accuracy at 1.03 to 20 × pickup:	±3.5% of operating time or ±1 cycle (whichever is greater)

NON-VOLATILE LATCHES

Type:	set-dominant or reset-dominant
Number:	16 (individually programmed)
Output:	stored in non-volatile memory
Execution sequence:	as input prior to protection, control, and FlexLogic™

OPEN POLE DETECTOR

Functionality:detects an open pole condition, monitoring breaker auxiliary contacts, the current in each phase and optional voltages on the line

Current pickup level:.....0.000 to 30.000 pu in steps of 0.001

Line capacitive reactances:300.0 to 9999.9 secondary ohms in steps of 0.1

Remote current pickup level:.....0.000 to 30.000 pu in steps of 0.001

Current dropout level:.....pickup + 3%; not less than 0.05 pu

OVERFREQUENCY

Elements:2

Pickup level:20.00 to 65.00 Hz in steps of 0.01

Dropout level:pickup level – 0.03 Hz

Level accuracy:±0.01 Hz

Time delay:0 to 65.535 seconds in steps of 0.001

Timer accuracy:±3% or 4 ms (whichever is greater)

PHASE DIRECTIONAL OVERCURRENT

Relay connection:90° (quadrature)

Quadrature voltage:phase A (V_{BC}), phase B (V_{CA}), phase C (V_{AB}) for ABC phase sequence; phase A (V_{CB}), phase B (V_{AC}), phase C (V_{BA}) for ACB phase sequence

Polarizing voltage threshold:0.000 to 3.000 pu in steps of 0.001

Current sensitivity threshold:0.05 pu

Characteristic angle:0 to 359° in steps of 1

Angle accuracy:±2°

Tripping operation time:<12 ms, typically (reverse load, forward fault)

Blocking operation time:<8 ms, typically (forward load, reverse fault)

PHASE DISTANCE

Characteristic:mho (memory polarized or offset) or quad (memory polarized or non-directional), selectable individually per zone

Zones:5

Directionality:forward, reverse, or non-directional per zone

Reach:0.02 to 250.00 ohms in steps of 0.01 (secondary ohms)

Reach accuracy:±5%, including the effect of CVT transients up to an SIR of 30 for $V < 1.1 \times V_{\text{nominal}}$

Distance characteristic angle:30 to 90° in steps of 1

Distance limit angle:30 to 90° in steps of 1

Directional supervision characteristic angle:30 to 90° in steps of 1

Directional supervision limit angle:30 to 90° in steps of 1

Right and left blinder reach:0.02 to 500.00 ohms in steps of 0.01

Right and left blinder characteristic angle:60 to 90° in steps of 1

Time delay:0.000 to 65.535 seconds in steps of 0.001

Timing accuracy:±3% or 4 ms (whichever is greater)

Current supervision level:line-to-line current

Current supervision pickup:0.050 to 30.000 pu in steps of 0.001

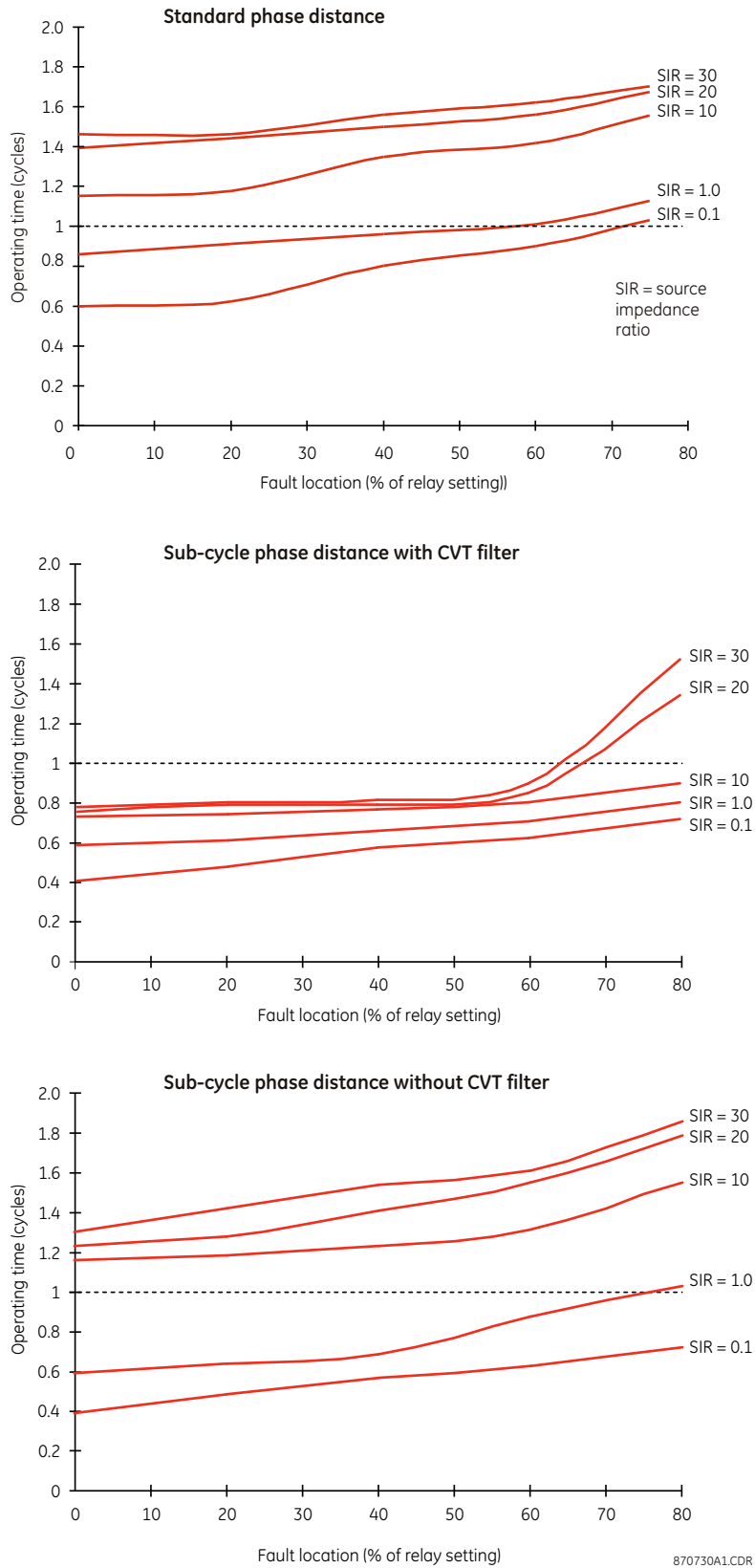
Memory duration:5 to 25 cycles in steps of 1

CT location:all delta-wye and wye-delta transformers

VT location:all delta-wye and wye-delta transformers

Voltage supervision pickup:0.000 to 5.000 pu in steps of 0.001 (series compensation applications)

Figure 15: Phase distance operating curves



PHASE INSTANTANEOUS OVERCURRENT

Pickup level: 0.000 to 30.000 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy at 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT: ±1.5% of reading
 Overreach: <2%
 Pickup delay: 0.00 to 600.00 seconds in steps of 0.01
 Reset delay: 0.00 to 600.00 seconds in steps of 0.01
 Operate time: <16 ms at 3 × pickup at 60 Hz
 Timing accuracy for operation at 1.5 × pickup: ±3% or ±4 ms (whichever is greater)

PHASE OVERVOLTAGE

Voltage: phasor only
 Pickup level: 0.000 to 3.000 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy: ±0.5% of reading from 10 to 208 V
 Pickup delay: 0.00 to 600.00 seconds in steps of 0.01
 Operate time: <3 cycles at 1.10 × pickup
 Timing accuracy: ±3% or ±4 ms (whichever is greater)

PHASE SELECTOR

Function: determines the fault type for the trip output scheme, fault locator, and fault report

PHASE TIME OVERCURRENT

Current: phasor or RMS
 Pickup level: 0.000 to 30.000 pu in steps of 0.001
 Dropout level: <98% of pickup
 Level accuracy at 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
 Level accuracy at >2.0 × CT: ±1.5% of reading
 Curve shapes: IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC (BS) A, IEC (BS) B, IEC (BS) C, IEC Short Inverse, IAC Inverse, IAC Short Inverse, IAC Very Inverse, IAC Extremely Inverse, I²t, FlexCurves™ (programmable), definite time (0.01 second base curve)
 Curve multiplier: 0.01 to 600.00 in steps of 0.01
 Reset type: instantaneous/timed (per IEEE)
 Timing accuracy at 1.03 to 20 × pickup: ±3.5% of operating time or ±1 cycle (whichever is greater)

PHASE UNDERVOLTAGE

Pickup level: 0.000 to 1.100 pu in steps of 0.001
 Dropout level: >102% of pickup
 Level accuracy: ±0.5% of reading from 10 to 208 V
 Curve shapes: GE IAV Inverse; Definite Time (0.1 second base curve)
 Curve multiplier: 0.00 to 600.00 in steps of 0.01
 Timing accuracy for operation at <0.90 × pickup: ±3.5% of operate time or ±4 ms (whichever is greater)

PILOT-AIDED SCHEMES

Available schemes: Direct Underreaching Transfer Trip (DUTT) Permissive Underreaching Transfer Trip (PUTT), Permissive Overreaching Transfer Trip (POTT), Hybrid POTT, Directional Comparison Blocking, Directional Comparison Unblocking

POWER SWING DETECT

Functions:	power swing block, out-of-step trip
Characteristic:	mho or quadrilateral
Measured impedance:	positive-sequence
Blocking and tripping modes:	two-step or three-step
Tripping mode:	early or delayed
Current supervision pickup:	0.050 to 30.000 pu in steps of 0.001
Current supervision dropout:	<98% of pickup
Forward reach:	0.10 to 500.00 ohms in steps of 0.01 (secondary ohms)
Reverse reach:	0.10 to 500.00 ohms in steps of 0.01 (secondary ohms)
Left and right blinders:	0.10 to 500.00 ohms in steps of 0.01 (secondary ohms)
Impedance accuracy:	±5%
Forward angles:	40 to 90° in steps of 1
Reverse angles:	40 to 90° in steps of 1
Angle accuracy:	±2°
Characteristic limit angles:	40 to 140° in steps of 1
Timers:	0.000 to 65.535 seconds in steps of 0.001
Timing accuracy:	±3% or 4 ms (whichever is greater)

PROTECTION FLEXLOGIC™

Programming:	Reverse Polish Notation with graphical visualization (keyboard programmable)
Lines of code:	512
Internal variables:	64
Supported operations:	NOT, XOR, OR (2 to 16 inputs), AND (2 to 16 inputs), NOR (2 to 16 inputs), NAND (2 to 16 inputs), latch (reset-dominant), edge detectors, timers
Inputs:	any logical variable, contact, or virtual input
Number of timers:	32
Pickup delay:	0 to 60000 (ms, seconds, or minutes) in steps of 1
Dropout delay:	0 to 60000 (ms, seconds, or minutes) in steps of 1

PROTECTION VIRTUAL INPUTS

Input points:	64
Programmability:	self-reset or latched

PROTECTION VIRTUAL OUTPUTS

Output points:	96
Programmability:	output of a protection FlexLogic™ equation or input to a protection FlexLogic™ equation

REMOTE INPUTS (IEC 61850 GSSE/GOOSE)

Input points:	64
Remote devices:	32
Default states on loss of communications:	on, off, latest/off, latest/on
Remote double-points status inputs:	16

REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)

Standard output points:	32
User output points:	32

TRIP OUTPUT

Functionality:	collects trip and reclose input requests and issues outputs to control tripping and reclosing
Communications timer delay:	0 to 65535 seconds in steps of 0.001
Evolving fault timer:	0.000 to 65.535 seconds in steps of 0.001
Timing accuracy:	±3% or 4 ms (whichever is greater)

UNDERFREQUENCY

Elements:	2
Minimum signal:	0.10 to 1.25 pu in steps of 0.01
Pickup level:	20.00 to 65.00 Hz in steps of 0.01
Dropout level:	pickup level + 0.03 Hz
Level accuracy:	±0.01 Hz
Time delay:	0 to 65.535 seconds in steps of 0.001
Timer accuracy:	±3% or 4 ms (whichever is greater)

VT FUSE FAILURE SUPERVISION

Elements:	1 per source
Monitored parameters:	V_2, V_1, I_1

WATTMETRIC ZERO-SEQUENCE DIRECTIONAL

Measured power:	zero-sequence
Elements:	2
Characteristic angle:	0 to 360° in steps of 1
Minimum power:	0.001 to 1.200 pu in steps of 0.001
Pickup level accuracy:	±1% or 0.0025 pu (whichever is greater)
Hysteresis:	3% or 0.001 pu (whichever is greater)
Pickup delay:	definite time (0 to 600.00 seconds in steps of 0.01), inverse time, or FlexCurve™
Inverse time multiplier:	0.01 to 2.00 seconds in steps of 0.01
Time accuracy:	±3% or ±20 ms (whichever is greater)
Operate time:	<30 ms at 60 Hz

Automation specifications**AUTOMATION LOGIC**

Number of lines of logic:	4096
Number of blocks:	1
Edit and view capability:	yes
Logic type:	cyclic
Programming language:	proprietary
Execution rate:	50 ms
Variable types:	Boolean, IEEE floating point
Boolean operations:	NOT, XOR, OR, AND, NOR, NAND, any contact input, any direct input, any teleprotection input, any remote input, any virtual input, any automation logic operand
Arithmetic operations:	add, subtract, multiply, divide, negation, absolute value, square root, exponent, logarithm, sine, cosine, tangent, arcsine, arccosine, arctangent, natural logarithm, base 10 logarithm, modulo, ceiling, floor
Control operations:	latch, timer, comparator, absolute timer functions
Boolean inputs:	any contact input, direct input, teleprotection input, remote input, virtual input, or automation logic operand
Analog inputs:	any FlexAnalog™ quantity
Virtual inputs:	128
Virtual outputs:	255
Remote inputs:	64
Remote outputs:	64
Remote devices:	32

AUTOMATION VIRTUAL INPUTS

Input points:	128
Programmability:	self-reset or latched

AUTOMATION VIRTUAL OUTPUTS

Output points: 255
 Programmability: output of an automation logic equation or input to an automation logic equation

BREAKER CONTROL

Mode: single-pole, three-pole
 Control: open/close, local/SCADA
 Control seal-in: 0 to 2000 ms in steps of 1

BREAKER INTERLOCKING

Interlocking inputs: 6

DISCONNECT CONTROL

Mode: single-pole, three-pole
 Control: open/close, local/SCADA
 Control seal-in: 0 to 2000 ms in steps of 1

DISCONNECT INTERLOCKING

Interlocking inputs: 3

SELECTOR SWITCH

Upper position limit: 1 to 7 in steps of 1
 Selecting mode: time-out or acknowledge
 Time-out timer: 3.0 to 60.0 seconds in steps of 0.1
 Control inputs: step-up and three-bit
 Power-up mode: restore from non-volatile memory or synchronize to a three-bit control input or synchronize/restore mode

SYNCHROCHECK

Elements: 2
 Maximum voltage difference: 0 to 100000 volts in steps of 1
 Maximum angle difference: 0 to 100° in steps of 1
 Maximum frequency difference: 0.00 to 2.00 Hz in steps of 0.01
 Hysteresis for maximum frequency difference: 0.00 to 0.10 Hz in steps of 0.01
 Dead source function: none, LV1 & DV2, DV1 & LV2, DV1 or DV2, DV1 xor DV2, DV1 & DV2 (L = live, D = dead)

Equipment manager

BATTERY MONITOR

Principle: monitors battery voltage and auxiliary alarms
 Hysteresis: 5%
 Timing accuracy: 1 cycle

BREAKER ARCING CURRENT

Elements: 1 per breaker (to a maximum of 2)
 Principle: accumulates contact wear ($I_x t$), measures fault magnitude and duration
 Auxiliary contact compensation: 0 to 50 ms in steps of 1
 Alarm threshold: 0 to 50000 kA²-cycle in steps of 1
 Fault duration accuracy: 0.25 of power cycle

Metering specifications

CURRENT METERING

Type:.....phase and ground RMS current
 Accuracy at 0.1 to $2.0 \times CT$:..... $\pm 0.25\%$ of reading or $\pm 0.1\%$ of rated (whichever is greater) at
 50/60 Hz nominal frequency
 Accuracy at $>2.0 \times CT$:..... $\pm 1.0\%$ of reading, at 50/60 Hz nominal frequency

DATA LOGGER

Channels:.....1 to 16
 Parameters:.....any FlexAnalog value
 Statistics:.....maximum and time of maximum, minimum and time of
 minimum, average
 Alarms:.....high, high-high, low, low-low

ENERGY METERING

Type:.....positive and negative watt-hours and var-hours
 Accuracy:..... $\pm 2.0\%$ of reading
 Range:..... -2.0×10^9 to 2.0×10^9 MWh/Mvarh
 Parameters:.....three-phase only
 Update rate:.....50 ms

FREQUENCY METERING

Accuracy at $V = 0.8$ to 1.2 pu:..... ± 0.001 Hz (when voltage signal is used for frequency
 measurement)
 Accuracy at $I = 0.1$ to 0.25 pu:..... ± 0.05 Hz (when current signal is used for frequency
 measurement)
 Accuracy at $I > 0.25$ pu:..... ± 0.001 Hz (when current signal is used for frequency
 measurement)

PHASOR MEASUREMENT UNIT

Output format:.....per IEEE C37.118 standard
 Channels:.....14 synchrophasors, 8 analogs, 16 digitals
 TVE (total vector error):..... $< 1\%$
 Triggering:.....frequency, voltage, current, power, rate of change of
 frequency, user-defined
 Reporting rate:.....1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second
 Number of clients:.....One over TCP/IP port, two over UDP/IP ports
 AC ranges:.....as indicated in appropriate specifications sections
 Network reporting format:.....16-bit integer or 32-bit IEEE floating point numbers
 Network reporting style:.....rectangular (real and imaginary) or polar (magnitude and
 angle) coordinates
 Post-filtering:.....none, 3-point, 5-point, 7-point
 Calibration:..... $\pm 5^\circ$

POWER METERING

Real power accuracy:..... $\pm 1.0\%$ of reading at $-1.0 \leq PF < 0.8$ and $0.8 < PF \leq 1.0$
 Reactive power accuracy:..... $\pm 1.0\%$ of reading at $-0.2 \leq PF \leq 0.2$
 Apparent power accuracy:..... $\pm 1.0\%$ of reading

VOLTAGE METERING

Type:.....RMS voltage
 Accuracy:..... $\pm 0.5\%$ of reading from 30 to 208 volts at 50/60 Hz nominal
 frequency

Digital fault recorder specifications

DISTURBANCE RECORDER

Storage capacity:	one record with all available channels at 60 samples per second for 40 seconds
Maximum records:	64
Sampling rate:	1 sample per cycle
Sampling accuracy:	<1 ms per second of recording
Analog channels:	64
Analog channel data:	any FlexAnalog™ quantity
Digital channels:	32
Digital channel data:	any contact input, direct input, remote input, virtual input, automation logic operand, or FlexLogic™ operand
Triggers:	any digital change of state (user-programmable), undervoltage, overvoltage, undercurrent, overcurrent, underfrequency, overfrequency, rate of change of frequency, 1 user-programmable trigger, 1 block
Storage modes:	automatic overwrite, protected
Triggering modes:	time window from rising edge of trigger, continuous recording as long as trigger is active
Pre-trigger window:	0 to 100%
Data storage:	non-volatile memory

EVENT RECORDER

Storage capacity:	8192 events
Time tag:	to 1 ms
Triggers:	any contact input, direct input, remote input, virtual input, logic operand, or self-test event
Data storage:	non-volatile memory

FAULT REPORT

Records:	15
Data:	station and circuit ID, date and time of trip, fault type, active setting group at time of trigger, pre-fault current and voltage phasors (2 cycles before 50DD associated with fault report source), fault current and voltage phasors (1 cycle after trigger), protection elements operated at time of trigger, firmware revision
Triggers:	user-selected operand
Data storage:	non-volatile memory

FAULT LOCATOR

Method:	single-ended
Accuracy:	2% of line length
Units:	miles or kilometers
Trigger:	from fault report
Data storage:	non-volatile memory

TRANSIENT RECORDER

Storage capacity:	one record with all available channels at 32 samples per cycle for 1 minute
Number of records:	1 to 64
Sampling rate:	16 to 256 samples per power cycle
Timestamp accuracy:	<10 μ s per second of recording
Analog channels:	up to twelve 16-bit, unprocessed, AC input channels
Analog channel data:	any FlexAnalog quantity
Digital channels:	up to 128
Digital channel data:	any contact input, direct input, remote input, virtual input, automation logic operand, or FlexLogic™ operand
Sampled channels:	up to 24
Sampled channel data:	16-bit, unprocessed sampled channels
Triggers:	any digital channel change of state, undervoltage, overvoltage, undercurrent, overcurrent, underfrequency, overfrequency, rate of change of frequency, one user-programmable, one block
Storage modes:	automatic overwrite, protected
Triggering modes:	time window from rising edge of trigger, continuous recording as long as trigger is active
Pre-trigger window:	0 to 100%
Data storage:	non-volatile memory

Front panel interface**ANNUNCIATOR**

Inputs:	288
Windows per page:	12 to 48
Pages:	up to 24
Sequence:	manual reset, locking
Off indication:	alarm inactive and reset
Flashing indication:	alarm active and not acknowledged, alarm inactive and not acknowledged
On indication:	alarm active and acknowledged, alarm inactive and not reset
Priority:	by active window and page number
Data storage:	non-volatile memory

CONTROL DISPLAY

Devices:	status and control of up to 8 power system devices
Pushbuttons:	30 dedicated user-programmable pushbuttons
Functionality:	supports select-before-operate functionality

DIGITAL FAULT RECORDER DISPLAY

Sequence of events:	displays the stored sequence of events record
Fault reports:	display and retrieval of the critical metrics of a stored fault report
Transient records:	retrieval of a stored transient record
Disturbance records:	retrieval of a stored disturbance record

EQUIPMENT MANAGER DISPLAY

Battery monitoring:	displays the current battery voltage and alarm states
---------------------	---

METERING DISPLAY

- Summary: displays present values of voltage, current, real power, reactive power, power factor, and frequency on a per-phase and total basis
- Phasors: digital and graphical display of present voltage and current magnitudes and angles
- Sequence components: displays present magnitudes and angles of current and voltage sequence components
- Energy: four-quadrant display of accumulated energy
- Demand: present and peak demand values for current and real, reactive, and apparent power

MAINTENANCE DISPLAY

- Input and output status: displays the current status of all contact inputs and outputs

Hardware specifications

AC CURRENT

- CT rated primary: 1 to 50000 A
- CT rated secondary: 1 A or 5 A
- Nominal frequency: 50 or 60 Hz
- Relay burden: <0.2 VA secondary
- Conversion range: 0.02 to 46 × CT rating RMS symmetrical
- Current withstand: 20 ms at 250 × rated, 1 second at 100 × rated, continuous at 3 × rated

AC VOLTAGE

- VT rated secondary: 50.0 to 240.0 V
- VT ratio: 1.00 to 24000.0
- Nominal frequency: 50 or 60 Hz
- Relay burden: <0.25 VA at 120 V
- Conversion range: 1 to 275 V
- Voltage withstand: continuous at 260 V to neutral, 1 minute per hour at 420 V neutral

CONTACT INPUTS

- Input rating: 300 V DC maximum
- Selectable thresholds: 24 to 250 V
- Maximum current: 10 mA during turn on, 0.5 mA steady-state
- Recognition time: <1 ms
- Debounce timer: 1.50 to 16.00 ms in steps of 0.25

CONTACT OUTPUTS: CRITICAL FAILURE RELAY

- Make and carry for 0.2 s: 10 A
- Continuous carry: 6 A
- Break at L/R of 40 ms: 0.250 A at 125 V DC; 0.125 A at 250 V DC
- Operate time: <8 ms
- Contact material: silver alloy

CONTACT OUTPUTS: FORM-A RELAY

- Make and carry for 0.2 s: 30 A as per ANSI C37.90
- Continuous carry: 6 A
- Break at L/R of 40 ms: 0.250 A at 125 V DC; 0.125 A at 250 V DC
- Operate time: <4 ms
- Contact material: silver alloy

CONTACT OUTPUTS: SOLID-STATE RELAY

Make and carry for 0.2 s:.....30 A as per ANSI C37.90
 Continuous carry:6 A
 Break at L/R of 40 ms:.....10 A at 250 V DC
 Operate time:.....<100 μ s
 Contact material:.....silver alloy

CONTROL POWER EXTERNAL OUTPUT

Capacity:100 mA DC at 48 V DC
 Isolation:.....2 kV

CRITICAL FAILURE RELAY

Make and carry for 0.2 s:.....30 A as per ANSI C37.90
 Carry continuous:6 A
 Break at L/R of 40 ms:.....0.250 A DC at 125 V DC; 0.125 A DC at 250 V DC; 0.10 A DC
 maximum at 125 V
 Operate time:.....<8 ms
 Contact material:.....silver alloy

ETHERNET PORTS

Standard:1 port supporting Modbus RTU and DNP 3.0
 Optional:.....2 ports supporting TFTP, HTTP, SNTP, PRP, DNP 3.0, IEC 60870-
 5-104, IEC 61850, or PRP on communications module
 100Base-FX media type:1300 nm, multi-mode, half/full-duplex, fiber optic with ST
 connector
 10/100Base-TX media type:RJ45 connector
 Power budget:10 dB
 Maximum optical input power:-14 dBm
 Receiver sensitivity:.....-30 dBm
 Typical distance:.....2.0 km
 SNTP clock synchronization:.....<10 ms typical

FORM-A RELAY

Make and carry for 0.2 s:.....30 A per ANSI C37.90
 Carry continuous:6 A
 Break at L/R of 40 ms:.....0.250 A DC at 125 V DC; 0.125 A DC at 250 V DC
 Operate time:.....<4 ms
 Contact material:.....silver alloy

IRIG-B INPUT

Amplitude modulation:.....1 to 10 V pk-pk
 DC shift:TTL
 Input impedance:.....50 k Ω
 Isolation:.....2 kV

POWER SUPPLY

Nominal DC voltage:.....125 to 250 V
 Minimum DC voltage:.....80 V
 Maximum DC voltage:300 V
 Nominal AC voltage:.....100 to 240 V at 50/60 Hz
 Minimum AC voltage:80 V at 48 to 62 Hz
 Maximum AC voltage:.....275 V at 48 to 62 Hz
 Voltage withstand:2 \times highest nominal voltage for 10 ms
 Voltage loss hold-up:.....200 ms duration at nominal
 Power consumption:30 VA typical, 65 VA maximum

RS485 PORT

Baud rates: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200
 Protocol: Modbus RTU and DNP 3.0
 Distance: 1200 m
 Isolation: 2 kV

SOLID-STATE RELAY

Make and carry for 0.2 s: 30 A as per ANSI C37.90
 Carry continuous: 6 A
 Break at L/R of 40 ms: 10.0 A DC at 250 V DC
 Operate time: < 100 μ s

USB PORT

Standard: type B USB connector for EnerVista software

Communications specifications

DIRECT INPUTS

Input points: 96 per channel
 Remote devices: 16
 Default states on loss of communications: On, Off, Latest/On, Latest/Off
 Ring configuration: yes, no
 Data rate: 64 or 128 kbps
 CRC: 32-bit
 CRC alarm: responding to rate of messages failing the CRC
 CRC alarm monitoring message count: ... 10 to 10000 in steps of 1
 CRC alarm threshold: 1 to 1000 in steps of 1
 Unreturned messages alarm: responding to rate of unreturned messages in the ring
 Unreturned messages alarm monitoring message count: 10 to 10000 in steps of 1
 Unreturned messages alarm threshold:.. 1 to 1000 in steps of 1

DIRECT OUTPUTS

Output points: 96 per channel

MODBUS USER MAP

Number: up to 256 Modbus addresses
 Programmability: any setting or actual value in decimal

REMOTE INPUTS (IEC 61850 GSSE/GOOSE)

Input points: 64
 Remote devices: 32
 Default states on loss of communications: On, Off, Latest/Off, Latest/On
 Remote double-point status inputs: 16

REMOTE OUTPUTS (IEC 61850 GSSE/GOOSE)

Standard output points: 32
 User output points: 32

TELEPROTECTION

Input points:.....	16 per channel
Remote devices:.....	3
Default states on loss of communications:.....	On, Off, Latest/On, Latest/Off
Ring configuration:.....	No
Data rate:.....	64 or 128 kbps
CRC:.....	32-bit

PARALLEL REDUNDANCY PROTOCOL (PRP) (IEC 62439-3 CLAUSE 4, 2012)

Ports used:.....	2 and 3
Networks used:.....	10/100 MB Ethernet

Inter-relay communications specifications

TYPICAL DISTANCE

RS422 interface:.....	1200 m (based on transmitter power; does not take into consideration the clock source provided by the user)
G.703 interface:.....	100 m
850 nm laser (multimode) interface:.....	2.0 km (50/125 μ m cable with ST connector); 2.9 km (62.5/125 μ m cable with ST connector)



NOTE

The typical distances shown are based on the assumptions for system loss shown below. As actual losses vary from one installation to another, the distance covered by your system may vary.

LINK LOSSES (850 NM LASER, MULTIMODE MODULE)

ST connector losses:.....	2 dB (total of both ends)
50/125 μ m fiber loss:.....	2.5 dB/km
62.5/125 μ m fiber loss:.....	3.0 dB/km
Splice loss:.....	one splice every 2 km, at 0.05 dB loss per splice
System margin:.....	3 dB of additional loss was added to calculations to compensate for all other losses, including age and temperature

LINK POWER BUDGET (850 NM LASER, MULTIMODE MODULE)

Maximum optical input power:.....	-9 dBm
Minimum transmit power:.....	-22 dBm (into 50 μ m fiber), -18 dBm (into 62.5 μ m fiber)
Maximum receiver sensitivity:.....	-32 dBm
Power budget:.....	10 dBm (for 50 μ m fiber), 14 dBm (for 62.5 μ m fiber)



NOTE

These power budgets are calculated from the manufacturer's worst-case transmitter power and worst-case receiver sensitivity.

Test specifications

PRODUCTION TESTS

Thermal:.....	products go through a 12 hour burn-in process at 60°C
---------------	---

TYPE TESTS

Vibration:	IEC 60255-21-1, 1G (class Bm)
Shock / bump:	IEC 60255-21-2, 10G (class Bm)
Seismic (single axis):	IEC60255-21-3, 1G / 3.5 mm (class 1)
Make and carry (30 A):	IEEE C37.90
Conducted immunity:	IEC 61000-4-6 / IEC60255-22-6, class 3 (10 V RMS)
Surge:	IEC 61000-4-5 or IEC 60225-22-5, 1.2/50 test up to level 4 (4 kV)
Burst disturbance (1 MHz oscillatory):	IEC60255-22-1 up to 2.5 kV at 1 MHz damped
Fast transients:	ANSI/IEEE C37.90.1, EC61000-4-4 class 4, (2 kV, 5 kHz / 4 kV, 2.5 kHz, 2 kV on data control ports and inputs/outputs), IEC 60255-22-4
Radiated immunity:	IEC 61000-4-3 / IEC 60255-22-3 class 3 (10 V/m) or IEEE C37.90.2 radiated RFI (35 V/m)
Power frequency disturbance:	IEC 61000-4-8 (30 A/m) class 4
Radiated/conducted emissions:	IEC 60255-25 / CISPR 11/22 class A
Insulation resistance:	IEC 60255-5
Dielectric strength:	IEC 60255-5, ANSI/IEEE C37.90
Dielectric across relay contacts:	IEEE C37.90 (1.6 kV)
Electrostatic discharge:	EN 61000-4-2, IEC60255-22-2 8 kV C, 15 kV A, L4
Voltage dips/interruptions/variatio	IEC 61000-4-11 (30% 1 cycle), IEC 60255-11
AC ripple:	IEC 61000-4-17 (standard)
Interruptions on DC power:	IEC61000-4-29
Damped magnetic immunity:	IEC61000-4-10 (level 5, 100A/m)
Impulse voltage withstand:	EN/IEC60255-5 (5 kV)
Humidity cyclic:	IEC60068-2-30, 6 days 55°C, 95%RH (variant 1)

Environmental specifications**OPERATING TEMPERATURE**

Cold:	IEC 60068-2-1, 16 hours at -40°C
Dry heat:	IEC 60068-2-2, 16 hours at 80°C

OTHER ENVIRONMENTAL SPECIFICATIONS

Altitude:	up to 2000 m
Installation category:	II
IP rating:	IP30 for front, IP10 for back
Noise:	Negligible

Approvals and certification**APPROVALS**

UL508 17th edition and C22.2 No.14-05: UL listed for the USA and Canada

CERTIFICATION

CE LVD 2006/95/EC:	EN/IEC 61010-1:2001 / EN60255-5:2000
CE EMC 89/336/EEC:	EN 60255-26:2004-08

D90^{Plus} Line Distance Protection System

Chapter 3: Installation

This chapter outlines installation of hardware and software. You unpack, check, mount, and wire the unit, then install the software and configure settings.

Unpack and inspect

Use this procedure to unpack and inspect the unit.

1. Open the relay package and check that the following items have been delivered:
 - D90^{Plus} Line Distance Protection System
 - Mounting screws
 - GE EnerVista™ CD (software and documentation)
 - Instruction Manual (soft copy on the CD; printed copy if ordered)
 - Communications Guide (soft copy on the CD; printed copy if Instruction Manual ordered)
 - Certificate of Calibration
 - Test Report
 - EC Declaration of Conformity
2. Inspect the unit for physical damage.
3. Verify that the correct model has been delivered.
4. For any issues, contact GE Grid Solutions as outlined in the For Further Assistance section in chapter 1.
5. Check that you have the latest copy of the Instruction Manual and the Communications Guide, for the applicable firmware version, at <http://gegridsolutions.com/multilin/manuals/index.htm>

The Instruction Manual outlines how to install, configure, and use the unit. The Communications Guide is for advanced use with communications protocols. The warranty is included at the end of this instruction manual and on the GE Grid Solutions website.

Panel cutouts

The D90^{Plus} is available as a 19-inch rack horizontal mount unit. The modular design allows the relay to be easily upgraded and repaired by qualified service personnel. The faceplate is hinged to allow access to the removable modules.



WARNING To minimize risk of electrical shock from contact with the power terminals, install the unit in an electrical closet/enclosure whereby the terminal connections are not readily accessible.

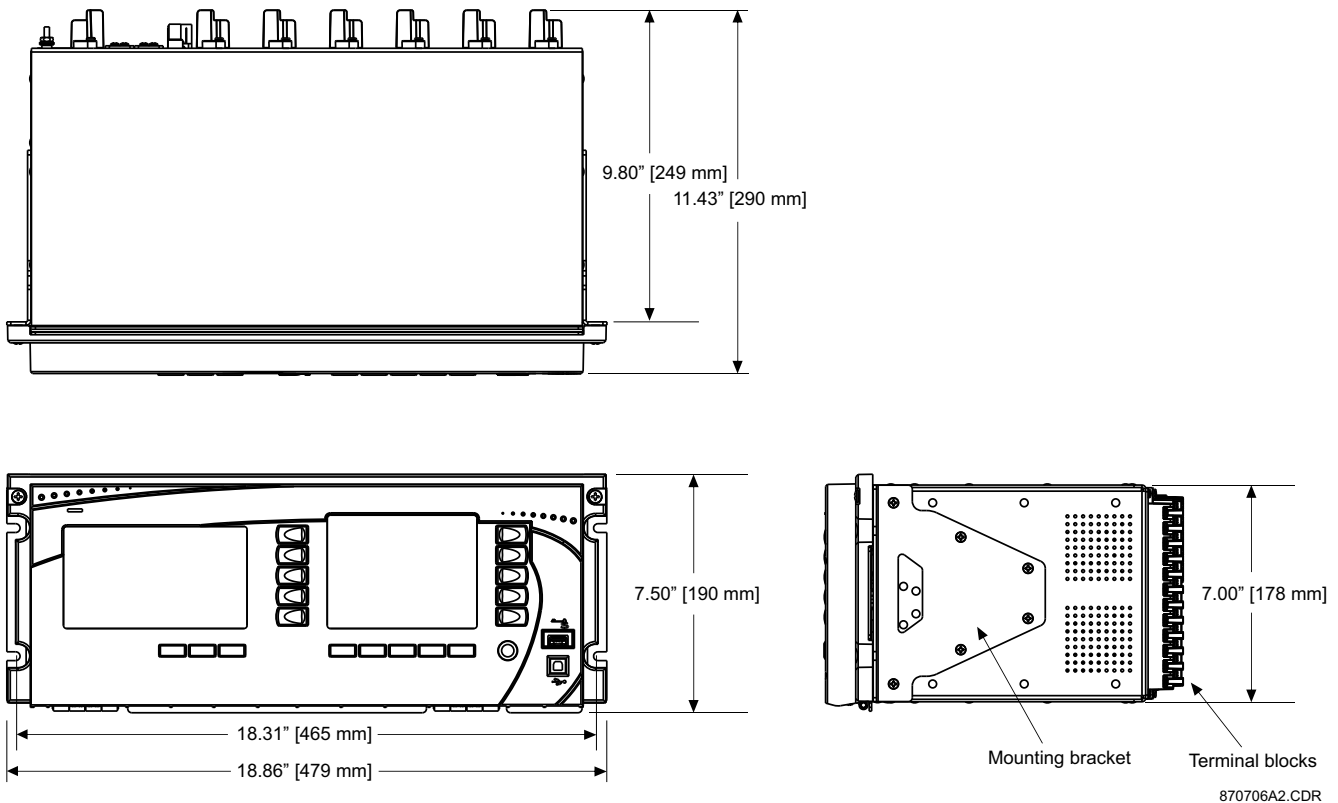
Dimensions

The case dimensions are shown here, along with panel cutout details for panel mounting. When planning the location of your panel cutout, ensure that provision is made for the faceplate to swing open without interference to or from adjacent equipment.

Mount the D90^{Plus} such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the front panel keys and USB communications port. Secure the D90^{Plus} to the panel with the use of four screws supplied with the relay.

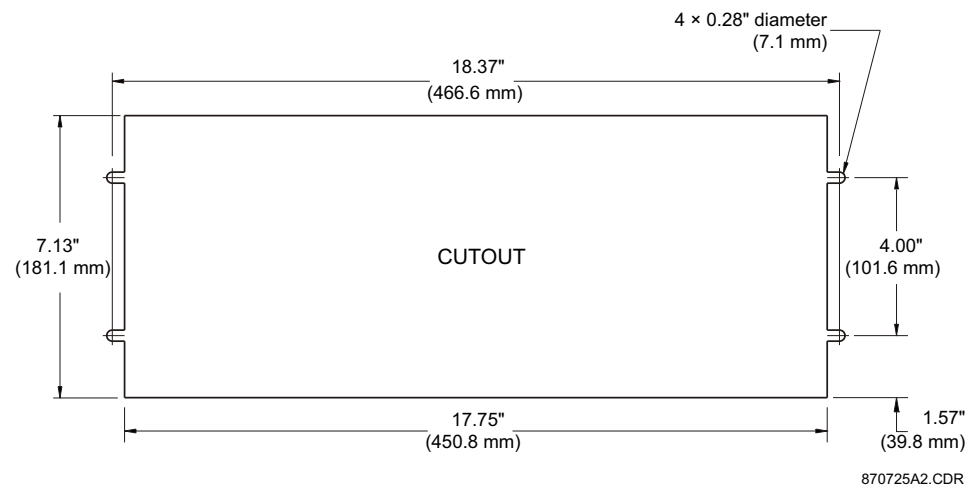
Leave a1U (1 rack-unit) space below the chassis when mounting for ventilation and to allow the front panel to swing open without obstruction.

Figure 16: D90^{Plus} dimensions



870706A2.CDR

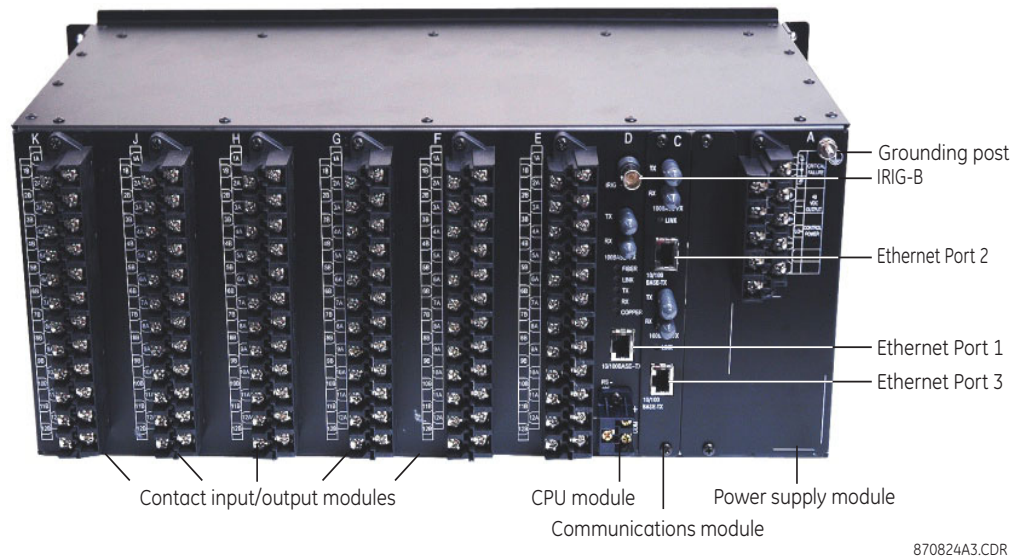
Figure 17: Panel cutout dimensions



Rear terminal layout

Terminal number assignments in the D90^{Plus} are represented by three characters, assigned in order by module slot position, row number, and column letter. The figure provides an example of rear terminal assignments.

Figure 18: Rear terminal view



Slot A houses the power supply module.

Slot B houses the inter-relay communication module (not shown).

Slot C houses the communications module.

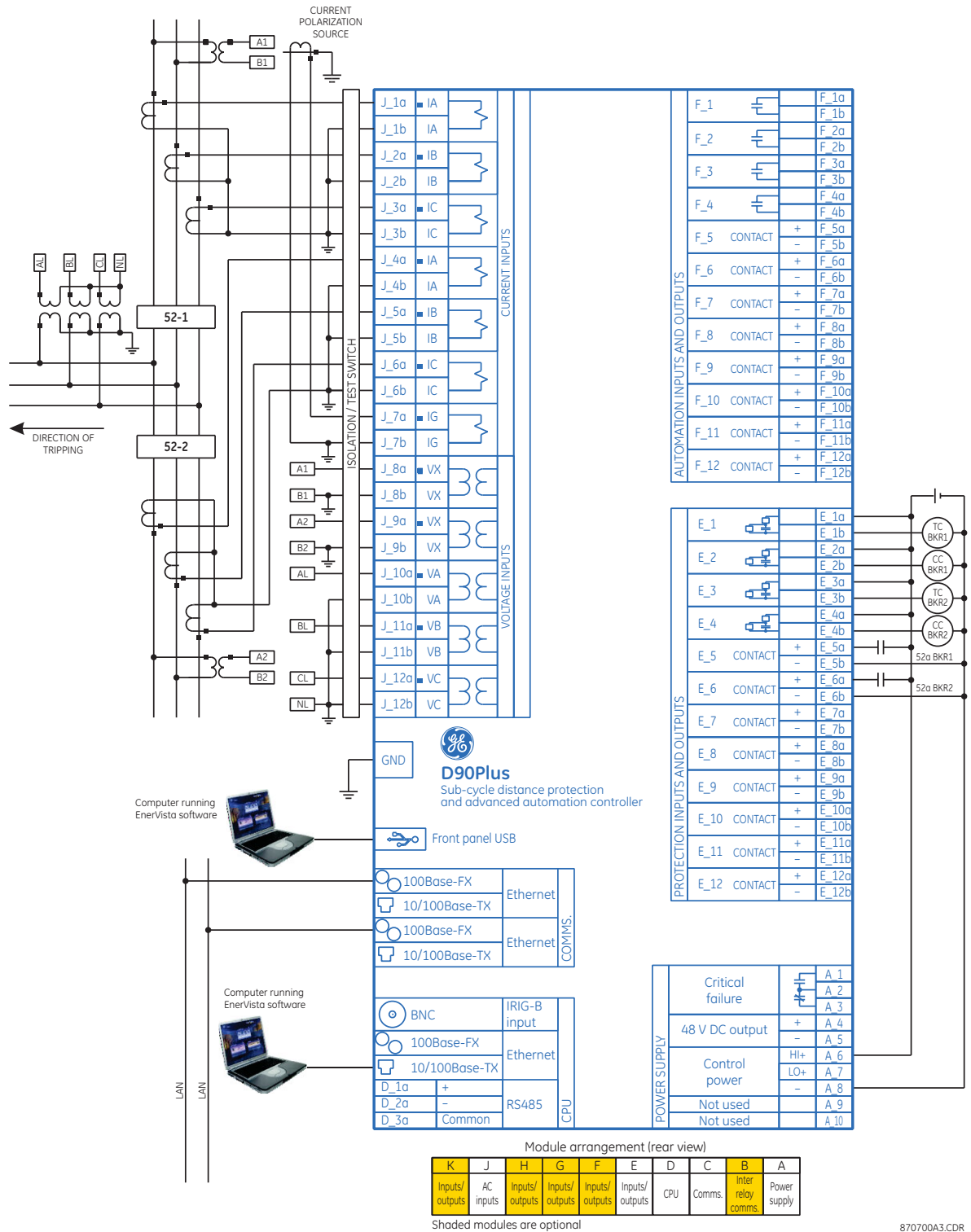
Slot D houses the main processing card.

Wiring

Typical wiring

The figure provides an example of how to wire the D90^{PLUS}. Actual wiring varies with application.

Figure 19: Typical wiring diagram



Dielectric strength

Dielectric strength is the maximum electric strength that can be sustained without breakdown. It is measured in volts.

The table shows the dielectric strength of the UR^{Plus}-series module hardware.

Table 1: Dielectric strength for UR^{Plus}-series hardware

Function	Terminals		Dielectric strength
	from	to	
Power supply module	high (+), low (+), (-)	chassis	2000 V AC for 1 minute
Power supply module	48 V DC (+) and (-)	chassis	2000 V AC for 1 minute
Power supply module	relay terminals	chassis	2000 V AC for 1 minute
Main CPU	RS485 port	chassis	2000 V AC for 1 minute
Main CPU	RJ45 port	chassis	1500 V AC for 1 minute
Main CPU	IRIG-B port	chassis	2000 V AC for 1 minute
Front panel	USB port	chassis	2000 V AC for 1 minute
Contact inputs/outputs	all	chassis	2000 V AC for 1 minute
AC module	all	chassis	2000 V AC for 1 minute
Communications module	RS45 ports	chassis	1500 V AC for 1 minute
G.703 module	all except 1a, 8a	chassis	1000 V AC for 1 minute
RS422 module	all except 1a, 8a	chassis	1500 V AC for 1 minute

Filter networks and transient protection clamps are used in the hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI).

NOTICE

The protective components can be damaged by application of any test voltage for a period longer than the specified minute.

Main processor module

The main processor module in slot D contains ports for Ethernet communications, serial RS485 communications, and IRIG-B connection.

Ethernet port

The fiber optic communication ports allow for fast and efficient communications between relays at 100 Mbps. Optical fiber can be connected to the relay supporting a wavelength of 1310 nm in multi-mode.

The optical fiber sizes supported are 50/125 μm and 62.5/125 μm . The fiber optic port is designed such that the response times do not vary for any core that is 62.5 μm or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter-receiver pair. When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.

CAUTION



Observing any fiber transmitter output can injure the eye.

Ensure the dust covers are installed when the fiber is not in use. Dirty or scratched connectors can lead to high losses on a fiber link.

RS485 port

RS485 data transmission and reception are accomplished over a single twisted-pair wire with transmit and receive data alternating over the same two wires. Through the use of this port, continuous monitoring and control from a remote computer, SCADA system, or Power Line Carrier (PLC) is possible.

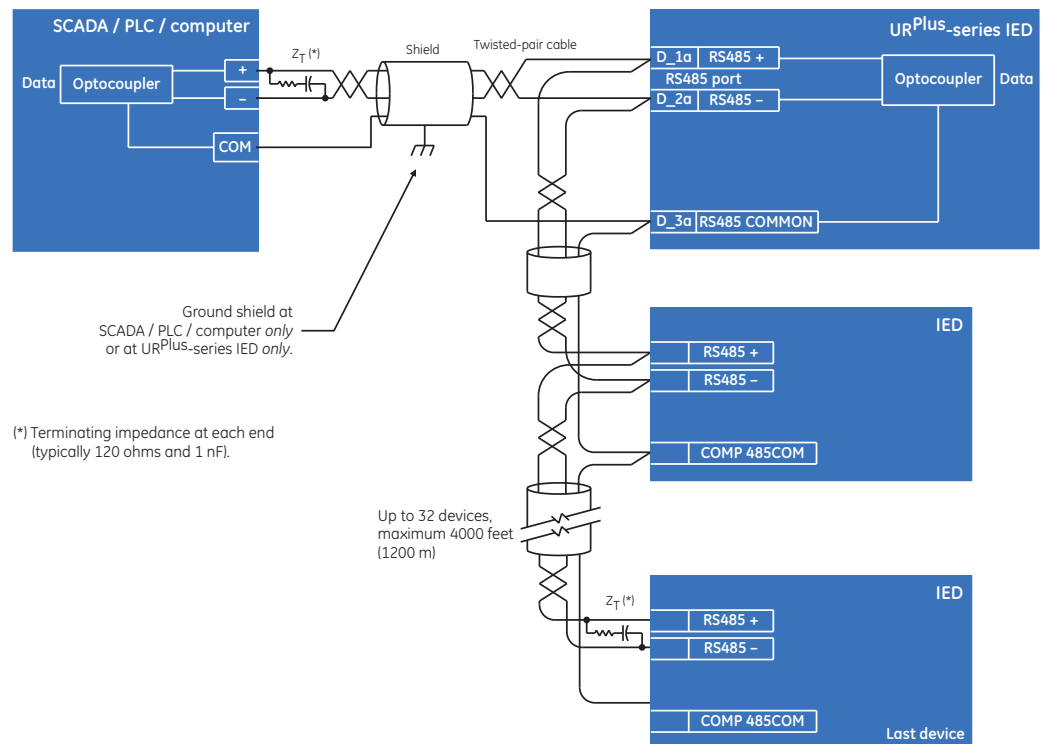
To minimize errors from noise, the use of shielded twisted-pair wire is recommended. Correct polarity must also be observed. For instance, the relays must be connected with all RS485 “+” terminals connected together, and all RS485 “-” terminals connected together. Though data is transmitted over a two-wire twisted-pair, all RS485 devices require a shared reference, or common voltage. This common voltage is implied to be a power supply common. Some systems allow the shield (drain wire) to be used as common wire and to connect directly to the D90^{PLUS} COM terminal (3a); others function correctly only if the common wire is connected to the D90^{PLUS} COM terminal, but insulated from the shield.

To avoid loop currents, ground the shield at only one point. If other system considerations require the shield to be grounded at more than one point, install resistors (typically 100 ohms) between the shield and ground at each grounding point. Each UR^{PLUS}-series device needs to be daisy-chained to the next one in the link. A maximum of 32 devices can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to have more than 32 devices on a single channel. Avoid star or stub connections entirely.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are provided internally at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, ensure that all equipment has similar transient protection devices installed.

Terminate both ends of the RS485 circuit with an impedance as shown in the figure.

Figure 20: RS485 serial connection



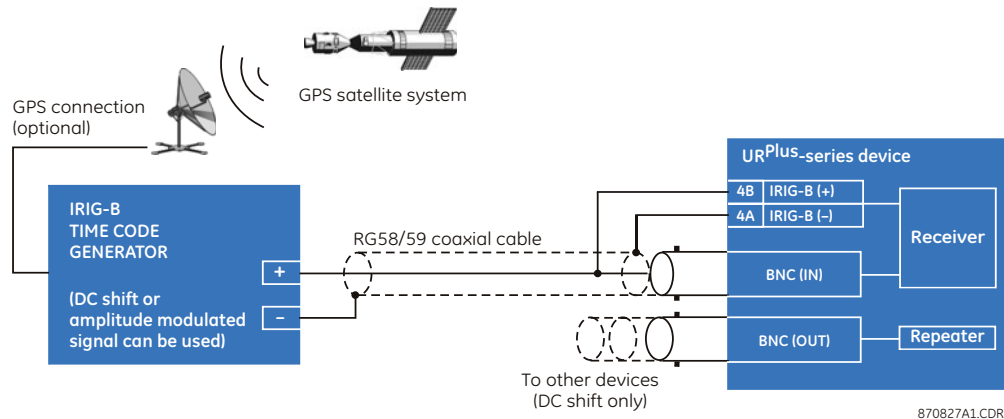
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IRIG-B port

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices. The IRIG-B code allows time accuracies of up to 100 ns. The IRIG time code formats are serial, pulse width-modulated codes that can be either DC level shifted or amplitude modulated (AM).

Third party equipment is available for generating the IRIG-B signal; this equipment can use a global positioning system (GPS) satellite system to obtain the time reference so that devices at different geographic locations can be synchronized.

Figure 21: IRIG-B connection



For additional information, refer to:

[Real-time clock](#) on page 145

Communications module

The communications module in slot C contains two ports for Ethernet communications, designated as port 2 and port 3. These are fully independent from each other and from port 1 on the main processor module. The communications module ports support redundancy and several protocols not supported by port 1.

The fiber optic ports allow for fast and efficient communication between devices at 100 Mbps. Optical fiber can be connected to the D90^{PLUS} supporting a wavelength of 1310 nm in multimode.

The optical fiber sizes supported are 50/125 μm and 62.5/125 μm. The fiber optic port is designed such that the response time does not vary for any core that is 62.5 μm or less. For optical power budgeting, splices are required every 1 km for the transmitter-receiver pair. When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.

CAUTION

Observing any fiber transmitter output can injure the eye.



Ensure the dust covers are installed when the fiber is not in use. Dirty or scratched connectors can lead to high losses on a fiber link.

Power supply module

The power supply module in slot A provides power to the relay and supplies power for dry contact input connections. It can be connected to any of the following standard power sources:

- DC power: 110, 125, 220, or 250 V DC
- AC power: 115 or 230 V AC

NOTICE

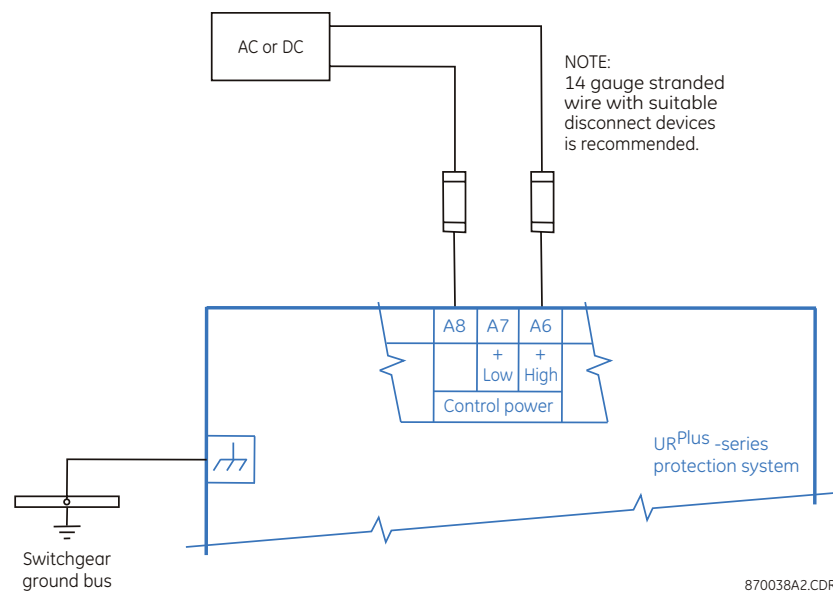
Control power supplied to the relay must be connected to the matching power supply range of the relay. If the voltage is applied to the wrong terminals, damage can occur.

NOTICE

The D90^{Plus} system, like almost all electronic relays, contains electrolytic capacitors. These capacitors are well known to deteriorate over time if voltage is not applied periodically. Deterioration can be avoided by powering up the relay at least once a year.

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see Typical Wiring Diagram earlier). The critical failure relay is a form-C device that is energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If on-going self-test diagnostic checks detect a critical failure or control power is lost, the relay de-energizes.

Figure 22: Control power connection



AC modules

An AC module has voltage inputs on channels 8 through 12 inclusive. Channel 10 is intended for connection to a source that represents phase A voltage of the power system (produced by a VT or CVT). Likewise, channel 11 is intended for connection to phase B, and channel 12 is intended for connection to phase C. The phase voltage channels are used for most metering and protection purposes.

Channels 8 and 9 are intended for connection to single-phase sources. In the D90^{Plus}, each of these inputs typically is used to measure the voltage on the side of the breaker opposite to the line terminal. Each of these channels is labeled as an auxiliary voltage (VX). The auxiliary voltage channels are used as inputs for synchrocheck, but can also be used for auxiliary undervoltage or overvoltage elements.

An AC module has current inputs on channels 1 through 7 inclusive. In a single breaker application, channel 1 is intended for connection to a source representing the phase A current of the power system (produced by a CT). Likewise, channel 2 is intended for connection to phase B, and channel 3 is intended for connection to phase C. In a breaker-and-a-half application, channels 1 through 3 are connected to the phase A, B, and C

currents from one breaker, while channels 4 through 6 are connected to the phase A, B, and C currents from the second breaker. The phase current channels are used for most metering and protection purposes.

Channel 7 can be used for either of two purposes. First, it can be connected to a CT that is directly measuring system ground current. It can also be connected to the CT residual circuit of a parallel line.



If connected to the CT residual circuit of a parallel line, the input provides a signal for zero-sequence mutual coupling compensation for the distance element. If this compensation is required, the zero-sequence current from the parallel line (3I₀) measured in the direction of the zone being compensated must be connected to the ground input CT of the CT bank configured as the distance source.

NOTICE

Verify that the connection made to the relay nominal current of 1 A or 5 A matches the secondary rating of the connected CTs. Unmatched CTs can result in equipment damage or inadequate protection.

CAUTION

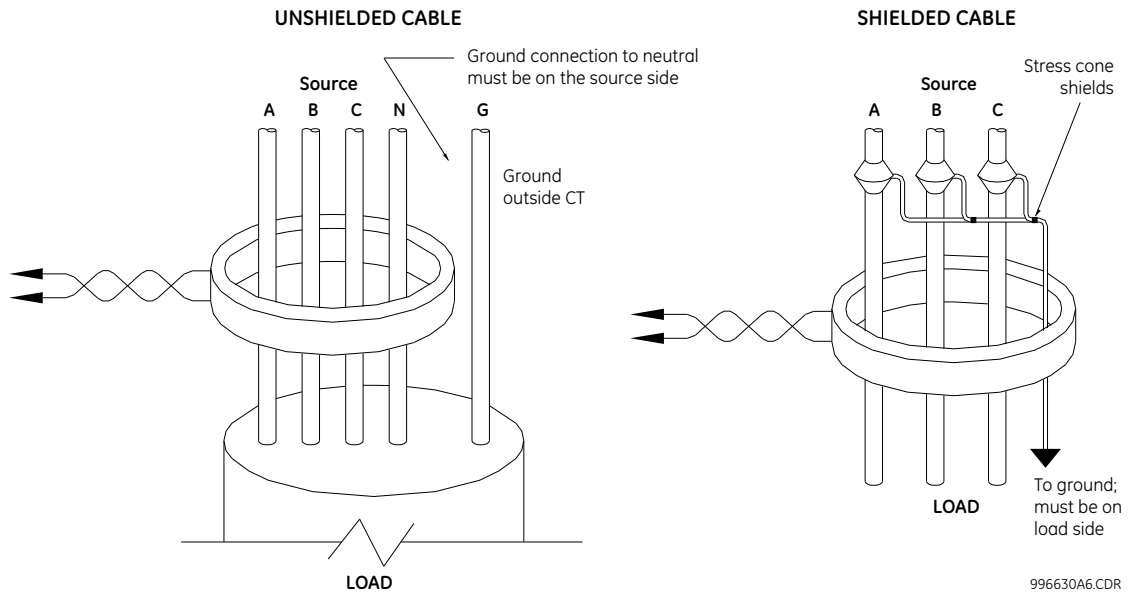
The CT secondaries should be connected to the AC terminals of the D90^{Plus} through a shorting-type test switch or shorting-type terminal blocks in order to facilitate safe withdrawal of the AC module.

There are no internal ground connections on the current inputs. Current transformers with 1 to 50000 A primaries and 1 A or 5 A secondaries can be used.

CT connections for both ABC and ACB phase rotations are identical, as shown in the Typical Wiring Diagram.

The exact placement of a zero-sequence core balance CT to detect ground fault current is shown below. Twisted-pair cabling on the zero-sequence CT is recommended.

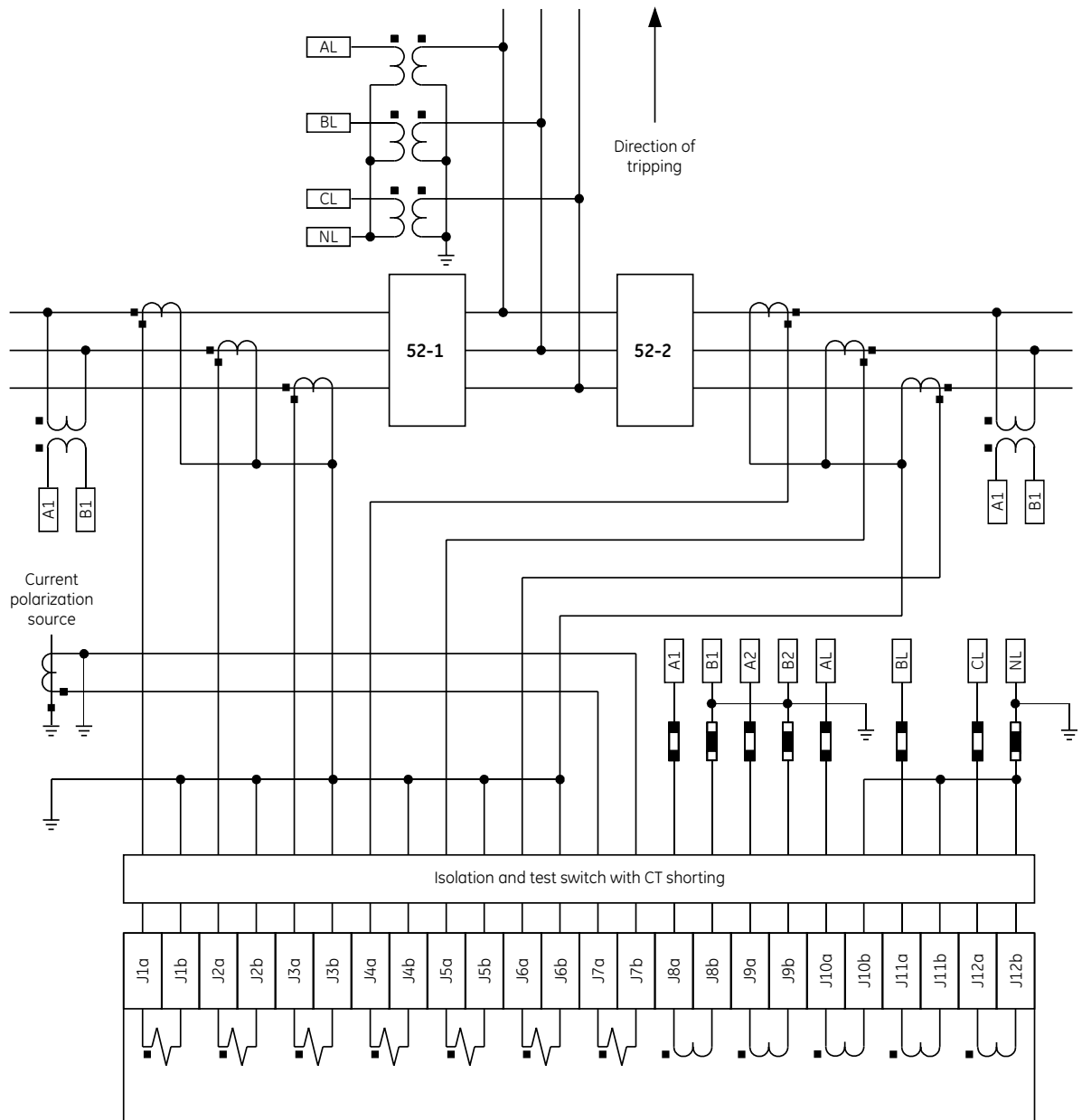
Figure 23: Zero-sequence core-balance CT installation



The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as an input for features such as synchrocheck, volts per hertz, and auxiliary undervoltage.

A typical AC module wiring diagram is shown as follows. Substitute the tilde “~” symbol with the slot position of the AC module.

Figure 24: Typical AC module wiring



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Contact input and output modules

Each contact input/output module has 24 terminal connections. They are arranged in two terminals per row, with twelve rows in total. A given row of two terminals can be used for the outputs of one relay. There are options of using current or voltage detection for feature supervision, depending on the module ordered.

All inputs and outputs are isolated from one another with each input and output having two dedicated terminals. Since an entire module row is used for a single contact input or output, the name is assigned using the module slot position and row number.

Form-A and solid-state relay output contacts

Some form-A and solid-state relay (SSR) outputs include circuits to monitor the DC voltage across the output contact when it is open, and the DC current through the output contact when it is closed. Each of the monitors contains a level detector whose output is set to logic 1 (on) when the current in the circuit is above the threshold setting. The voltage monitor is intended to check the health of the overall trip circuit, and the current monitor can be used to seal-in the output contact until an external contact has interrupted current flow.

Figure 25: Form-A relay contact input functions

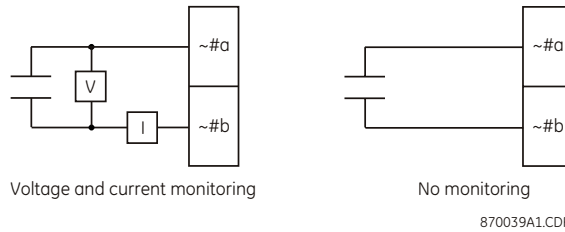
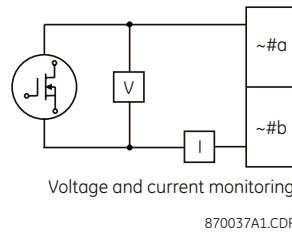


Figure 26: Solid-state relay contact input functions



The operation of voltage and current monitors is reflected with the corresponding FlexLogic operands (*Cont Op ### Von*, *Cont Op ### Voff*, *Cont Op ### Ion*, and *Cont Op ### Ioff*) that can be used in protection, control, and alarm logic. The typical application of the voltage monitor is breaker trip circuit integrity monitoring; a typical application of the current monitor is seal-in of the control command.



Relay contacts are unsafe to touch when the unit is energized. If the relay contacts need to be used for low voltage accessible applications, it is the customer's responsibility to ensure proper insulation levels.



When current monitoring is used to seal-in the form-A and solid-state relay contact outputs, give the FlexLogic operand driving the contact output a reset delay of 10 ms to prevent damage of the output contact (in situations when the element initiating the contact output is bouncing, at values in the region of the pickup value).

Contact inputs wiring

Contact inputs are not polarity sensitive. A dry contact has one side connected to terminal A_5. This is the positive 48 V DC voltage rail supplied by the power supply module. The other side of the dry contact is connected to either of the contact input terminals. The other contact input terminal is connected to the DC negative terminal (A_4) of the power supply module. When a dry contact closes, a 10 mA current initially flows through the associated circuit. Once the relay has validated the state change of the contact, the input current is reduced to 1 mA.

A wet contact has one side connected to the positive terminal of an external DC power supply. The other side of this contact is connected to the one of the contact input terminals. In addition, the negative side of the external source must be connected to the

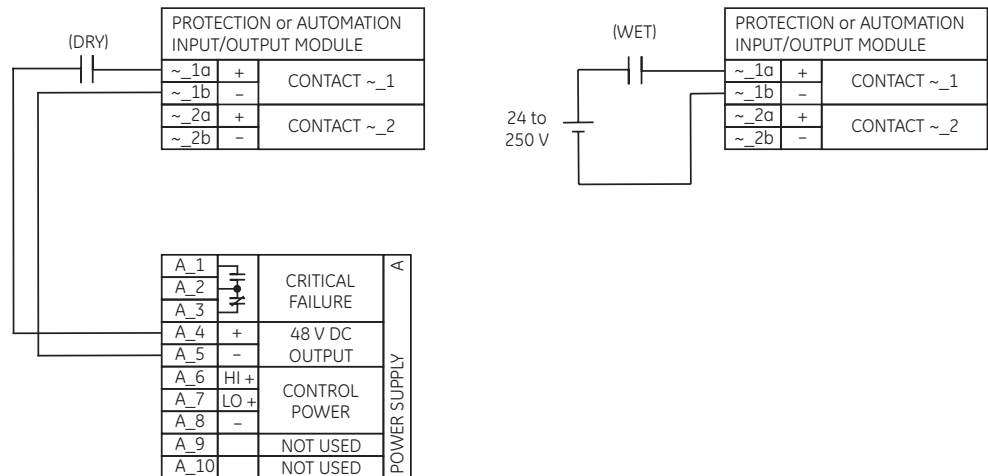
other contact input terminal. The maximum external source voltage for this arrangement is 300 V DC. The voltage threshold at which each group of four contact inputs will detect a closed contact input is programmable as from 24 to 250 V DC.



NOTE

Wherever a tilde “~” symbol appears, substitute with the slot position of the module.

Figure 27: Dry and wet contact input connections



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Contact outputs wiring

Contact outputs can be ordered as form-A or solid-state relays. Depending on the module ordered, these contacts can be connected for external circuit supervision. These contacts are provided with voltage and current monitoring circuits used to detect the loss of DC voltage in the circuit, and the presence of DC current flowing through the contacts when the form-A contact closes. If enabled, the current monitoring can be used as a seal-in signal to ensure that the form-A contact does not attempt to break the energized inductive coil circuit and weld the output contacts.



NOTE

There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.

Contact input/output module configuration

There are six types of contact input and output modules available for the D90^{PLUS}.

- Type A — Eight contact inputs, four form-A contact outputs with voltage and current monitoring
- Type B — Eight contact inputs, four solid-state (SSR) contact outputs with voltage and current monitoring
- Type C — Eight contact inputs, four form-A contact outputs
- Type D — Four contact inputs, eight form-A contact outputs
- Type E — 23 contact inputs
- Type F — 12 form-A contact outputs

The following figure and table show the terminal block pin assignments for all module types.

Figure 28: Terminal block pin view

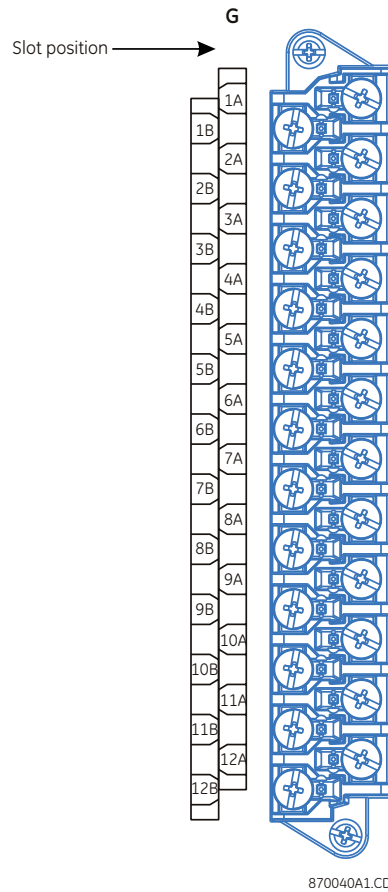


Table 2: Module configuration

Pin	Contact input/output module					
	Type A	Type B	Type C	Type D	Type E	Type F
1A	Form-A output 1 +	SSR output 1 +	Form-A output 1 +	Form-A output 1 +	Contact input 1 +	Form-A output 1 +
1B	Form-A output 1 -	SSR output 1 -	Form-A output 1 -	Form-A output 1 -	Contact input 2 +	Form-A output 1 -
2A	Form-A output 2 +	SSR output 2 +	Form-A output 2 +	Form-A output 2 +	Contact input 3 +	Form-A output 2 +
2B	Form-A output 2 -	SSR output 2 -	Form-A output 2 -	Form-A output 2 -	Contact input 4 +	Form-A output 2 -
3A	Form-A output 3 +	SSR output 3 +	Form-A output 3 +	Form-A output 3 +	Contact input 5 +	Form-A output 3 +
3B	Form-A output 3 -	SSR output 3 -	Form-A output 3 -	Form-A output 3 -	Contact input 6 +	Form-A output 3 -
4A	Form-A output 4 +	SSR output 4 +	Form-A output 4 +	Form-A output 4 +	Contact input 7 +	Form-A output 4 +
4B	Form-A output 4 -	SSR output 4 -	Form-A output 4 -	Form-A output 4 -	Contact input 8 +	Form-A output 4 -
5A	Contact input 1 +	Contact input 1 +	Contact input 1 +	Form-A output 5 +	Contact input 9 +	Form-A output 5 +
5B	Contact input 1 -	Contact input 1 -	Contact input 1 -	Form-A output 5 -	Contact input 10 +	Form-A output 5 -
6A	Contact input 2 +	Contact input 2 +	Contact input 2 +	Form-A output 6 +	Contact input 11 +	Form-A output 6 +

Pi n	Contact input/output module					
	Type A	Type B	Type C	Type D	Type E	Type F
6B	Contact input 2 -	Contact input 2 -	Contact input 2 -	Form-A output 6 -	Contact input 12 +	Form-A output 6 -
7A	Contact input 3 +	Contact input 3 +	Contact input 3 +	Form-A output 7 +	Contact input 13 +	Form-A output 7 +
7B	Contact input 3 -	Contact input 3 -	Contact input 3 -	Form-A output 7 -	Contact input 14 +	Form-A output 7 -
8A	Contact input 4 +	Contact input 4 +	Contact input 4 +	Form-A output 8 +	Contact input 15 +	Form-A output 8 +
8B	Contact input 4 -	Contact input 4 -	Contact input 4 -	Form-A output 8 -	Contact input 16 +	Form-A output 8 -
9A	Contact input 5 +	Contact input 5 +	Contact input 5 +	Contact input 1 +	Contact input 17 +	Form-A output 9 +
9B	Contact input 5 -	Contact input 5 -	Contact input 5 -	Contact input 1 -	Contact input 18 +	Form-A output 9 -
10 A	Contact input 6 +	Contact input 6 +	Contact input 6 +	Contact input 2 +	Contact input 19 +	Form-A output 10 +
10 B	Contact input 6 -	Contact input 6 -	Contact input 6 -	Contact input 2 -	Contact input 20 +	Form-A output 10 -
11 A	Contact input 7 +	Contact input 7 +	Contact input 7 +	Contact input 3 +	Contact input 21 +	Form-A output 11 +
11 B	Contact input 7 -	Contact input 7 -	Contact input 7 -	Contact input 3 -	Contact input 22+	Form-A output 11 -
12 A	Contact input 8 +	Contact input 8 +	Contact input 8 +	Contact input 4 +	Contact input 23 +	Form-A output 12 +
12 B	Contact input 8 -	Contact input 8 -	Contact input 8 -	Contact input 4 -	Common -	Form-A output 12 -

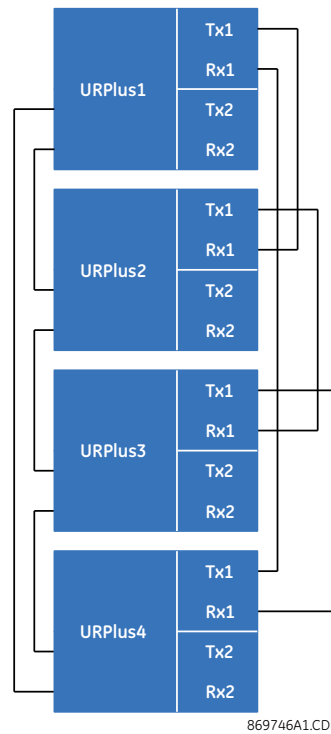
Inter-relay communication modules

The inter-relay communication modules support high-speed, direct communication between UR^{Plus}-series devices. The direct inputs and outputs feature uses the communication channels provided by these modules to exchange digital state information. This feature is available on all UR^{Plus}-series devices.

The communications channels are normally connected in a ring configuration as shown in the following figure. The transmitter of one module is connected to the receiver of the next module. The transmitter of this second module is then connected to the receiver of the next module in the ring. This is continued to form a communications ring.

The interconnection for dual-channel communication modules is shown. Two channel modules allow for a redundant ring configuration. That is, two rings can be created to provide an additional independent data path. The required connections are: URPlus1-Tx1 to URPlus2-Rx1, URPlus2-Tx1 to URPlus3-Rx1, URPlus3-Tx1 to URPlus4-Rx1, and URPlus4-Tx1 to URPlus1-Rx1 for the first ring; and URPlus1-Tx2 to URPlus4-Rx2, URPlus4-Tx2 to URPlus3-Rx2, URPlus3-Tx2 to URPlus2-Rx2, and URPlus2-Tx2 to URPlus1-Rx2 for the second ring.

Figure 29: Direct input and output dual channel connection



The interconnection requirements are described in further detail in this section for each inter-relay communication module, which is specified at the time of ordering. The table lists these modules. All fiber modules use ST type connectors.

Table 3: Inter-relay communication modules

Order code option	Specification
B	G.703, 64/128 kbps, two channels
C	RS422, 64/128 kbps, two channels, two clock inputs
D	850 nm, 64/128 kbps, ST multimode laser, two channels with DDMI

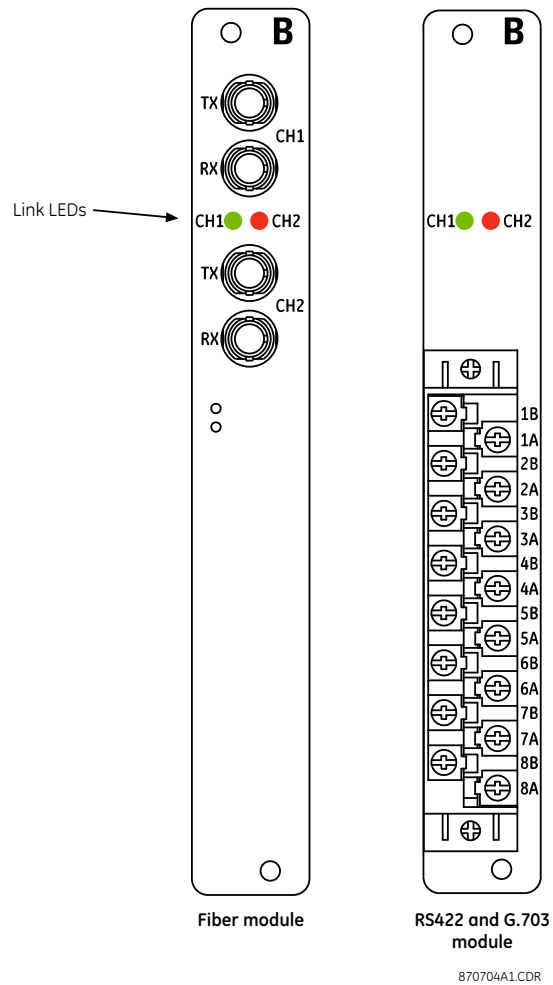


The 850 nm module uses a class 1 VCSEL laser that is harmful to the eye. Observing any fiber transmitter output can cause serious injury to the eye.

Direct input and output link LEDs

The link LEDs for channels 1 and 2 are located on the rear of the inter-relay communications card, which is located in slot B.

Figure 30: Link LEDs for fiber, RS422, and G.703 modules



The table describes the operation of the link LEDs.

Table 4: Link LED operation

Protocol	LED indications			
	Red, solid	Green, solid	Green, blinking	Yellow, blinking
IEEE C37.94	Loss of signal	Signal detected, but not receiving valid data	Signal detected and receiving valid data; yellow bit alarm not set	Signal detected, receiving valid data and the received yellow bit alarm is set; the yellow bit indicates that remote unit is not receiving valid data
Direct fiber	Loss of signal	Signal detected, but not receiving valid data	Signal detected and receiving valid data	Not used
G.703	Loss of signal	Signal detected, but not receiving valid data	Signal detected and receiving valid data	Not used
RS422	Loss of clock	Clock detected, but not receiving valid data	Clock detected and receiving valid data	Not used

G.703 communication interface

AWG 24 twisted shielded pair is recommended for external connections, with the shield grounded only at one end. Connecting the shield to pin B1a or B8a grounds the shield since these pins are internally connected to ground. Thus, if pin B1a or B8a is used to ground the shield at one end, do not ground the shield at the other end. The G.703 module chassis is protected by surge suppression devices.

The following figure shows the 64 kbps ITU G.703 co-directional interface configuration.

Figure 31: G.703 module connections

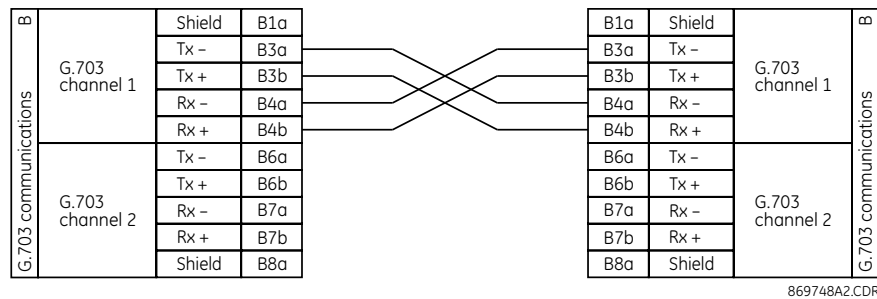
G.703 communications	G.703 channel 1	Shield	B1a
		Tx -	B3a
		Tx +	B3b
		Rx -	B4a
	G.703 channel 2	Rx +	B4b
		Tx -	B6a
		Tx +	B6b
		Rx -	B7a
		Rx +	B7b
		Shield	B8a

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The G.703 octet timing and timing mode are set using the **Protocol Encoding** setting.

The following figure shows the typical pin interconnection between two G.703 interfaces. All pin interconnections are to be maintained for a connection to a multiplexer.

Figure 32: Typical pin interconnection between two G.703 interfaces



Pin nomenclature differs from one manufacturer to another. It is not uncommon to see pinouts numbered Tx_A, Tx_B, Rx_A, and Rx_B. In such cases, assume that “A” is equivalent to “+” and “B” is equivalent to “-.”

RS422 communication interface

The RS422 inter-relay communications module is a dual-channel dual-clock RS422 interface. The module can be configured to run at 64 or 128 kbps. AWG 24 twisted shielded pair cable is recommended for external connections. The module is protected by an optically-isolated surge suppression device.

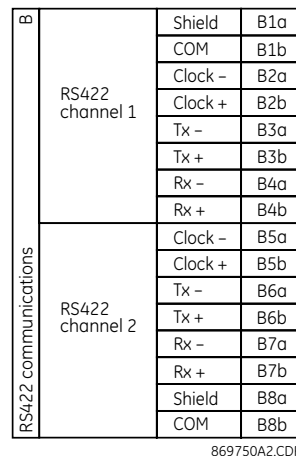
The two-channel two-clock RS422 interface is intended for use with two independent channel banks with two independent clocks. It is intended for situations where a single clock for both channels is not acceptable.

The shield pins (B1a and B8a) are connected internally to chassis ground. Proper shield termination is as follows:

- Site 1 — Terminate shield to pin B1a
- Site 2 — Connect COM pin B1b to site 1 COM pin B1b. Note that pins B1b and B8b are connected internally.

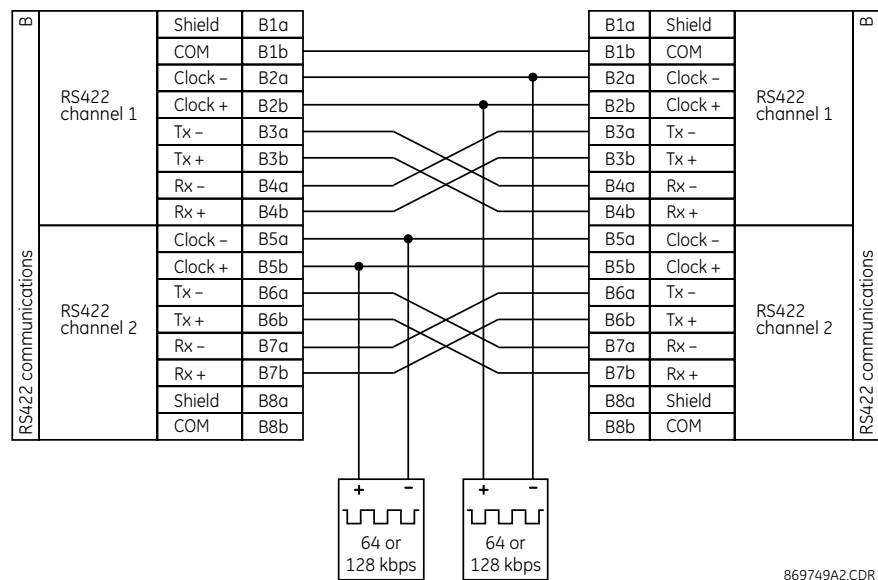
Match the clock terminating impedance with the impedance of the line.

Figure 33: RS422 interface connections



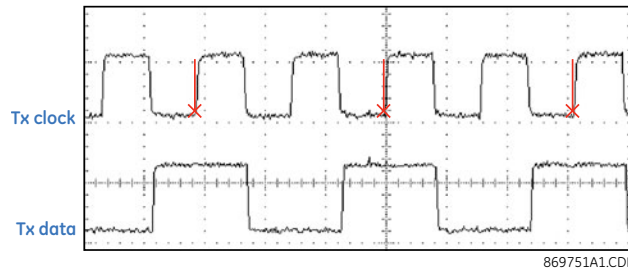
The following figure shows the typical pin interconnection between two dual-channel RS422 interfaces. All pin interconnections are to be maintained for a connection to a multiplexer.

Figure 34: Typical connection between two RS422 interfaces



Each channel of the RS422 interface accepts a clock input for transmit timing. It is important that the rising edge of the 64 kHz transmit timing clock of the multiplexer interface is sampling the data in the center of the transmit data window. Therefore, it is important to confirm clock and data transitions to ensure proper system operation. For example, the following figure shows the positive edge of the Tx clock in the center of the Tx data bit.

Figure 35: Clock and data transitions



The RS422 interface utilizes NRZI-MARK modulation code and therefore does not rely on an Rx clock to recapture data. NRZI-MARK is an edge-type, invertible, self-clocking code.

To recover the Rx clock from the data-stream, an integrated digital phase lock loop (DPLL) circuit is utilized. The DPLL is driven by an internal clock, which is 16-times over-sampled, and uses this clock along with the data-stream to generate a data clock that can be used as the serial communication controller (SCC) receive clock.

Fiber communication interface

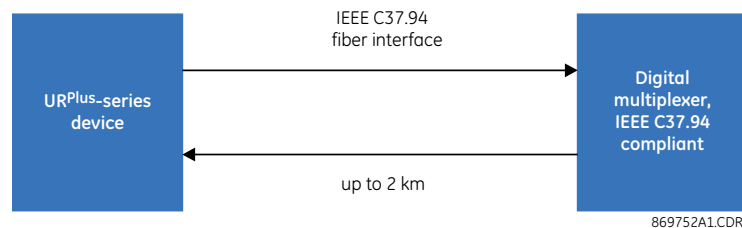
The UR^{Plus}-series communication module is designed to interface with IEEE C37.94 compliant digital multiplexers or an IEEE C37.94 compliant interface converter for use with direct input and output applications when the **Protocol Encoding** setting is “C37.94” or for direct fiber interfaces using the Differential Manchester protocol when the **Protocol Encoding** setting is “Direct Fiber.” The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to 64n kbps, where n = 1, 2, ..., 12. The UR^{Plus}-series C37.94 communication modules are either 64 kbps (with n fixed at 1) for 128 kbps (with n fixed at 2). The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

The specifications for the module are as follows:

- IEEE standard — C37.94 for 2 × 64/128 kbps optical fiber interface
- Differential Manchester protocol — 2 × 64/128 kbps optical fiber interface
- Fiber optic cable type — 50 mm or 62.5 mm core diameter optical fiber
- Fiber optic mode — Multimode
- Fiber optic cable length — Up to 2 km
- Fiber optic connector — Type ST
- Wavelength — 850 nm VCSEL laser
- Connection — As per all fiber optic connections, a Tx to Rx connection is required

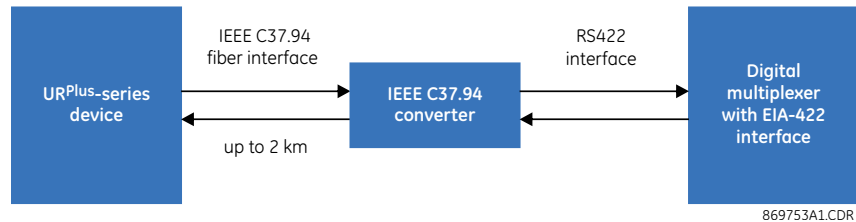
The UR^{Plus}-series C37.94 communication module can be connected directly to any compliant digital multiplexer that supports the IEEE C37.94 standard. The figure shows the concept.

Figure 36: IEEE C37.94 connection to compliant digital multiplexer



The UR^{Plus}-series C37.94 communication module can be connected to the electrical interface (G.703, RS422, or X.21) of a non-compliant digital multiplexer via an optical-to-electrical interface converter that supports the IEEE C37.94 standard. The following figure shows the concept.

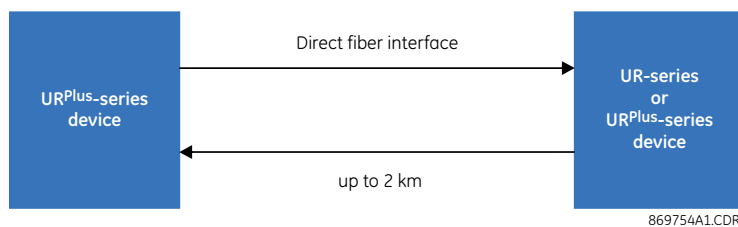
Figure 37: IEEE C37.94 connection to non-compliant digital multiplexer



The **Protocol Encoding** setting is used to set the protocol and clock option for the IEEE C37.94 protocol selection. If the setting is programmed as “C37.94 Internal Clock”, then the system clock is generated internally. For an external or loop timing scheme, the system clock is derived from the received line signal. For these cases, the program the setting to “C37.94 External Clock” or “Default” for connection to higher-order systems.

The UR^{Plus}-series direct fiber module can be connected directly to another UR^{Plus}-series or UR-series device with an installed direct fiber module.

Figure 38: Direct fiber to direct fiber connection



Install software

The EnerVista UR^{Plus} Setup software provides tools to monitor the status of your protected asset, maintain the device, and integrate information measured by the D90^{Plus} into DCS or SCADA monitoring systems. Convenient COMTRADE and sequence of events viewers are an integral part of the software included with every D90^{Plus}. This allows the user to carry out post-mortem event analysis to ensure proper protection system operation.

System requirements

The relay front panel EnerVista UR^{Plus} Setup software can be used to communicate with the D90^{Plus}. The software is the preferred method to edit settings and view actual values because the computer monitor can display more information.

The minimum system requirements for the EnerVista software are as follows:

- Pentium class or higher processor (Pentium II 300 MHz or higher recommended)
- Windows XP, Vista, 7 (64-bit), or Server 2008 (64-bit)
- Internet Explorer 4.0 or higher
- 128 MB of RAM (256 MB recommended)
- 200 MB of available space on system drive and 200 MB of available space on installation drive
- 800 × 600 display or higher in high-color mode (16-bit color)

- USB 2.0 or Ethernet port
- Internet access or CD drive

The software and unit are backwards-compatible with UR^{Plus}-series devices having any previous firmware version.

Install software

After ensuring that the requirements for using EnerVista UR^{Plus} Setup software are met, install the software from the CD, or download EnerVista Launchpad software from <http://gegridsolutions.com/multilin> and install it. To install the software from the CD:

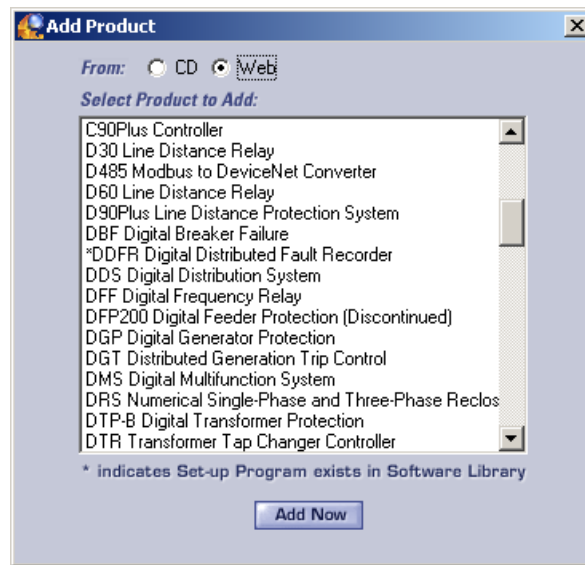
1. Insert the CD into the CD-ROM drive of your computer.
2. Click the **Install Now** button and follow the instructions.
3. When installation is complete, start the EnerVista Launchpad application.
4. Click the **IED Setup** button in the Launch Pad window.

Figure 39: Adding a device in Launchpad window



5. In the EnerVista Launch Pad window, click the **Add Product** button and select the "D90^{Plus} Line Distance Protection System" from the Install Software window. Select the **Web** option to ensure the most recent software release, or select **CD** if you do not have an Internet connection, then click the **Add Now** button to list software items for the D90^{Plus}. EnerVista Launchpad obtains the software from the Internet or CD and automatically starts the installation program.

Figure 40: Identifying the device type



6. Select the complete path, including the new directory name, where the EnerVista UR^{Plus} Setup is to be installed.
7. Click the **Next** button to begin the installation. The files are installed in the directory indicated, and the installation program automatically creates icons and adds an entry to the Windows start menu.
8. Click **Finish** to complete the installation. The UR^{Plus}-series device is added to the list of installed intelligent electronic devices (IEDs) in the EnerVista Launchpad window, as follows.

Figure 41: UR^{Plus}-series device added to Launchpad window

Connect for first time with Quick Connect

The most convenient way to establish communication to the D90^{Plus} for the first time using the EnerVista UR^{Plus} Setup software is to use the USB interface located on the front of the relay. Once communications has been established the settings for the RS485 and Ethernet port can then be configured as described in the following sections. This procedure assumes the EnerVista UR^{Plus} Setup software has been installed.

1. Ensure that the USB cable is not connected to the D90^{Plus}.
2. Start EnerVista UR^{Plus} Setup software.
3. Connect the USB cable between the computer and the front panel of the D90^{Plus}.

Figure 42: Computer and device connected with USB cable



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- The first time that the computer is connected, a hardware configuration wizard opens. Complete the wizard. For the driver location, browse to the EnerVista UR^{Plus} Setup software location and locate the **USB Driver** folder that contains the SerialUSB.inf driver file. The path is typically **C:/Program Files/GE Power Management//USB Driver**, or for Windows 7 64-bit **C:/Program Files/GE Power Management//USB Driver 64-bit**.

If an error message displays and the wizard does not complete, the Multilin Relay USB Serial Emulation driver software is being blocked. The following fix uses Windows XP Service Pack 3 as an example. Access the **Control Panel** application in Windows, then click **System**, click the **Hardware** tab, then click the **Driver Signing** button. Change the setting to **Warn** or **Ignore**. Then restart the hardware wizard in the Control Panel by clicking **Administrative Tools**, then **Computer Management**, then **Device Manager**, and search for the **GE Protective Relay** entry. Reinstall the driver.

- Launch the EnerVista software, and click the **Quick Connect** icon to open the Quick Connect window.
- The EnerVista software creates a site named “Quick Connect” with a corresponding device also named “Quick Connect” and displays them on the upper-left corner of the screen. Expand the sections to view data directly from the D90^{Plus} device.

Each time the EnerVista UR^{Plus} Setup software is initialized, click the **Quick Connect** button to establish direct communications to the D90^{Plus}. This ensures that configuration of the EnerVista UR^{Plus} Setup software matches the D90^{Plus} model number.

Configure the D90^{Plus} for software access

You connect remotely to the D90^{Plus} through the rear Ethernet port with a computer running the EnerVista UR^{Plus} Setup software. The D90^{Plus} also can be accessed locally with a computer through the front panel USB port or the rear Ethernet port using the Quick Connect feature. The following options are outlined:

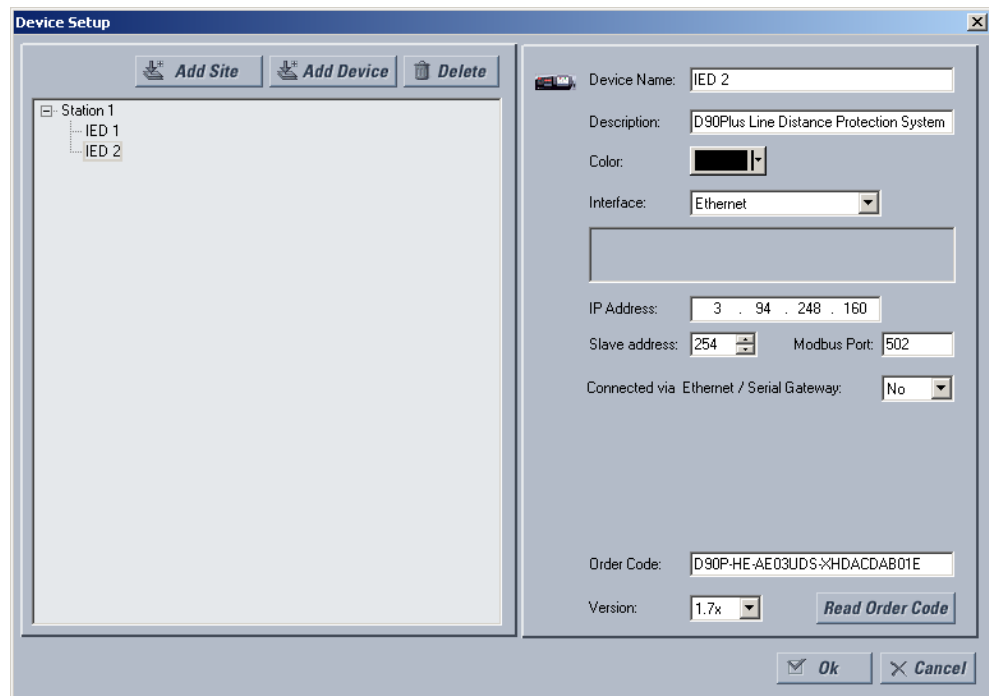
- Configure the D90^{Plus} for remote access via the rear Ethernet port
- Configure the D90^{Plus} for local access with a computer through the front USB port

Configure Ethernet communication

You connect the cable, define a site, then add the D90^{Plus} as a device at that site.

- Connect the Ethernet network cable to the Ethernet port on the back of the device

- (slot C communications module).
2. On the computer, select the “UR^{Plus}” device from the EnerVista Launchpad to start EnerVista UR^{Plus} Setup.
 3. Click the **Device Setup** button to open the Device Setup window, then click the **Add Site** button to define a new site.
 4. Enter a site name in the “Site Name” field.
If required, a short description of site can also be entered along with the display order of devices defined for the site.
 5. Click the **OK** button when complete.
The new site appears in the upper-left list in the EnerVista UR^{Plus} Setup window.
 6. Click the **Device Setup** button then select the new site to re-open the Device Setup window.
 7. Click the **Add Device** button to define the new device.
 8. Enter a name in the “Device Name” field and a description (optional) of the site.
 9. Select “Ethernet” from the **Interface** drop-down list.



This displays a number of interface parameters that must be entered for proper Ethernet functionality.

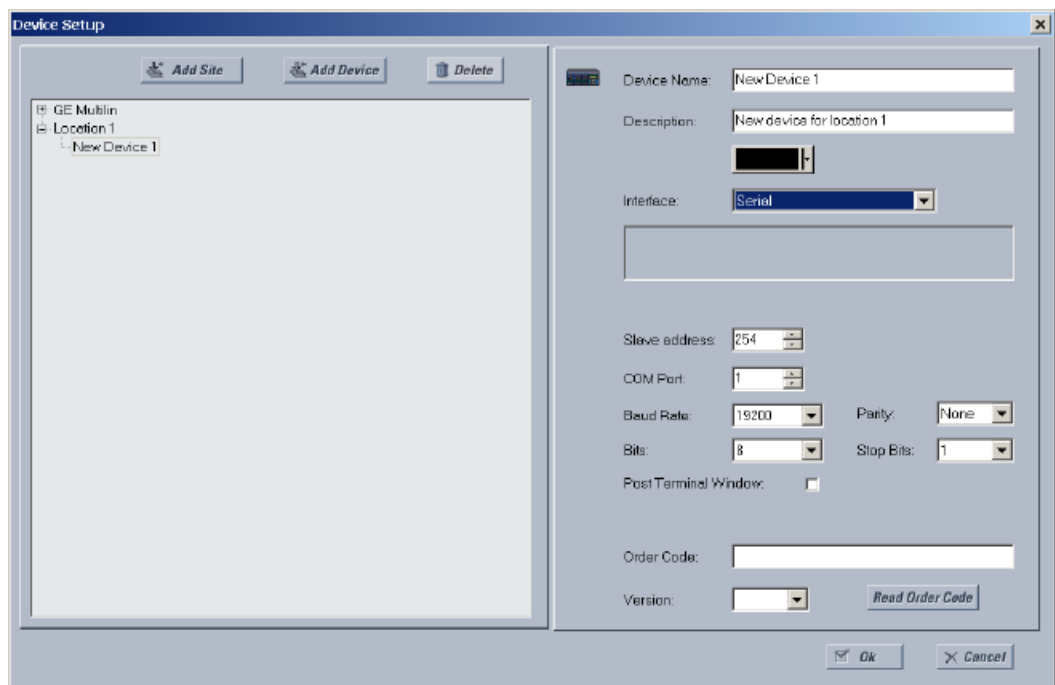
10. Enter the device IP address specified in the **Settings > Communications > Network > Addressing** menu in the “IP Address” field.
11. Enter the relay slave address and Modbus port address values from the respective settings in the **Settings > Communications > Modbus > Protocol** menu.
12. Click the **Read Order Code** button to connect to the D90^{Plus} device and upload the order code. If an communications error occurs, ensure that the three EnerVista UR^{Plus} Setup values entered in the previous steps correspond to the relay setting values.
13. Click **OK** when the relay order code has been received. The new device is added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR^{Plus} Setup window.

The Site Device has now been configured for Ethernet communications. Proceed to the Connect to the D90^{PLUS} section to begin communications.

Configure serial communication

You connect the cable, add the site, then the device. To use the RS485 port at the back of the D90^{PLUS}, a GE Grid Solutions F485 converter (or compatible RS232-to-RS485 converter) is required. See the F485 instruction manual for details.

1. Connect the computer to the F485 and the F485 to the RS485 terminal on the back of the D90^{PLUS}.
2. Select the “D90^{PLUS}” device from the EnerVista Launchpad to start EnerVista UR^{PLUS} Setup.
3. Click the **Device Setup** button to open the Device Setup window, and click the **Add Site** button to define a new site.
4. Enter a site name in the “Site Name” field. Optionally add a short description of site along with the display order of devices defined for the site. This example uses “Location 1” as the site name. When done, click the **OK** button. The new site appears in the upper-left list in the EnerVista UR^{PLUS} Setup window.
5. Click the **Device Setup** button, then select the new site to re-open the Device Setup window.
6. Click the **Add Device** button to define the new device.
7. Enter a name in the “Device Name” field and a description (optional) of the site.
8. Select “Serial” from the **Interface** drop-down list. This displays a number of interface parameters that must be entered for serial communications.



9. Enter the relay slave address, COM port, baud rate, and parity settings from the **Settings > Communications > Serial Ports** menu in their respective fields.
10. Click the **Read Order Code** button to connect to the D90^{PLUS} device and upload the order code to the software. If a communications error occurs, ensure that the EnerVista UR^{PLUS} Setup serial communications values entered in the previous step correspond to the relay setting values.

11. Click **OK** button when the relay order code has been received. The new device is added to the Site List window (or Online window) located in the top left corner of the main EnerVista UR^{Plus} Setup window.

The device has now been configured for serial communications. Proceed to the Connect to the D90^{Plus} section to begin communication.

Activate the D90^{Plus}

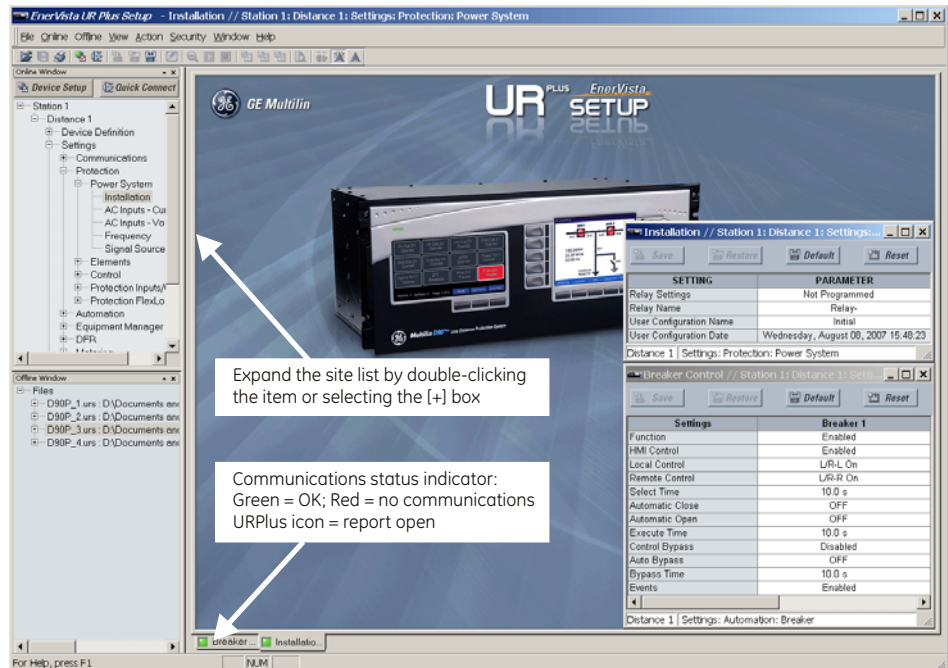
The relay is in the default “Not Programmed” state when it leaves the factory. When powered up in this state, a **UNIT NOT PROGRAMMED** self-test message displays. Activate the relay as follows.

1. In the EnerVista software, navigate to **Settings > Protection > Power System > Installation**.
2. Set the **Relay Settings** field to “Programmed.”
3. Save the change.

Connect to the D90^{Plus}

This example shows how to connect to the D90^{Plus} and configure the breaker settings.

1. Open the Breakers window through the site list tree.



The breaker configuration window opens and a status indicator displays on the lower left of the EnerVista UR^{Plus} Setup window.

2. If the status indicator is red, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the device and that the D90^{Plus} has been properly setup for communications.

If a relay icon appears in place of the status indicator, than a report (such as an oscillography or event record) is open. Close the report to re-display the green status indicator.

3. The breaker settings can now be edited, printed, or changed according to user specifications.

See the software chapter or the EnerVista UR^{Plus} Setup help file for more information about the using the software interface.

D90^{Plus} Line Distance Protection System

Chapter 4: Front panel interface

This chapter explains use of the front panel interface.

Front panel

The front panel provides an interface with the D90^{Plus}. It includes two color liquid crystal displays (LCDs) (annunciators) and two sets of user-programmable pushbuttons. This interface provides immediate access to all major D90^{Plus} functions.

The pushbuttons located at the bottom of the display are for navigation. The pushbuttons located at both sides of the display are for control functions.

The annunciators are color LCDs that provides alarm and trip information. They also provide indication of any active self-diagnostic messages and include a product information screen.

The front panel contains a USB port for communication with a computer running the EnerVista software.

No settings are entered on the front panel; use the software instead.

Figure 43: Front panel interface

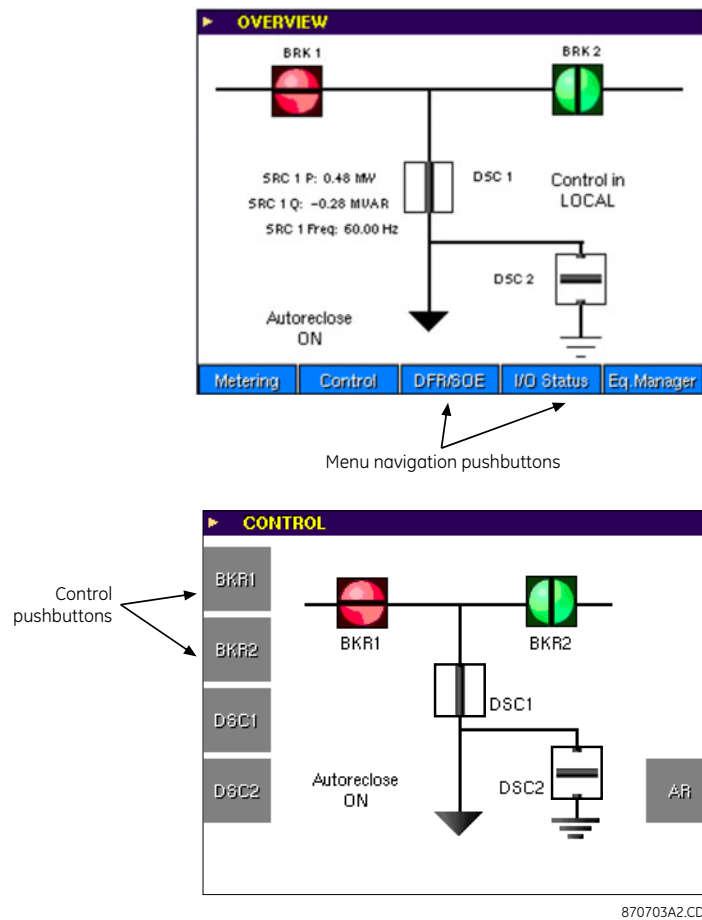


Front panel operation

The front panel has two displays and several pushbuttons.

The control pushbuttons are shown only in the control menu. Otherwise, the menu navigation pushbuttons are shown. The number of control pushbuttons depends on the number of disconnects and breakers in the selected mimic diagram.

Figure 44: Front panel interface operation



The following figure shows a typical menu structure. The structure for any specific D90^{Plus} varies according to its order code.

Figure 45: Menu structure

Metering	Control	DFR	I/O Status	Equipment
<ul style="list-style-type: none"> • User page • Energy • Phasors • Sequence components 	<ul style="list-style-type: none"> • Primary • Pushbutton 1 • Pushbutton 2 • Pushbutton 3 	<ul style="list-style-type: none"> • Summary • SOE • Fault report • Transient records • Disturbance records 	<ul style="list-style-type: none"> • Summary • I/O States • IRC Info 	<ul style="list-style-type: none"> • Battery monitor

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Metering menu

The system metering quantities are available from the front panel in the metering menu. These values are derived automatically from the metering source. There are four user-configurable metering summary screens and three fixed metering screens available.

There are four user-configurable metering pages. Each location in the metering grid can be either text or an actual value. The EnerVista UR^{Plus} Setup software provides the ability to configure each of the metering display pages.

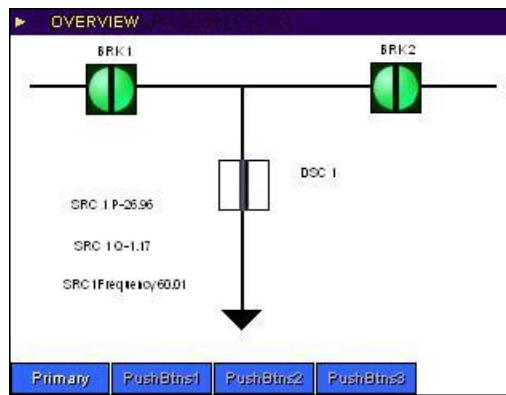
The following three fixed metering screens are also available:

- The energy page displays and allows the user to reset four quadrant energy values
- The phasor screen graphically displays the phasor components of the system voltage (phase-neutral) and current for the selected metering source
- The sequence screen graphically displays the sequence components of the system voltage and currents for the selected metering source

Control menu

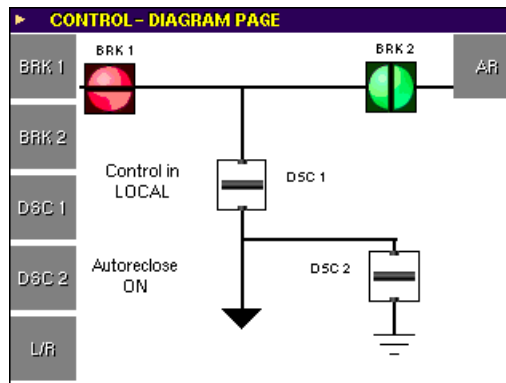
The control menu provides the option to select a control diagram view or one of the user-programmable pushbutton views. The menu names are user-configurable. The following figure shows the overview window.

Figure 46: Control menu overview display



The user accesses the mimic diagram and dedicated control pushbuttons through the primary control menu. The mimic page provides status of circuit breakers and disconnect switches. Operation of these devices also is available through the control pushbuttons.

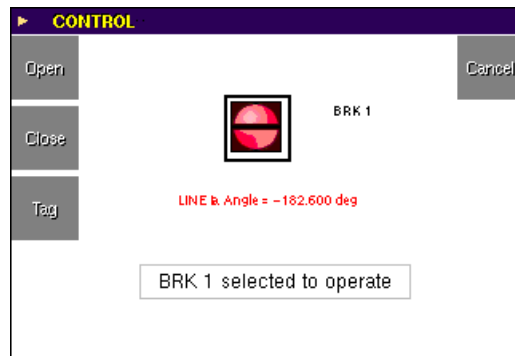
Figure 47: Mimic page - operate example



The configurable selected component display allows the user to position the selected control element and display other diagram components like metering values, breakers, disconnect switches, local/remote status, or autoreclose. The following figure shows the selected component display.

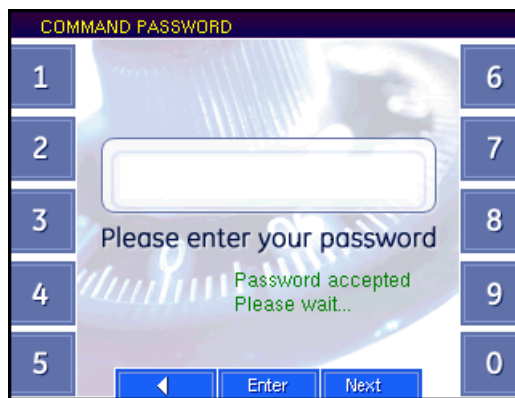
Figure 48: Mimic page - Selected breaker with operate actions menu and dynamic

display of current phase angle



The front panel control pushbuttons can be placed under password security. When password security is enabled, the front panel requests the command password before performing any actions. Use the **Next** button to access additional alphanumeric characters.

Figure 49: Command password entry screen



Digital fault recorder menu

The digital fault recorder menu provides access to records stored within the D90^{Plus}, including sequence of events, fault report, transient records, and disturbance records. The summary page displays the status of each function, as follows:

- A green indicator indicates that the function is enabled and more than 20% of the memory is available
- A yellow indicator indicates that the available memory is between zero and 20%
- A red indicator indicates that the memory is full

If the function is configured for protected mode, then the enabled indicator also switches to red indicating that new records can be captured. If the function is configured for automatic overwrite, then the element overwrites old records and the enabled LED remains green.

For details on the indicators for the fault report, transient recorder, and disturbance recorder, see [Digital fault recorder](#) on page 505.

Figure 50: Digital fault recorder - example summary page

DFR - SUMMARY		
Ready to Capture Memory Available		
FAULT REPORT	●	●
TRANSIENT RECORDER	●	●
DISTURBANCE RECORDER	●	●
Records	Latest	Total
EVENTS	2007/08/08 10:59:23	111419
FAULTS	2007/08/08 10:59:03	43420
TRANSIENTS	2007/08/08 10:58:25	8
DISTURBANCES	No records available	-
Summary 80E Fault Report Transient Disturbance		

The sequence of events record can be accessed from this page. Using the navigations keys, scroll or page through the events list. Two cursors are provided for measurement of the time difference between events.

Figure 51: Example of sequence of events record

DFR - SEQUENCE OF EVENTS		
Delta	0 day, 00:00:00.000000	Event# 112283 & 112283
Evrnt #	Date/Time	Cause
112283	Aug 08 2007 11:39:35.096375	AR ZONE 1 EXTENT
112282	Aug 08 2007 11:39:35.096375	AR ENABLED
112281	Aug 08 2007 11:39:33.095112	MAN CLOSE Off
112280	Aug 08 2007 11:39:32.895133	AR RESET
112279	Aug 08 2007 11:39:32.895133	AR DISABLED
112278	Aug 08 2007 11:39:32.893868	MAN CLOSE On
112277	Aug 08 2007 11:39:32.893868	BKR1 CLOSED
112276	Aug 08 2007 11:38:54.788677	AR BKR1 BLK
112275	Aug 08 2007 11:38:54.757440	BKR1 SUBST ON
112274	Aug 08 2007 11:38:54.757440	BKR1 OPENED
Up Down Retrieve LockCursor more		

Principal fault information measured by D90^{Plus} can also be accessed from the digital fault recorder menu.

Figure 52: Example of fault record


DFR - FAULT REPORT - FAULT 43640					
Aug 08 2007 11:01:53.002147					
Cause of Trip:		TRIP 3-POLE			
Location:		354.7	Type:	BCG	
Active Setting Group:		1	Shot Count:	0	
Prefault					
Van	292.482 KV	360.1 °	Ia	370.874 A	10.6 °
Vbn	292.373 KV	240.0 °	Ib	373.163 A	250.6 °
Vcn	292.407 KV	120.0 °	Ic	372.009 A	131.3 °
Fault					
Van	286.431 KV	0.2 °	Ia	364.003 A	353.2 °
Vbn	250.418 KV	238.5 °	Ib	2.317 KA	166.7 °
Vcn	254.867 KV	124.9 °	Ic	2.070 KA	19.7 °
Duration: NA					
Prev Recd Next Recd Events					

The digital fault recorder menu transient record menu lists all of the records currently stored in the D90^{Plus}. It also indicates the status of the trigger, where:

- Green indicates that the trigger is not active
- Red indicates an active trigger

Records can be retrieved and deleted, and triggers can be generated manually from this screen.

Figure 53: Example of transient record

DFR – TRANSIENT RECORDER	
Channel Active 	
Record	Date
45	Nov 14 2008 10:24:51
44	Nov 14 2008 10:24:45
43	Nov 14 2008 10:24:39
42	Nov 14 2008 10:24:33
41	Nov 14 2008 10:24:27
40	Nov 14 2008 10:24:21
39	Nov 14 2008 10:24:15
38	Nov 14 2008 10:24:09
37	Nov 14 2008 10:24:03
36	Nov 14 2008 10:23:57


Up Down Retrieve Clear All Force Trig

The digital fault recorder menu disturbance record menu lists all disturbance records stored in the D90^{PLUS}. It also indicates the status of the trigger, where:

- Green indicates that the trigger is not active
- Red indicates an active trigger

Records can be retrieved and deleted, and triggers can be manually generated from this screen.

Figure 54: Example of disturbance record

DFR – DISTURBANCE RECORDS	
Channel Active 	
Record	Date
11	Nov 14 2008 10:44:31
10	Nov 14 2008 10:43:41
9	Nov 14 2008 10:42:35
8	Nov 14 2008 10:41:05
7	Nov 14 2008 10:40:44
6	Nov 14 2008 10:40:08
5	Nov 14 2008 10:39:54
4	Nov 14 2008 10:39:43
3	Nov 14 2008 10:39:28
2	Nov 14 2008 10:39:10

Up Down Retrieve Clear All Force Trig

Equipment manager menu

This menu provides access to the battery monitor function. There are three status indicators, colored red, yellow, and green.

- A green indication denotes no alarms for the device
- A yellow indication denotes at least one non-critical alarm and no critical alarms
- A red indication denotes at least one critical alarm

The battery monitor page displays the state of all battery monitor alarms for a particular device. Alarms can be reset from this page.

Figure 55: Equipment manager battery alarms example

EQUIPMENT MANAGER – BATTERY MONITOR	
Battery Alarm Status	
PRESENT VALUE	46 Volts
HIGH VOLTAGE	●
LOW VOLTAGE	●
SUPPLY VOLTAGE	●
CHARGER FAIL	●
DC BREAKER TRIP	●
DC GND FAULT	●

Annunciator

An annunciator is a color panel on the front of the unit.

Annunciator operation

The annunciator supports three types of alarms: self-reset, latched, and acknowledgeable. Each location in an annunciator display page can be configured to be one of the three alarm types and can also display an optional metered value. The value of each self-reset alarm is refreshed approximately every half second.

Alarms are organized in a table and numbered increasing from left to right horizontally and then top to bottom. The first alarm in the top left corner of the first page is denoted as indicator 1 by the EnerVista UR^{Plus} Setup software. The top left location of the next page is the bottom right alarm number on the previous page plus one. Up to 288 individual alarms or metered values can be configured.

Each location in the alarm table can be configured as an alarm only, metering only, or mixed content. With the exception of metering only table entries, a FlexLogic alarm input operand is required for each alarm table location. Selecting an operand of “None” hides the entry from view.

Alarms can display up to three lines of text using specified foreground and background colors. A configured metering value replaces the specified line of text. The figure shows a typical annunciator display.

Figure 56: Typical annunciator display

Phase Distance Zone 1	Phase Distance Zone 2	Ground Distance Zone 1	Ground Distance Zone 2
Line Pickup	Pilot Scheme	Breaker 1 Failure	Breaker 2 Failure
Autoreclose Lockout	Fuse Failure	Setting Group 2 Active	Fault Report
Alarms: 6 Selftest: 1 Page 1 of 1			
		Ad.	Next Alarm
			Next Page

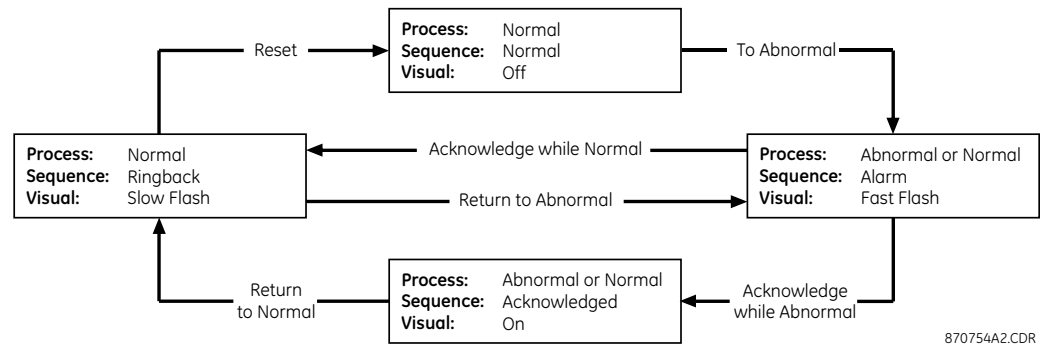
There are three control buttons at the bottom of the display.

- The Next Page button navigates through the configured alarm, self-test, and product information pages. Pages that contain no configured alarms are not displayed.

- The Next Alarm button navigates horizontally through the current alarms that are active, from left-to-right, starting with the first row of alarms. A border is drawn around the current alarm.
- The Ack/Reset button is used to acknowledge alarms or reset latched and acknowledgeable alarms that are in the ringback state.

The annunciator alarm sequence conforms to ISA 18.1-1979 (R1992) standard, type R.

Figure 57: Annunciator alarm sequence



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The table outlines annunciator states.

Table 5: Acknowledgeable alarm states

Sequence (initial state)	Process (status)	Pushbutton (input)	Sequence (final state)	Visual indication
Normal	Normal	N/A	N/A	Off
Normal	Abnormal	N/A	Alarm	Fast flash
Alarm	Normal	N/A	Alarm	Fast flash
Alarm	Normal	Acknowledged	Normal	Off
Alarm	Abnormal	Acknowledged	Acknowledged	On
Acknowledged	Abnormal	N/A	Acknowledged	On
Acknowledged	Normal	N/A	Ringback	Slow flash
Ringback	Normal	Reset	Normal	Off
Ringback	Abnormal	N/A	Acknowledged	On

The visual indications display as follows:

- Off – Grey text on a darker grey background
- On – User-configurable
- Fast flash – Alternating between off and on state two times per second
- Slow flash – Alternating between off and on state one time per second

In the event of an alarm, the page containing the alarm is promoted to active page. If there are multiple pages with alarms, the page with the lowest page number is promoted.

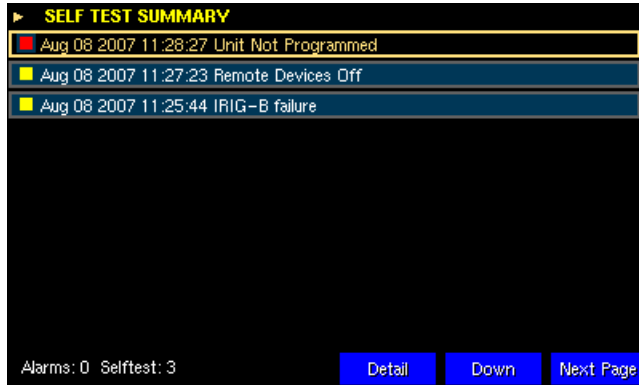
If there are alarms on multiple pages, and alarms on some pages have already been acknowledged (but not cleared) by the user, then the pages with active alarms move ahead of the pages that have acknowledged alarms. The user always has to navigate through the pages of alarms to view them.

Display of alarm pages is prioritized according to active window (unacknowledged or flashing alarm) and page number (for example, if two pages have an unacknowledged alarm, the page with the lowest number is promoted automatically as the displayed page).

Self-test page

This page displays any active self-test alarms as well as the time of occurrence and the severity of the alarm (yellow for non-critical and red for critical).

Figure 58: Self-test page example



Product information page

The product information page contains data describing the device, including the order code, serial number, device identification name, setting configuration name, time of last change, firmware version, and firmware release date.

Figure 59: Sample product information page



The **Relay ID** value reflects the string entered as the **Relay Name** in the **Settings > Protection > Power System > Installation** menu. The **Configuration** value reflects the string entered as the **User Configuration Name** in the **Settings > Protection > Power System > Installation** menu. The setup program automatically updates the **Configuration Date** after each setting change. The current D90^{Plus} date and time display on all annunciator pages, as does the total number of active self-tests and alarms.

Communication status page

This page outlines the available TCP/IP connections for the supported protocols and the IP addresses of the ports used.

The D90^{Plus} supports up to five Manufacturing Message Specification (MMS) connections, four Modbus connections, two Distributed Network Protocol (DNP) connections, and one Phasor Measurement Unit (PMU) connection. The DNP connections are shown as available if the protocol has been enabled and the D90^{Plus} restarted.

The configured IP protocol values display for each of the available Ethernet ports. Ethernet port 1 is the port on the main CPU card in slot D, while port 2 is located at the top of the slot C communications processor and port 3 at the bottom. The displayed MAC address is for Ethernet port 1. The MAC address of Ethernet port 2 is the MAC address of Ethernet port 1 incremented by 1. The MAC address of Ethernet port 3 is the MAC address of Ethernet port 1 incremented by 2.

Figure 60: Communication status page

COMMUNICATION STATUS			
Remaining Connections			
MMS	5	Modbus Address: 254	
MODBUS	3	Modbus IP Port: 502	
DNP	0		
PMU	1		
	Port1	Port 2	Port 3
IP Address	172.20.1.250	192.168.252.252	192.168.253.253
Subnet Mask	255.255.255.0	255.255.255.0	255.255.255.0
Gateway	0.0.0.0	0.0.0.0	0.0.0.0
MAC Address:	00 A0 F4 00 88 1C		
Tests: 3	Alarms: 0	2009/12/22	Next Page
		10:01:24	

D90^{Plus} Line Distance Protection System

Chapter 5: EnerVista software

This chapter describes the EnerVista UR^{Plus} Setup software.

Introduction

The EnerVista UR^{Plus} Setup software provides a graphical user interface (GUI) to configure, monitor, maintain, and troubleshoot the operation of UR^{Plus}-series devices connected locally to a computer or over local or wide area communications networks. The software can be initiated in either offline (not communicating) or online (communicating) modes with a UR^{Plus}-series device. In offline mode, a device settings file can be created or configured for eventual downloading to that device. In online mode, the settings and actual values of a UR^{Plus}-series device can be configured or monitored utilizing real-time communications. The software provides the tools to integrate information measured by the D90^{Plus} into DCS or SCADA monitoring systems. Convenient COMTRADE and sequence of events viewers are integrated. This allows the user to carry out post-mortem event analysis to ensure proper protection system operation.

Settings templates

Settings file templates simplify the configuration and commissioning of multiple devices that protect similar assets. An example is a substation that has 10 similar feeders protected by 10 UR^{Plus}-series relays.

In these situations, typically 90% or greater of the settings are identical among devices. The templates allow engineers to configure and test these common settings, then lock them so that they are not available to users. For example, locked settings can be hidden from view for field engineers, allowing them to quickly identify and concentrate on specific settings.

The remaining settings (typically 10% or less) can be specified as editable and made available to field engineers installing the devices. These are settings such as protection element pickup values and CT and VT ratios.

The settings template mode allows the user to define which settings are visible in the software. Settings templates can be applied to both settings files (settings file templates) and online devices (online settings templates). The functionality is identical for both purposes.

Settings file conversion from previous firmware versions is supported.

Enable the settings template in offline mode

The settings file template feature is disabled by default. It can be enabled in offline or online mode.

The following procedure outlines how to enable in offline mode the settings template for UR^{Plus}-series settings files.

1. Select a settings file from the offline window of the EnerVista UR^{Plus} Setup main screen.
2. Right-click the selected settings file and select the **Settings File Template > Create Template** option.

The settings file template is now enabled and the file menus displayed in light blue. A message displays. The settings file is now in template editing mode.

Enable the settings template in online mode

Alternatively, the settings template can be applied to online settings, as follows.

1. Select an installed device in the online window of the EnerVista UR^{Plus} Setup window.
2. Right-click the selected device and select the **Template Mode > Create Template** option.

The software prompts for a template password. This password is required to use the template feature and must be at least four characters in length.

Figure 61: Entering a settings file password



3. Enter and re-enter the new password, then click **OK** to continue.

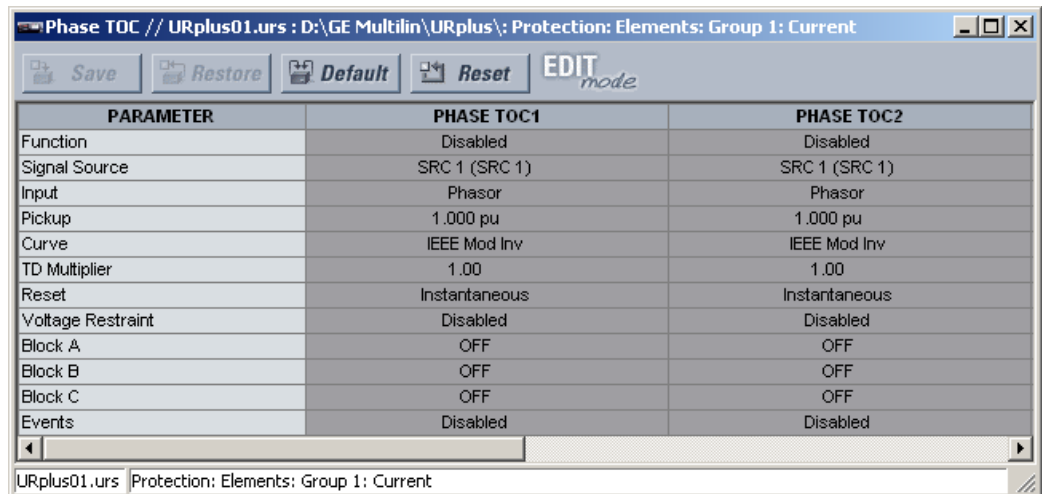
The online settings template is now enabled. The device is now in template editing mode.

Edit the settings template

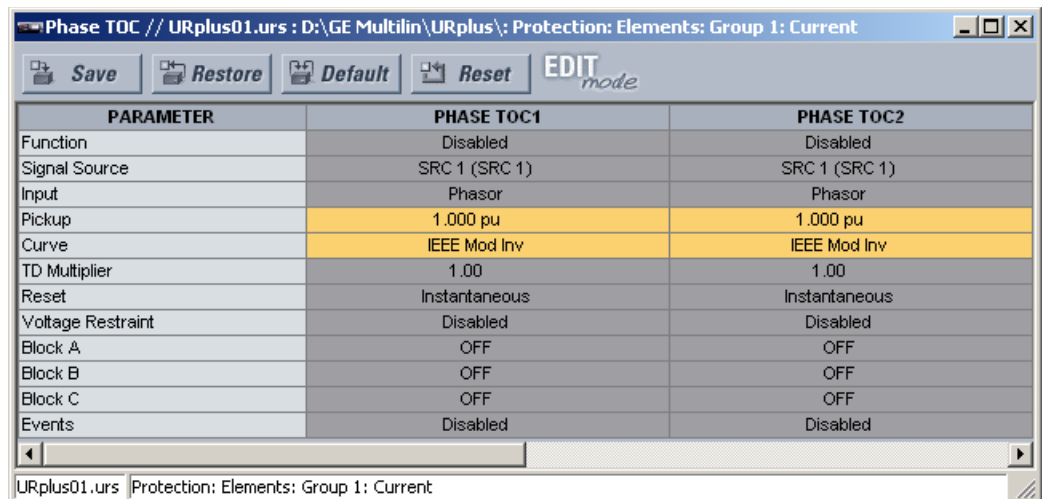
The settings template editing feature allows the user to specify which settings are available for viewing and modification in EnerVista UR^{Plus} Setup. By default, all settings except the FlexLogic equation editor settings are locked.

1. Select an installed device or a settings file from the menu on the left side of the EnerVista UR^{Plus} Setup window.
2. Right-click and select the **Template Mode > Edit Template** option (online mode) or the **Settings File Template > Edit Template** option (offline mode) to place the device in template editing mode.

3. If prompted, enter the template password then click **OK**.
4. Open the relevant settings windows that contain settings to be specified as viewable.
By default, all settings are specified as locked and displayed against a grey background. The icon on the upper right of the settings window also indicates that the EnerVista software is in **EDIT mode**. The following example shows the phase time overcurrent settings window in edit mode.



5. Specify settings to make viewable by clicking them.
A setting available to view is displayed against a yellow background.



6. Click the **Save** button to save changes to the settings template.
7. Continue through any other settings window to specify all viewable settings.

Add password protection to a template

It is highly recommended that templates be saved with password protection to maximize security.

The following procedure outlines how to add password protection to a settings file template.

1. Select a settings file from the offline window on the left of the EnerVista UR^{Plus} Setup window.
2. Select the **Settings File Template > Password Protect Template** option.

The software prompts for a template password. This password must be at least four characters in length.

Figure 62: Template password entry window



3. Enter and re-enter the new password, then click **OK** to continue.

The settings file template is now secured with password protection.



When templates are created for online settings, the password is added during the initial template creation step. It does not need to be added after the template is created.

View the settings template

Once all necessary settings are specified for viewing, users are able to view the settings template on the online device or settings file.

To display only the settings available for editing:

1. Select an installed device or a settings file from the menu on the left of the EnerVista UR^{PLUS} Setup window.
2. Select the **Template Mode > View in Template Mode** option (online) or the **Settings File Template > View in Template Mode** option (offline).
3. Enter the template password then click **OK** to apply the template.

Once the template has been applied, users are limited to view and edit the settings specified by the template. The effect of applying the template to the phase time overcurrent settings is shown.

Figure 63: Applying templates using the View in Template Mode command

PARAMETER	PHASE TOC1	PHASE TOC2
Function	Disabled	Disabled
Signal Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Input	Phasor	Phasor
Pickup	1 000 pu	1 000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Voltage Restraint	Disabled	Disabled
Block A	OFF	OFF
Block B	OFF	OFF
Block C	OFF	OFF
Events	Disabled	Disabled

Phase time overcurrent settings window without template applied.

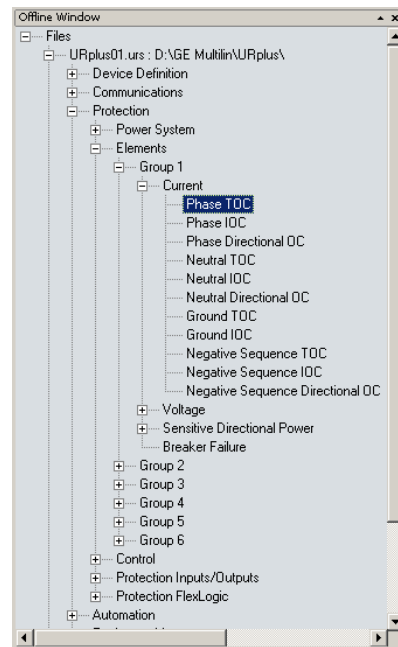
PARAMETER	PHASE TOC1	PHASE TOC2
Function	Disabled	Disabled
Signal Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Input	Phasor	Phasor
Pickup	1 000 pu	1 000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Voltage Restraint	Disabled	Disabled
Block A	OFF	OFF
Block B	OFF	OFF
Block C	OFF	OFF
Events	Disabled	Disabled

Phase time overcurrent window with template applied via the **View In Template Mode** command. The template specifies that only the **Pickup** and **Curve** settings be available.

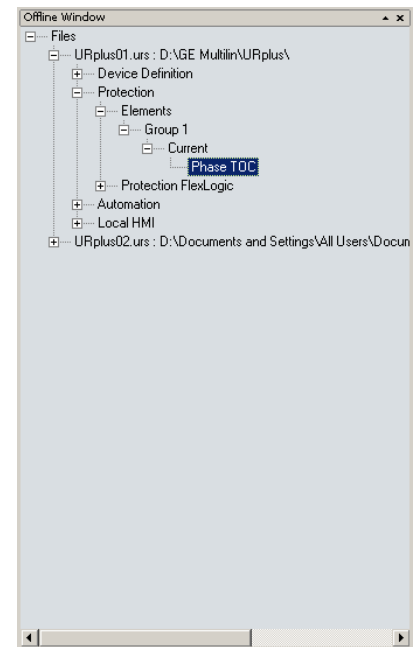
870863A1.CDR

Viewing the settings in template mode also modifies the settings menu, showing only the settings categories that contain editable settings. The effect of applying the template to a typical settings menu is shown as follows.

Figure 64: Applying templates using the View in Template Mode settings command



Typical settings tree view without template applied.



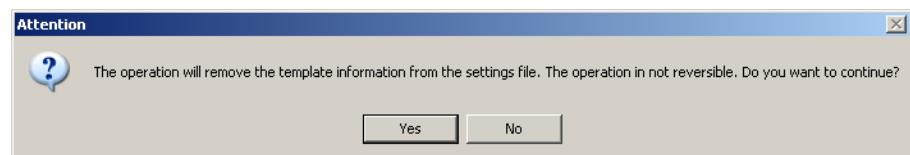
Typical settings tree view with template applied via the **View In Template Mode** command.

870864A1.CDR

Remove the settings template

It can be necessary at some point to remove a settings template. Once a template is removed, it cannot be reapplied and a new settings template needs to be defined before use.

1. Select an installed device or settings file from the left side of the EnerVista UR^{Plus} Setup window.
2. Select the **Template Mode > Remove Settings Template** option (online) or the **Settings File Template > Remove Settings Template** option (offline).
3. Enter the template password and click **OK** to continue.
4. Confirm that you want to remove the template by clicking **Yes**.



The EnerVista software removes all template information and all settings are available.

Secure and lock FlexLogic equations

The D90^{Plus} allows users to secure parts or all of a FlexLogic equation, preventing unauthorized viewing or modification of critical FlexLogic applications. This is accomplished using the settings template feature to lock individual entries within FlexLogic equations.

Secured FlexLogic equations remain secure when files are sent to and retrieved from any UR^{Plus}-series device.

Locking can be tied to the serial number too.

Lock FlexLogic equations

To lock individual entries of a FlexLogic equation:

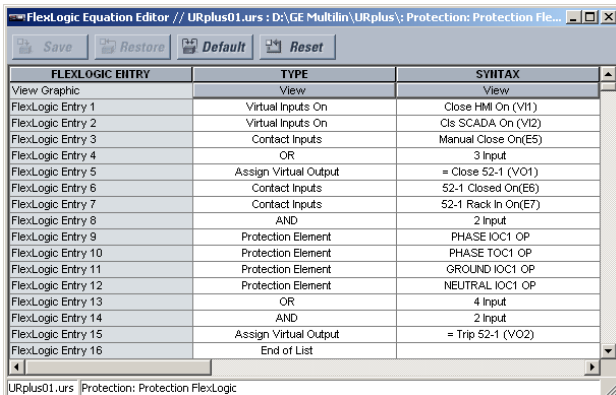
1. Right-click the settings file or online device and select the **Template Mode > Create Template** item to enable the settings template feature.
2. Select the **Protection > Protection FlexLogic > FlexLogic Equation Editor** settings menu item.

By default, all FlexLogic entries are specified as viewable and displayed against a yellow background. The icon on the upper right of the window also indicates that EnerVista UR^{Plus} Setup is in **EDIT mode**.

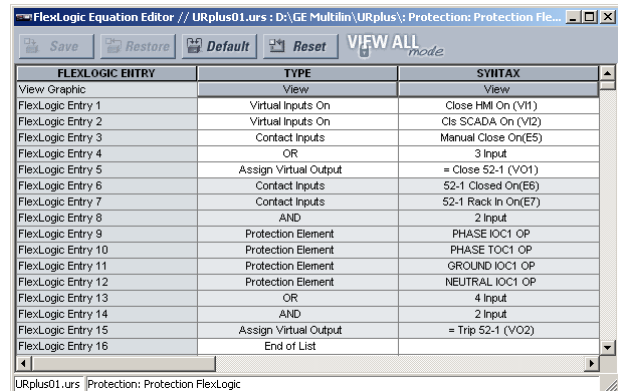
3. Specify which entries to lock by clicking them.

The locked entries display against a grey background as shown in the example.

Figure 65: Locking FlexLogic entries through setting templates



Typical FlexLogic™ entries without template applied.



Typical FlexLogic™ entries locked with template via the **View In Template Mode** command.

870865A1.CDR

Lock FlexLogic equations to a serial number

A settings file and associated FlexLogic equations also can be locked to a D90^{Plus} serial number. Once FlexLogic entries in a settings file have been secured, use the following procedure to lock the settings file to a serial number.

1. Right-click the settings file in the offline window area and select the **Manage Settings File > Edit Properties** item. The window opens.

2. Enter the serial number of the D90^{Plus} device to lock to the settings file in the **Serial # Lock** field.
3. Click the **OK** button to apply the change.

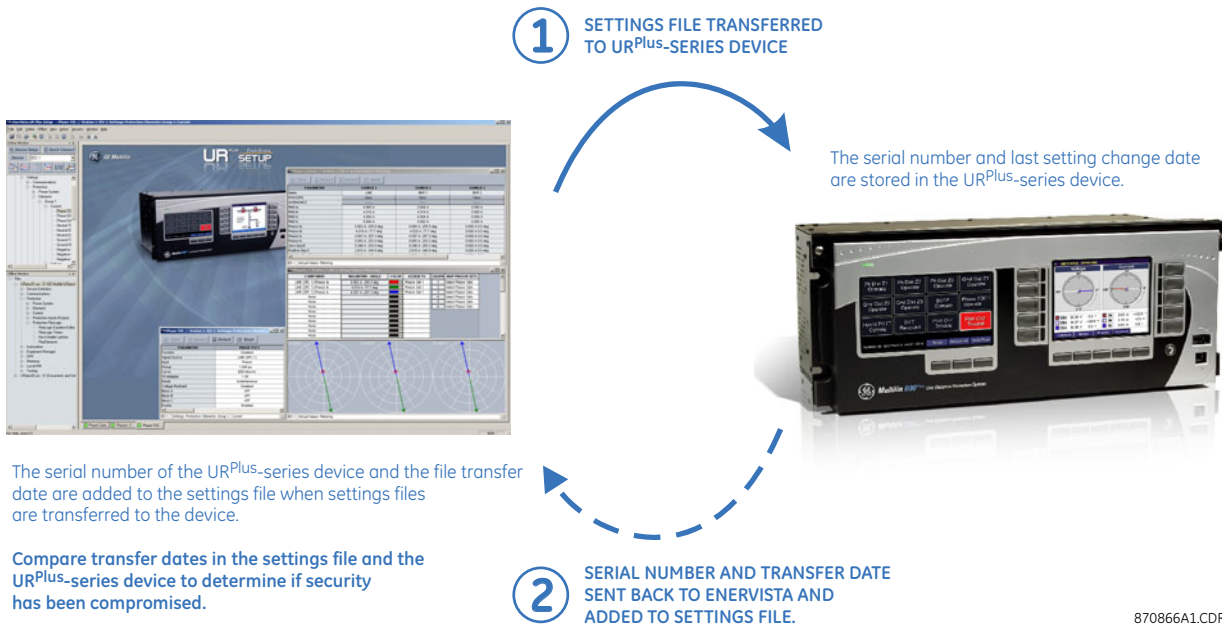
The settings file and corresponding secure FlexLogic equations are now locked to the D90^{Plus} device specified by the serial number.

Settings file traceability

A traceability feature for settings files allows the user to quickly determine if the settings in a D90^{Plus} device have been changed since the time of installation from a settings file. When a settings file is transferred to a D90^{Plus} device, the date, time, and serial number of the D90^{Plus} are sent back to EnerVista UR^{Plus} Setup and added to the settings file on the local computer. This information can be compared with the D90^{Plus} actual values at any later date to determine if security has been compromised.

The traceability information is only included in the settings file if a complete settings file is either transferred to the D90^{Plus} device or obtained from the D90^{Plus} device. Any partial settings transfers by way of drag and drop do not add the traceability information to the settings file.

Figure 66: Settings file traceability



With respect to the figure, the traceability feature is used as follows.

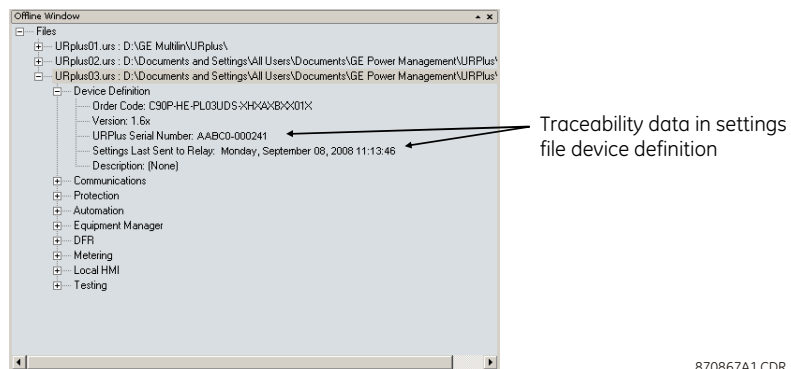
1. The transfer date of a settings file written to a D90^{Plus} is logged in the device and can be viewed in the EnerVista software or the front panel display. Likewise, the transfer date of a settings file saved to a local computer is logged in the EnerVista software.
2. Comparing the dates stored in the device and on the settings file at any time in the future indicates if any changes have been made to the D90^{Plus} configuration since the settings file was saved.

Settings file traceability information

The serial number and file transfer date are saved in the settings files when they are sent to the D90^{Plus} device.

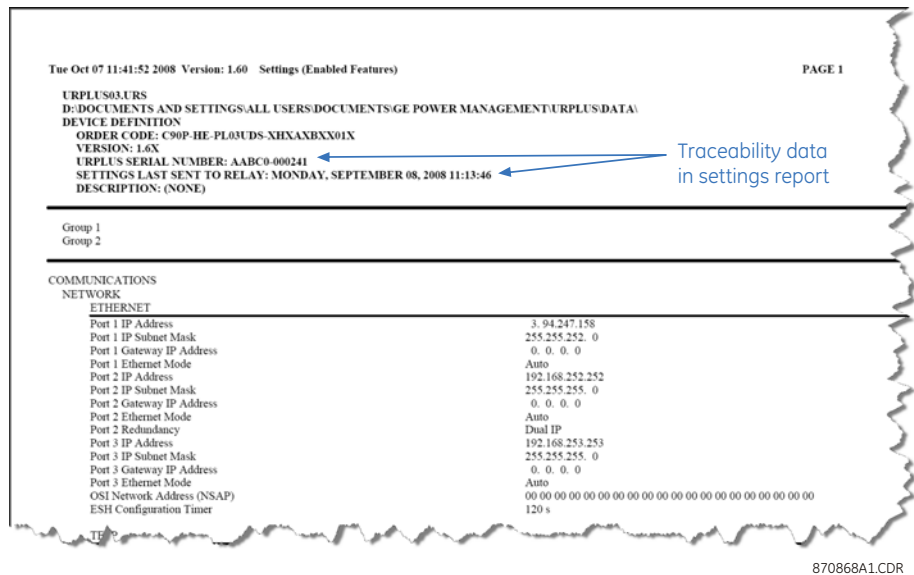
The D90^{Plus} serial number and file transfer date are included in the settings file device definition within the EnerVista UR^{Plus} Setup offline window as shown in the example.

Figure 67: Device definition showing traceability data



This information is also available in printed settings file reports as shown in the example.

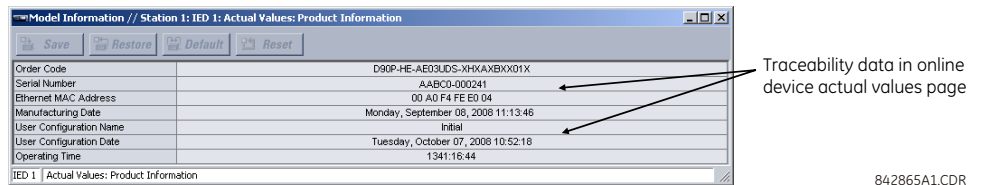
Figure 68: Settings file report showing traceability data



Online device traceability information

The D90^{Plus} serial number and file transfer date are available for an online device through the actual values. Select the **Actual Values > Product Information > Model Information** menu item within the EnerVista online window as shown in the example.

Figure 69: Traceability data in Actual Values window



Additional traceability rules

The following additional rules apply for the traceability feature:

- If the user changes any settings within the settings file in the offline window, then the traceability information is removed from the settings file
- If the user creates a new settings file, then no traceability information is included in the settings file
- If the user converts an existing settings file to another revision, then any existing traceability information is removed from the settings file
- If the user duplicates an existing settings file, then any traceability information is transferred to the duplicate settings file

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Chapter 6: Communications

This chapter outlines how to program the D90^{Plus} communications settings.

Communications overview

The D90^{Plus} has one Ethernet port (port 1) on the main CPU module in slot D and two Ethernet ports (ports 2 and 3) on the communications module in slot C. Each port supports 100Base-FX over multimode fiber and 10/100Base-TX over twisted-pair wire, with auto-negotiation. Port 1 is intended for configuration and file retrieval and has a dedicated IP address. Ports 2 and 3 are intended for SCADA and peer-to-peer messaging. Additionally, there is one serial RS485 port on the rear panel.

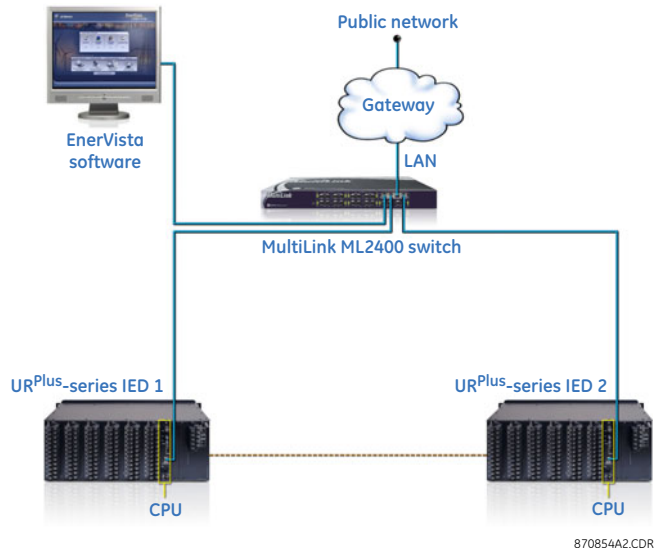
The following protocols are available, depending on the configuration of the unit:

- Ethernet port 1 — Modbus TCP, TFTP, SNTP, HTTP
- Ethernet ports 2 and 3 — Modbus TCP, DNP 3.0, IEC 60870-5-104, IEC 61850, SNTP, TFTP, HTTP, PRP
- RS485 port — Modbus serial

Ethernet network topology

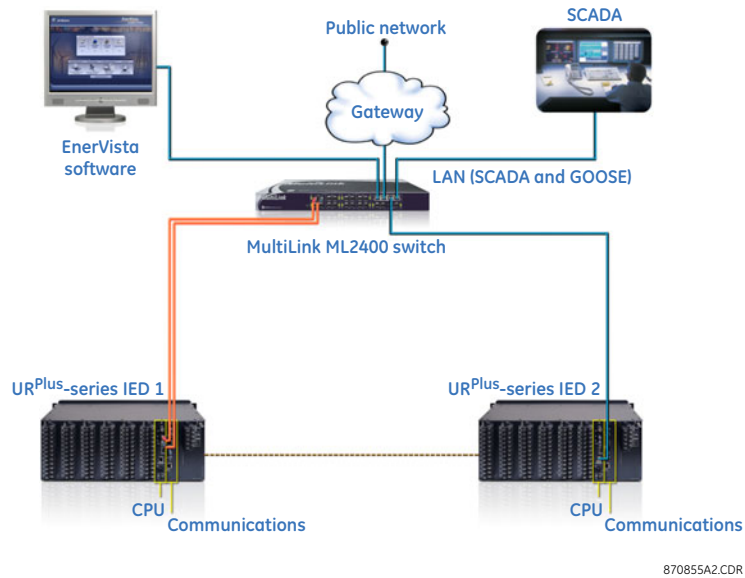
The topology shown here allows several D90^{Plus} devices to communicate with a computer running EnerVista software or with a gateway for remote access. This allows device configuration, monitoring, and file transfers (transient records, sequence of events, and so on) to be carried out over Ethernet. Communications processor cards are not required and no redundancy is provided.

Figure 70: Simple network topology without communications cards



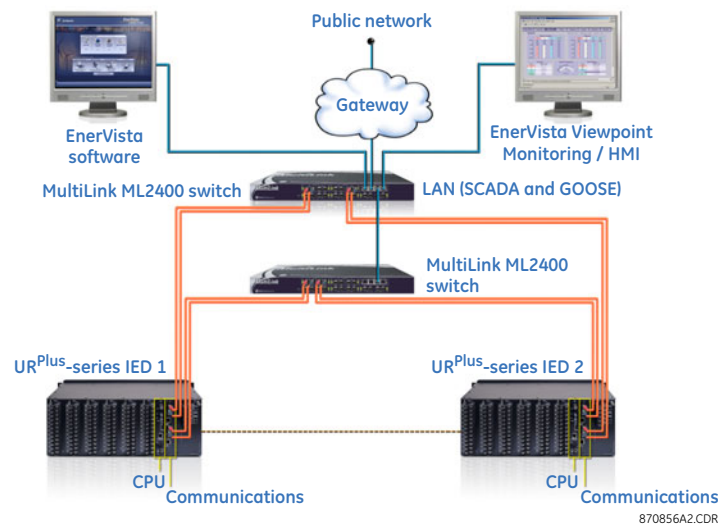
The topology shown as follows allows SCADA, GOOSE, configuration, and monitoring functions to share a single network. No redundancy is provided. A communications processor is required in each D90^{Plus} device to facilitate SCADA and GOOSE messaging. Ports 2 and 3 can be configured for single or dual IP redundancy. This network topology is backwards-compatible with UR-series devices that are configured with a single Ethernet port.

Figure 71: Simple single network topology with no redundancy



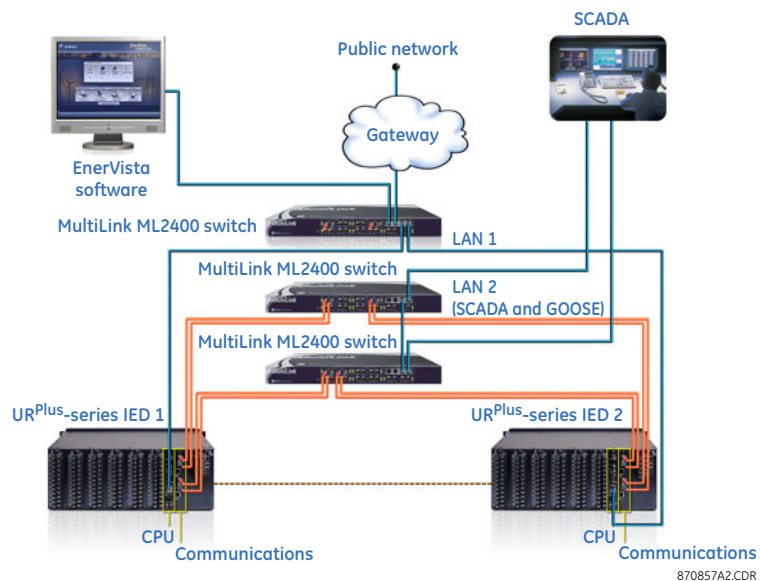
The following topology illustrates a single network for SCADA, GOOSE, configuration, and monitoring functions. This configuration provides redundant hardware and media redundancy. All communications are handled by port 2 under normal circumstances. Failure of a fiber or Ethernet switch causes the communications to be re-routed to port 3. Ports 2 and 3 are configured for single IP redundancy in this case. This network topology is backwardly compatible with UR-series devices that are configured with dual Ethernet ports.

Figure 72: Simple single network topology with redundancy



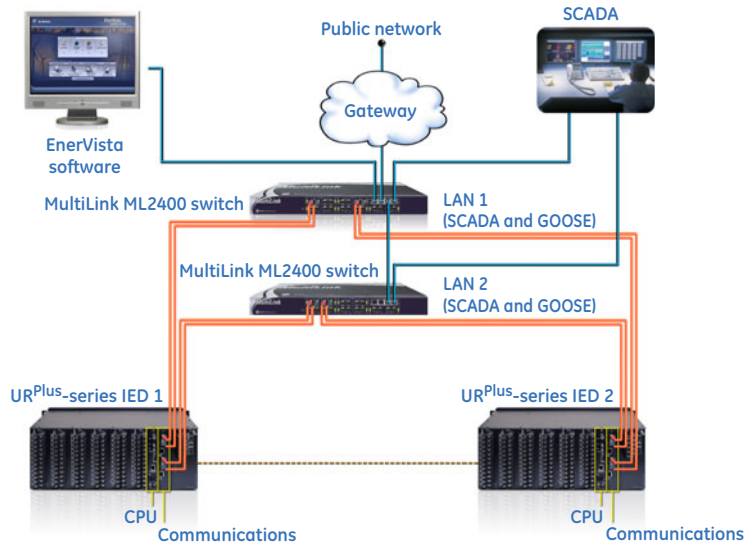
The following topology illustrates a dual LAN network. Configuration and monitoring functions are provided on LAN 1 with no redundancy. LAN 2 is dedicated to SCADA and GOOSE communications and includes redundant hardware and media. Ports 2 and 3 are configured for single IP redundancy.

Figure 73: Simple dual network topology



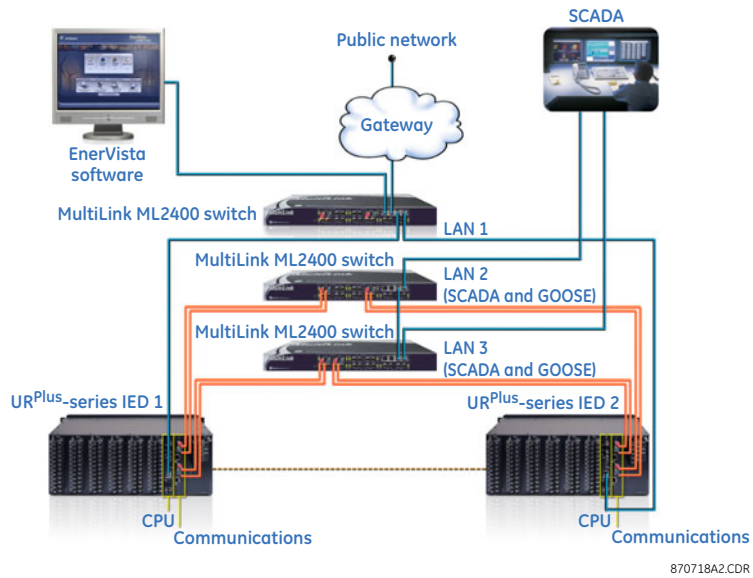
The following topology illustrates a dual redundant LAN network. Ports 2 and 3 are always active. Each D90^{PLUS} device serves clients on either network as required. GOOSE messages are transmitted and received on both LANs simultaneously. Ports 2 and 3 are configured for dual IP redundancy. In dual IP redundancy, both ports operate independently. Loss of communication on one port does not result in connections being closed or connections being transferred to the other port. With dual IP redundancy, both GOOSE and GSSE messages are sent and received on both ports (there is no main or alternate designation), but have a source MAC address of the sending port.

Figure 74: Simple dual redundant network topology



The following topology illustrates a dedicated LAN for configuration and monitoring functions and dual redundant LANs for SCADA and GOOSE traffic. Each D90^{Plus} device services clients on either network as required. GOOSE messages are transmitted and received on both LANs simultaneously. Ports 2 and 3 are configured for dual IP redundancy.

Figure 75: Simple three network topology



Network settings

Settings are available to configure for Ethernet, TFTP, SNMP, and other protocols.

Ethernet ports

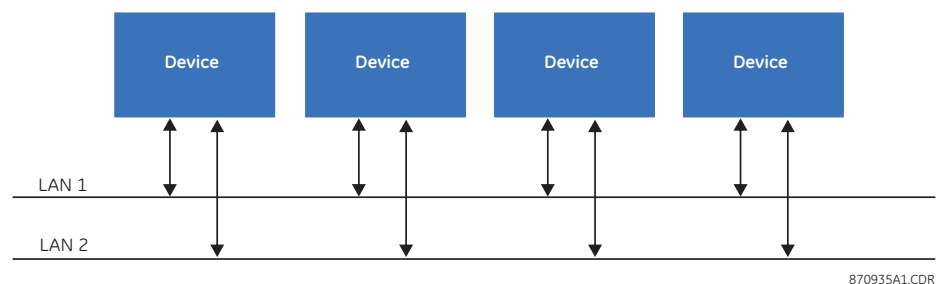
The Ethernet ports can be configured for single IP, dual IP, or redundancy using the Parallel Redundancy Protocol (PRP).

The single IP redundancy configuration provides compatibility with UR-series relays and other devices with single-IP redundancy. In this configuration, the port 2 IP address, subnet mask, and gateway address are used and the port 3 settings are ignored. All communications traffic is normally routed on port 2. If a failure occurs (determined at the hardware layer upon detecting loss of link signal on the active channel), then the traffic is re-routed to port 3. Switchover to port 3 takes place in less than 10 ms from the moment that the physical layer detects a failure. The device reverts from port 3 to port 2 as soon as port 2 becomes available, regardless of the state of port 3. Switchover to port 2 takes place in less than 500 ms. A link pulse is maintained in the transmit direction on both ports regardless of which port is in use. This ensures that communications are established with minimal delays. An Ethernet broadcast message is transmitted immediately upon switching ports, thereby forcing all Ethernet switches in the network to immediately update their routing tables.

In the dual IP redundancy configuration, each port has a unique IP address, subnet mask, and gateway address. Multiple client-server connections can be opened on each port simultaneously. Under normal conditions, GOOSE messages are sent on both ports.

If the PRP option was purchased, the D90^{Plus} supports PRP as per IEC 62439-3 (Clause 4, 2012). PRP provides seamless recovery in case of a single failure in the network, by using a combination of local area network (LAN) duplication and frame duplication. Identical frames are sent on two independent networks that connect source and destination. Under normal circumstances, both frames reach the destination and one of them is used while the second frame is discarded. If an error occurs in one of the networks and traffic is prevented from flowing on that path, connectivity is still provided over the other network. When designing the two LANS, take care that no single point of failure (such as a common power supply) is encountered, because it can bring down both LANs simultaneously. Similar to single and dual-IP configuration, ports 2 and 3 are used on the D90^{Plus} communications card for PRP. The following figure shows an example of a PRP redundant network.

Figure 76: Sample PRP redundant network



To configure the Ethernet ports, select the **Settings > Communications > Network > Ethernet** menu to open the Ethernet configuration window. A selection of settings, commands, and actual values is available. Options visible depend on whether PRP was purchased with the D90^{Plus}.

The IP addresses are used with the DNP, Modbus/TCP, IEC 61580, IEC 60870-5-104, TFTP, and PRP protocols.



NOTE

When the network service access point (NSAP) address or any user map setting (when used with DNP) is changed, it becomes active when power to the relay has been cycled (off-to-on).

The following settings are available for each Ethernet port, except for **OSI Network Address (NSAP)** and **ESH Configuration Time**, which are not port-specific, and the **Port 2 Redundancy**, which applies only to Ethernet port 2.

Port 1 IP Address, Port 2 IP Address, Port 3 IP Address

Range: standard IP address range

Default: 192.168.251.251 (port 1), 192.168.252.252 (port 2), 192.168.253.253 (port 3)

These settings specify the dedicated IP address for each Ethernet port. When using multiple Ethernet ports, each port must be configured for a different subnet.

This setting is valid on port 3 when **Port 2 Redundancy** is set to "Dual IP."

Port 1 IP Subnet Mask, Port 2 IP Subnet Mask, Port 3 IP Subnet Mask

Range: standard IP address range

Default: 255.255.255.0

These settings specify the dedicated subnet mask for each Ethernet port.

The subnet mask settings for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The subnet mask setting for port 3 is not available when the **Port 2 Redundancy** setting is "Single IP."

This setting is valid on port 3 when **Port 2 Redundancy** is set to "Dual IP."

Port 1 Gateway IP Address, Port 2 Gateway IP Address, Port 3 Gateway IP Address

Range: standard IP address range

Default: 0.0.0.0

These settings specify the dedicated gateway address for the selected Ethernet port. One gateway address can be configured for the relay.

The gateway IP address settings for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The gateway IP address setting for port 3 is not available when the **Port 2 Redundancy** setting is "Single IP."

This setting is valid on port 3 when **Port 2 Redundancy** is set to "Dual IP."

Port 1 Ethernet Mode, Port 2 Ethernet Mode, Port 3 Ethernet Mode

Range: Auto, 10/100 Base-TX, 100 Base-TX

Default: Auto

These settings select the Ethernet connection hardware type, either 10/100Base-TX (twisted-pair) or 100Base-FX (fiber optic). The "Auto" selection is used to detect automatically the Ethernet hardware type.

The Ethernet mode settings for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The Ethernet mode setting for port 3 is not available when the **Port 2 Redundancy** setting is "Single IP."

Port 2 Redundancy

Range: Single IP, Dual IP, PRP

Default: Dual IP

This setting is available when the D90^{Plus} contains a communications card. It selects single-IP, dual-IP, or PRP operation for Ethernet ports 2 and 3.

In single-IP mode, the link status of both ports is monitored continuously but only one port is active at a time. Each port uses the same source MAC address and IP parameters specified for Ethernet port 2.

In dual-IP mode, Ethernet ports 2 and 3 operate independently with their own MAC addresses and IP parameters.

When set to either Single IP or PRP, ports 2 and 3 operate in redundant mode. The differences between the two settings are explained as follows.

If set to Single IP, ports 2 and 3 operate as follows:

- Ports 2 and 3 use the port 2 MAC address, IP address, mask, and gateway

- The configuration fields for IP address, mask, and gateway on port 3 are hidden
- Port 3 is in a standby mode in that it does not actively communicate on the Ethernet network but monitors its link to the Multilink switch. If port 2 detects a problem with the link, communications is switched to port 3. Port 3 is, in effect, acting as a redundant or backup link to the network for port 2. Once port 2 detects that the link between port 2 and the switch is good, communications automatically switch back to port 2 and port 3 goes back to standby mode.

If set to PRP, ports 2 and 3 operate as follows:

- Ports 2 and 3 use the port 2 MAC address, IP address, mask, and gateway
- The configuration fields for IP address, mask, and gateway on port 3 are hidden
- Port 2 PRP Multicast Address field is visible so that it can be configured; configure it

Port 2 PRP Multicast Address

Range: 01-15-4E-00-01-00 to 01-15-4E-00-01-FF

Default: 01-15-4E-00-01-00

This setting allows the user to change the multicast address used by the PRP supervision frames. This setting is available when the communications card is installed and **Redundancy** is set to "PRP."

OSI Network Address (NSAP)

Range: 20 alphanumeric characters

Default: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 49 00 00 00

This setting specifies the NSAP address used with the IEC 61850 protocol over the OSI (CLNP/TP4) stack.

ESH Configuration Timer

Range: 0 to 32767 seconds in steps of 1

Default: 120 seconds

The End System to Intermediate System Routing Exchange protocol used with ISO 8473 mandates that the end system construct and transmit an End System Hello (ESH) signal for each NSAP it serves, based on an internal timer. This setting specifies the transmission time for the ESH signal. This setting takes affect when the D90^{Plus} is started.

The following command is also available from this window.

Configure IP Network

This command validates the IP address, subnet mask, and gateway IP address settings for all ports. When validation is successful, the **Configure IP Network Status** value is "OK" and the new settings take effect immediately. When validation fails, the **Configure IP Network Status** value indicates the reason for failure and the network settings are restored to their previous values.

The following actual values are also available from this window.

Configure IP Network Status

Range: OK, PORT 1 NETMASK ERROR, PORT 2 NETMASK ERROR, PORT 3 NETMASK ERROR, PORT 1 IP ADDR RSVD, PORT 2 IP ADDR RSVD, PORT 3 IP ADDR RSVD, PORT 1 IP ADDR LPBK, PORT 2 IP ADDR LPBK, PORT 3 IP ADDR LPBK, PORT 1 IP ADDR NETWK, PORT 2 IP ADDR NETWK, PORT 3 IP ADDR NETWK, PRT 1-2 SUBNET OVRLP, PRT 1-3 SUBNET OVRLP, PRT 2-3 SUBNET OVRLP, >1 GATEWAY DEFINED

This actual value displays the status of the **Configure IP Network** command. The following status values are indicated.

- "OK" — All supplied user IP parameters are valid and have been applied to the network stack.

- "PORT 1 NETMASK ERROR", "PORT 2 NETMASK ERROR", "PORT 3 NETMASK ERROR" — An invalid network mask value was entered for Ethernet port 1, 2, or 3, respectively.
- "PORT 1 IP ADDR RSVD", "PORT 2 IP ADDR RSVD", "PORT 3 IP ADDR RSVD" — A reserved IP address was entered for Ethernet port 1, 2, or 3, respectively. Reserved IP addresses include 0.---.---.--- (for self-identification), 224.---.---.--- through 239.---.---.--- (multicast), and 240.---.---.--- through 255.---.---.--- (reserved by IANA).
- "PORT 1 IP ADDR LPBK", "PORT 2 IP ADDR LPBK", "PORT 3 IP ADDR LPBK" — A loopback IP address was entered for Ethernet port 1, 2, or 3, respectively.
- "PORT 1 IP ADDR NETWK", "PORT 2 IP ADDR NETWK", "PORT 3 IP ADDR NETWK" — The entered IP address is the network address for Ethernet port 1, 2, or 3, respectively.
- "PRT 1-2 SUBNET OVRLP" — The entered network parameters for Ethernet port 1 overlap the network parameters for Ethernet port 2.
- "PRT 1-3 SUBNET OVRLP" — The entered network parameters for Ethernet port 1 overlap the network parameters for Ethernet port 3.
- "PRT 2-3 SUBNET OVRLP" — The entered network parameters for Ethernet port 2 overlap the network parameters for Ethernet port 3.
- ">1 GATEWAY DEFINED" — The user has entered more than one default gateway.

Active Port 1 IP Address, Active Port 2 IP Address, Active Port 3 IP Address

Range: standard IP address range

These actual values display the configured IP address for each Ethernet port.

The active port IP address actual values for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The active port IP address actual value for port 3 is not available when the [Port 2 Redundancy](#) setting is "Dual IP."

Active Port 1 IP Subnet Mask, Active Port 2 IP Subnet Mask, Active Port 3 IP Subnet Mask

Range: standard IP address range

These actual values display the configured subnet mask for each Ethernet port.

The active port subnet mask actual values for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The active port subnet mask actual value for port 3 is not available when the [Port 2 Redundancy](#) setting is "Dual IP."

Active Port 1 Gateway IP Address, Active Port 2 Gateway IP Address, Active Port 3 Gateway IP Address

Range: standard IP address range

These actual values display the configured gateway address for the selected Ethernet port.

The active port gateway address actual values for ports 2 and 3 are available when the D90^{Plus} contains a communications card. The active port gateway address actual value for port 3 is not available when the [Port 2 Redundancy](#) setting is "Dual IP."

TFTP protocol

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the D90^{Plus} over a network. The D90^{Plus} operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows XP. The `dir.txt` file obtained from the D90^{Plus} contains a list and description of all available files, for example, event records and oscillography.

Select the **Settings > Communications > Network > TFTP** menu to open the TFTP configuration window.

Figure 77: TFTP configuration settings

SETTING	PARAMETER
Main UDP Port Number	69
TFTP Data UDP Port Number 1	0
TFTP Data UDP Port Number 2	0
TFTP Data UDP Port Number 3	0
TFTP Data UDP Port Number 4	0

The following settings are available.

Main UDP Port Number

Range: 1 to 65535 in steps of 1

Default: 69

This setting specifies the main UDP port number.

TFTP Data UDP Port Number 1, TFTP Data UDP Port Number 2, TFTP Data UDP Port Number 3, TFTP Data UDP Port Number 4

Range: 0 to 65535 in steps of 1

Default: 0

These settings specify data for UDP port numbers 1 through 4. A TFTP data port value of zero specifies that the D90^{Plus} automatically assigns a port number.



Changes to the TFTP protocol settings become active when power to the D90^{Plus} has been cycled (off-to-on).

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocol.

SNTP protocol

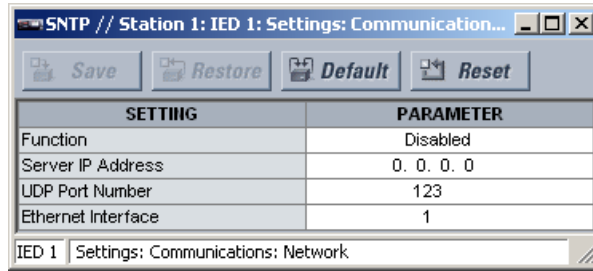
The D90^{Plus} supports the Simple Network Time Protocol (SNTP) specified in RFC-2030. With SNTP, the D90^{Plus} can obtain clock time over an Ethernet network. The D90^{Plus} acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver.

Unicast and broadcast SNTP are supported. The UR^{Plus}-series relays do not support multicast or anycast SNTP functionality.

If SNTP functionality is enabled at the same time as IRIG-B, the IRIG-B signal provides the time value to the D90^{Plus} clock for as long as a valid signal is present. If the IRIG-B signal is removed, the time obtained from the SNTP server is used. If either SNTP or IRIG-B is enabled, the D90^{Plus} clock value cannot be changed using the EnerVista UR^{Plus} Setup software.

Select the **Settings > Communications > Network > SNTP** menu item to open the SNTP configuration window.

Figure 78: SNTP configuration settings



The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the SNTP protocol.

Server IP Address

Range: standard IP address

Default: 0.0.0.0

This setting specifies the SNTP/NTP server IP address.

To use SNTP in unicast mode, this setting must be programmed to the SNTP/NTP server IP address. Once this address is set, the D90^{Plus} attempts to obtain time values from the SNTP/NTP server. Since many time values are obtained and averaged, it generally takes three to four minutes until the D90^{Plus} clock is closely synchronized with the SNTP/NTP server. It can take up to two minutes for the D90^{Plus} to signal an SNTP self-test error if the server is offline.

To use SNTP in broadcast mode, program this setting to “0.0.0.0”. The D90^{Plus} then listens to SNTP messages sent to the *all ones* broadcast address for the subnet. The D90^{Plus} waits up to eighteen minutes (1024 seconds) without receiving an SNTP broadcast message before signaling an SNTP self-test error.

UDP Port Number

Range: 0 to 65535 in steps of 1

Default: 123

This setting specifies the UDP port number for use with the SNTP protocol.

Ethernet Interface

Range: 1, 2, or 3

Default: 1

This setting selects the Ethernet port to use for SNTP communications. Port 1 on slot D at the back of the device is intended for configuration and file retrieval and has a dedicated IP address. Ports 2 and 3 on slot C are intended for SCADA and peer-to-peer messaging.

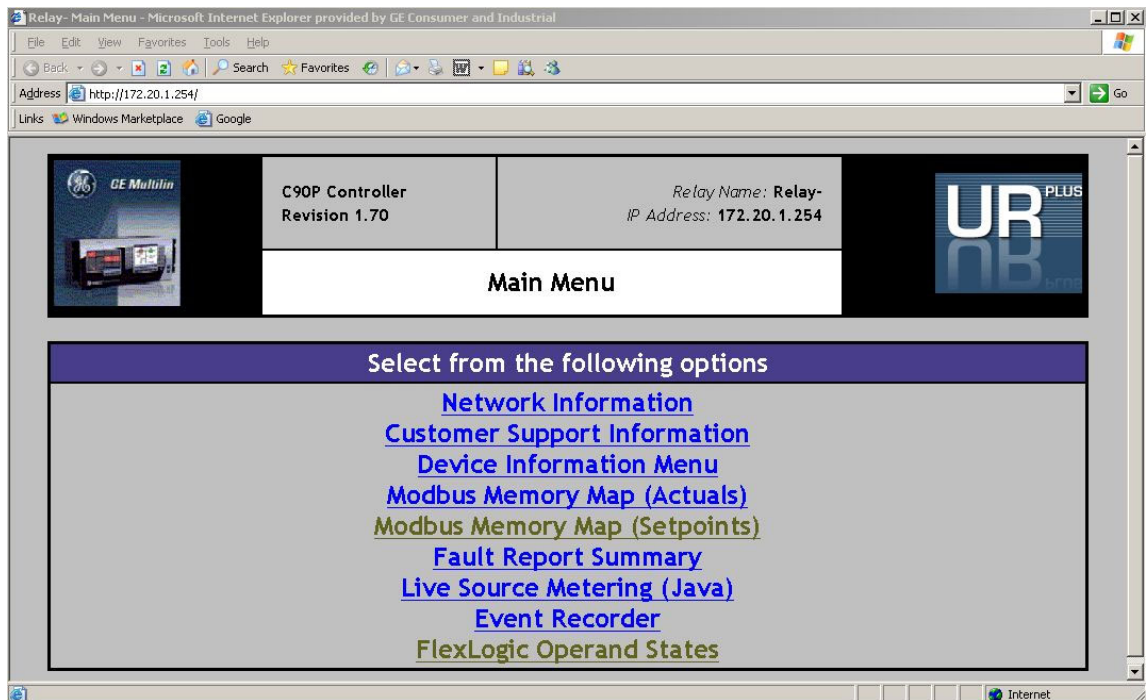


Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

HTTP protocol

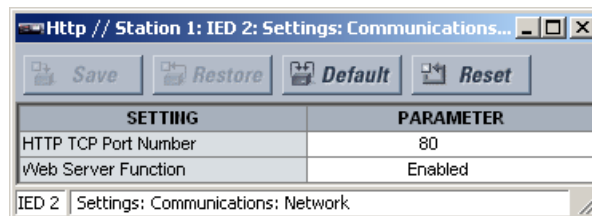
The D90^{Plus} contains an embedded web server and can display pages in a web browser. The web pages are organized as a series of menus that can be accessed starting at the D90^{Plus} main menu. Web pages are read-only and are available showing DNP and IEC 60870-5-104 points lists, Modbus registers, event records, fault reports, and so on. Enable the feature, then enter the IP address of the D90^{Plus} in the address field of the web browser.

Figure 79: Sample web access page



Select the **Settings > Communications > Network > HTTP** menu item to open the HTTP configuration window.

Figure 80: HTTP configuration settings



The following settings are available.

HTTP TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 80

This setting specifies the TCP port number for the embedded web server. This setting takes effect upon restart of the D90^{PLUS}.

Web Server Function

Range: Disabled, Enabled

Default: Disabled

This setting enables and disables the web server feature.



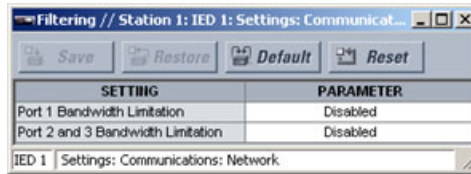
NOTE

Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

Network filtering

Select the **Settings > Communications > Network > Filtering** menu to open the network filtering configuration window.

Figure 81: Network filtering configuration settings



The following settings are available.

Port 1 Bandwidth Limitation

Range: Disabled, Enabled
 Default: Disabled

This setting is used to enable IP protocol bandwidth limiting on Ethernet port 1. The COMM HIGH TRAFFIC self-test message is issued when the D90^{PLUS} is actively limiting IP bandwidth usage. This is a minor self-test error that does not interfere with protection functionality.

Port 2 and 3 Bandwidth Limitation

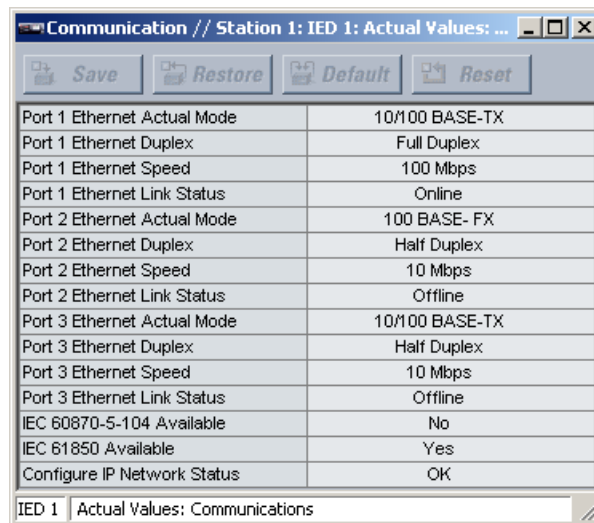
Range: Disabled, Enabled
 Default: Disabled

This setting is used to enable IP protocol bandwidth limiting on Ethernet ports 2 and 3. The COMM HIGH TRAFFIC self-test message is issued when the D90^{PLUS} is actively limiting IP bandwidth usage. This is a minor self-test error that does not interfere with protection functionality. IP bandwidth limiting of Ethernet ports 2 and 3 does not affect GOOSE messaging.

Ethernet actual values

Select the **Actual Values > Communications > Communication** menu to open the communications actual values window.

Figure 82: Ethernet actual values



The following actual values relate to the Ethernet communications feature.

Port 1 Ethernet Actual Mode, Port 2 Ethernet Actual Mode, Port 3 Ethernet Actual Mode

Range: 10/100 BASE-TX, 10/100 BASE-FX

This actual value indicates the Ethernet hardware type Mbps on each of the three ports.

Port 1 Ethernet Duplex, Port 2 Ethernet Duplex, Port 3 Ethernet Duplex*Range: Full Duplex, Half Duplex*

This actual value indicates the Ethernet duplex mode on each of the three ports.

Port 1 Ethernet Speed, Port 2 Ethernet Speed, Port 3 Ethernet Speed*Range: 10 Mbps, 100 Mbps*

This actual value indicates the network speed on each of the three Ethernet ports.

Port 1 Ethernet Link Status, Port 2 Ethernet Link Status, Port 3 Ethernet Link Status*Range: Online, Offline*

This actual value indicates the connection status on each of the three Ethernet ports.

IEC 60870-5-104 Available*Range: No, Yes*

This actual value indicates if the IEC 60870-5-104 protocol is enabled on the Ethernet ports.

IEC 61850 Available*Range: No, Yes*

This actual value indicates if the IEC 61850 protocol is enabled on the Ethernet ports.

Configure IP Network Status*Range: OK, PORT 1 NETMASK ERROR, PORT 2 NETMASK ERROR, PORT 3 NETMASK ERROR, PORT 1 IP ADDR RSVD, PORT 2 IP ADDR RSVD, PORT 3 IP ADDR RSVD, PORT 1 IP ADDR LPBK, PORT 2 IP ADDR LPBK, PORT 3 IP ADDR LPBK, PORT 1 IP ADDR NETWK, PORT 2 IP ADDR NETWK, PORT 3 IP ADDR NETWK, PRT 1-2 SUBNET OVRLP, PRT 1-3 SUBNET OVRLP, PRT 2-3 SUBNET OVRLP, > 1 GATEWAY DEFINED*

This actual value indicates the validity of the IP parameters applied to the network stack. For details on the status values, see [Ethernet ports](#) on page 95. The Ethernet parameters for ports 2 and 3 exist only when the D90^{Plus} contains a communications card.

Remaining TCP/IP connections

Select the **Actual Values > Communications > Remaining Connection** menu item to open the remaining TCP/IP connections actual values window.

Figure 83: Remaining TCP/IP connections actual values

Category	Value
MMS Available TCP/IP Connections	0
Modbus Available TCP/IP Connections	0
DNP Available TCP/IP Connections	0
PMU Available TCP/IP Connections	0
IEC Available TCP/IP Connections	0

IED 1 | Actual Values: Communications

The following actual values are available to display the remaining TCP/IP connections.

MMS Available TCP/IP Connections*Range: 0, 1, 2, 3, 4, 5*

This actual value indicates the number of connections available for IEC 61850 MMS communications.

Modbus Available TCP/IP Connections*Range: 0, 1, 2, 3, 4*

This actual value indicates the number of connections available for Modbus communications.

DNP Available TCP/IP Connections

Range: 0, 1, 2

This actual value indicates the number of connections available for DNP communications. The number of DNP connections is zero unless the “Network - TCP” value has been selected for both the **DNP Channel 1 Port** and **DNP Channel 2 Port** settings.

PMU Available TCP/IP Connections

Range: 0, 1

This actual value indicates the number of connections available for the phasor measurement unit.

IEC Available TCP/IP Connections

Range: 0, 1, 2

This actual value indicates the number of connections available for IEC 60870-5-104 communications.

PRP actual values

Select the **Actual Values > Communications > PRP** menu to open the window.

Figure 84: PRP actual values

PARAMETER	VALUE
Total Received Port A	0
Total Received Port B	0
Total Errors	0
Total Mismatches Port A	0
Total Mismatches Port B	0

The following actual values display.

Total Received Port

Range: 0 to 4G, blank if PRP disabled

This is a counter of total messages received on a port.

Total Errors

Range: 0 to 4G, blank if PRP disabled

This is a counter of total messages received with an error (bad port code, frame length too short).

Total Mismatches

Range: 0 to 4G, blank if PRP disabled

This is a counter of total messages received with an error on a port (PRP frame, but port received through and LAN ID in the frame do not match).

Date and time actual values and commands

Select the **Actual Values > Communications > Commands > Set Date and Time** menu to open the date and time commands window.

Figure 85: Date and time actual values and commands

SETTING	PARAMETER
Computer Date	12/16/09
Computer Time	12:14:38
Device Date	01/21/02
Device Time	01:05:55
Sync Relay to Computer	Select
Manual Date	12/16/2009
Manual Time	12:12:54
Set Manual Date and Time	Select

IED 1 | Actual Values: Communications: Commands

The following actual values display.

Computer Date

Range: date in MM/DD/YY format

This actual value displays the date specified by the computer running the EnerVista UR^{Plus} Setup software.

Computer Time

Range: time in HH:MM:SS format

This actual value displays the time specified by the computer running the EnerVista UR^{Plus} Setup software.

Device Date

Range: date in MM/DD/YY format

This actual value displays the date programmed in the D90^{Plus}.

Device Time

Range: time in HH:MM:SS format

This actual value displays the time programmed in the D90^{Plus}.

The following date and time commands are available.

Sync Relay to Computer

This command sets the D90^{Plus} date and time values to the date and time of the computer running the EnerVista UR^{Plus} Setup software.

Set Manual Date and Time

This command sets the D90^{Plus} date and time values to the date and time values specified by the **Manual Date** and **Manual Time** entries.

Modbus communications

The Modbus protocol is supported by the D90^{Plus}. Modbus is available via the RS485 serial link (Modbus RTU) or Ethernet (Modbus/TCP). The D90^{Plus} supports Modbus RTU.

The D90^{Plus} always acts as a slave device, meaning that it never initiates communications; it listens and responds to requests issued by a master device.

See the D90^{Plus} Communications Guide for information on developing communication drivers and for the Modbus memory map. The map is also viewable in a web browser; enter the IP address of the D90^{Plus} in a web browser and click the option. The rest of this section outlines Modbus configuration settings.

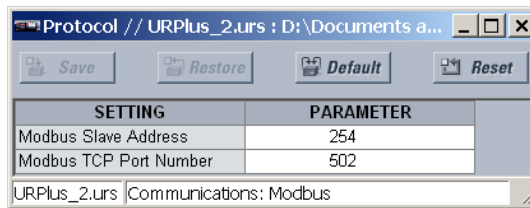
Modbus protocol

The Modbus server can simultaneously support one client over serial RS485 and four clients over Ethernet. The server is capable of reporting any indication or measurement and operating any output present in the device. A user-configurable input and output map is also implemented.

The D90^{Plus} operates as a Modbus slave device only.

Select the **Settings > Communications > Modbus > Protocol** menu to open the Modbus protocol configuration window.

Figure 86: Modbus protocol configuration settings



The following settings are available.

Modbus Slave Address

Range: 1 to 254 in steps of 1

Default: 254

This setting specifies the Modbus slave address for the D90^{Plus}. Each device must have a unique slave address from 1 to 254. Address 0 and addresses from 248 and up are reserved by the Modbus protocol specification, and so their use here is not recommended. Address 0 is the broadcast address to which all Modbus slave devices listen. Addresses do not have to be sequential, but no two devices can have the same address or conflicts resulting in errors occur. Generally, starting at 1, set each device added to the link to use the next higher address.

Modbus TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 502

Modbus over TCP/IP can also be used on any of the Ethernet ports. This setting specifies the Modbus TCP port number for Ethernet communications. Power to the D90^{Plus} must be cycled for changes to this setting to take effect.



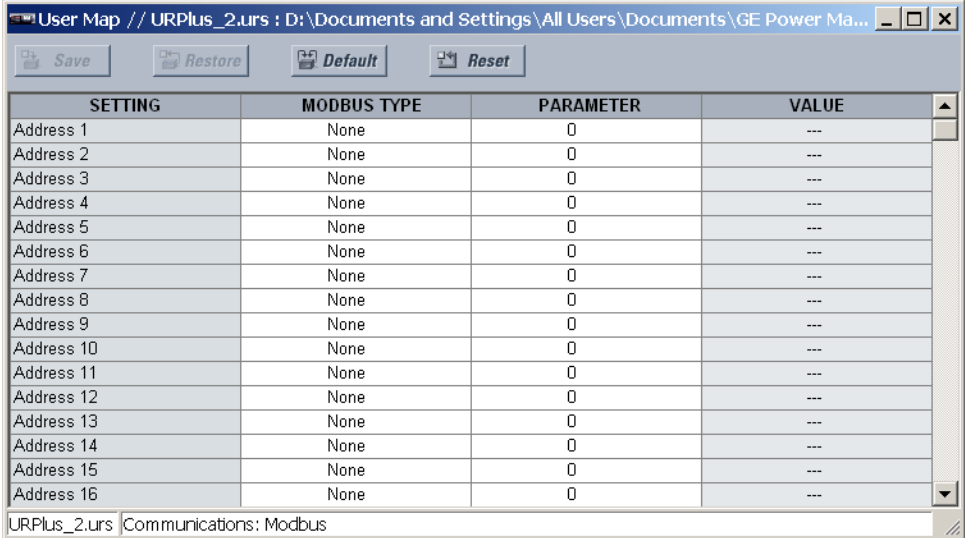
Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

Modbus user map

The Modbus user map provides read-only access for up to 256 registers. To obtain a memory map value, enter the address in the **Parameter** field (converted from hexadecimal to decimal format). The corresponding value (if programmed) displays in the **Value** field. A value of "0" in subsequent register **Address** lines automatically returns values for the previous Address lines incremented by 1. An address value of "0" in the initial register means "none" and values of "0" displays for all registers. Different Address values can be entered as required in any of the register positions.

Select the **Settings > Communications > Modbus > User Map** menu to open the Modbus user map configuration window.

Figure 87: Modbus user map configuration settings



SETTING	MODBUS TYPE	PARAMETER	VALUE
Address 1	None	0	---
Address 2	None	0	---
Address 3	None	0	---
Address 4	None	0	---
Address 5	None	0	---
Address 6	None	0	---
Address 7	None	0	---
Address 8	None	0	---
Address 9	None	0	---
Address 10	None	0	---
Address 11	None	0	---
Address 12	None	0	---
Address 13	None	0	---
Address 14	None	0	---
Address 15	None	0	---
Address 16	None	0	---

The following settings are available for each of the 256 registers.

Modbus Type

Range: None, Settings, Actuals

Default: None

This setting indicates if the Modbus user map address represents a setting or an actual value.

Parameter

Range: Modbus memory map address in decimal representation

Default: 0

This setting represents the value of the programmed Modbus memory map address.

DNP communications

The Distributed Network Protocol (DNP) allows for the optimization of control and data acquisition between the equipment in the substation and the central control center. The protocol is scalable; that is, it is designed to be compatible with the latest high speed LAN technology yet still be implemented over slower speed serial links.

The DNP improves upon many master-slave protocols by improving overall communication performance requirements and provides time-stamping with millisecond accuracy.

See the D90^{PLUS} Communications Guide for details on the DNP.

DNP protocol

The DNP server can simultaneously support one client over serial RS485 and one client over Ethernet or two clients over Ethernet. Level 3 is supported for parsing requests and generating responses. It is capable of reporting any indication or measurement and

operating any output present in the device. Both direct-operate and select-before-operate modes of control are supported. Two user-configurable input and output maps are implemented.

Select the **Settings > Communications > DNP > Protocol** menu to open the DNP protocol configuration window.

Figure 88: DNP protocol configuration settings

SETTING	PARAMETER
DNP Channel 1 Port	NONE
DNP Channel 2 Port	NONE
DNP Channel Address	1
DNP Client Address 1	0. 0. 0. 0
DNP Client Address 2	0. 0. 0. 0
DNP Client Address 3	0. 0. 0. 0
DNP Client Address 4	0. 0. 0. 0
DNP Client Address 5	0. 0. 0. 0
DNP TCP/UDP Port Number	20000
DNP Unsolicited Response Function	Disabled
DNP Unsolicited Response Timeout	5 s
DNP Unsolicited Response Maximum Re-Tries	10
DNP Unsolicited Response Destination Address	1
<hr/>	
DNP Current Scale Factor	1
DNP Voltage Scale Factor	1
DNP Power Scale Factor	1
DNP Other Scale Factor	1
DNP Power Factor Scale Factor	1
DNP Current Default Deadband	30000
DNP Voltage Default Deadband	30000
DNP Power Default Deadband	30000
DNP Other Default Deadband	30000
DNP Power Factor Default Deadband	30000
DNP Time Sync IIN Period	1440 min
DNP Message Fragment Size	240
<hr/>	
DNP Object 1 Default Variation	2
DNP Object 2 Default Variation	2
DNP Object 20 Default Variation	1
DNP Object 21 Default Variation	1
DNP Object 22 Default Variation	1
DNP Object 23 Default Variation	1
DNP Object 30 Default Variation	1
DNP Object 32 Default Variation	1
DNP Number of Paired Controls	0
DNP TCP Connection Timeout	120

The following settings are available.

DNP Channel 1 Port, DNP Channel 2 Port

Range: None, COM1-RS485, Network-TCP, Network-UDP

Default: None

These settings specify the communications port assigned to the DNP protocol for each channel. Once DNP is assigned to a serial port, the Modbus protocol is disabled on that port. When this setting is set to “Network-TCP,” the DNP protocol can be used over TCP/IP on channels 1 or 2. When this value is set to “Network-UDP,” the DNP protocol can be used over UDP/IP on channel 1 only.

Changes to these settings take effect after power has been cycled to the relay.

DNP Channel Address*Range: 0 to 65519 in steps of 1**Default: 1*

This setting specifies the DNP slave address. This number identifies the D90^{Plus} on a DNP communications link. Assign a unique address to each DNP slave.

DNP Client Address 1, DNP Client Address 2, ..., DNP Client Address 5*Range: any standard IP address**Default: 0.0.0.0*

These settings force the D90^{Plus} to respond to a maximum of five specific DNP masters.

DNP TCP/UDP Port Number*Range: 1 to 65535 in steps of 1**Default: 20000*

This setting specifies the TCP/UDP port to use for DNP communications.

DNP Unsolicited Response Function*Range: Enabled, Disabled**Default: Disabled*

Program this setting to "Disabled" for RS485 applications, since there is no collision avoidance mechanism.

DNP Unsolicited Response Timeout*Range: 0 to 60 seconds in steps of 1**Default: 5 seconds*

This setting specifies how long the D90^{Plus} waits for a DNP master to confirm an unsolicited response.

DNP Unsolicited Response Maximum Re-Tries*Range: 1 to 255 in steps of 1**Default: 10*

This setting specifies the number of times the D90^{Plus} retransmits an unsolicited response without receiving confirmation from the master. A value of "255" allows infinite retries.

DNP Unsolicited Response Destination Address*Range: 0 to 65519 in steps of 1**Default: 1*

This setting specifies the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the D90^{Plus} from the current TCP connection or the most recent UDP message.

DNP Current Scale Factor, DNP Voltage Scale Factor, DNP Power Scale Factor, DNP Power Factor Scale Factor, DNP Other Scale Factor*Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000**Default: 1*

These settings scale the analog input current values. For example, if the **DNP Current Scale Factor** is "10," all DNP analog input points that represent currents are returned with values 10 times smaller (for example, a value of 700 amps on the D90^{Plus} is returned as 70). Likewise, if the **DNP Voltage Scale Factor** is "0.01," all DNP analog input points that represent voltages are returned with values 100 times larger (for example, a value of 17 volts on the D90^{Plus} is returned as 1700).

These settings are useful when analog input values must be adjusted to fit within certain ranges in DNP masters.

DNP Current Default Deadband, DNP Voltage Default Deadband, DNP Power Default Deadband, DNP Power Factor Default Deadband, DNP Other Default Deadband

Range: 0 to 100000000 in steps of 1

Default: 30000

These settings determine when to trigger unsolicited responses containing analog input data. These settings group the D90^{Plus} analog input data into types: current, voltage, power, energy, and other. Each setting represents the default deadband value for all analog input points of that type. For example, to trigger unsolicited responses from the D90^{Plus} when any current values change by 15 amps, configure the **DNP Current Default Deadband** setting to "15."

These settings are the deadband default values. DNP object 34 points can be used to change deadband values from the default for each individual DNP analog input point. Whenever power is removed and re-applied to the D90^{Plus}, the default deadbands are in effect.

DNP Time Sync IIN Period

Range: 1 to 10080 minutes in steps of 1

Default: 1440 minutes

This setting determines how often the Need Time Internal Indication (IIN) bit is set by the D90^{Plus}. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

DNP Message Fragment Size

Range: 30 to 2048 in steps of 1

Default: 240

This setting determines the size, in bytes, at which message fragmentation occurs. Large fragment sizes allow for more efficient throughput; smaller fragment sizes cause more application layer confirmations to be necessary, which provides for more robust data transfer over noisy communication channels.

DNP Object 1 Variation, DNP Object 2 Variation, DNP Object 20 Variation, DNP Object 21 Variation, DNP Object 22 Variation, DNP Object 23 Variation, DNP Object 30 Variation, DNP Object 32 Variation

Range: 1, 2 (object 1); 1, 2, 3 (object 2); 1, 2, 5, 6 (objects 20, 22, and 23); 1, 2, 9, 10 (object 21); 1, 2, 3, 4, 5 (object 30); 1, 2, 3, 4, 5, 7 (object 32)

Default: 1 (objects 20, 21, 22, 23, 30, and 32); 2 (objects 1 and 2)

These settings select the DNP default variation number for object types 1, 2, 20, 21, 22, 23, 30, and 32. The default variation refers to the variation response when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. See the DNP Implementation appendix.

DNP Number of Paired Controls

Range: 0 to 32 in steps of 1

Default: 0

The DNP binary outputs typically map one-to-one to IED data points. That is, each DNP binary output controls a single physical or virtual control point in an IED. In the D90^{Plus}, DNP binary outputs are mapped to protection and/or automation virtual inputs.

Mapping is updated in the web page browser. Use this DNP Points Lists web page to verify the DNP configuration.

Some legacy DNP implementations use a mapping of one DNP binary output to two physical or virtual control points to support the concept of trip/close (for circuit breakers) or raise/lower (for tap changers) using a single control point. That is, the DNP master can operate a single point for both trip and close, or raise and lower, operations. The D90^{Plus} can be configured to support paired control points, with each paired control point operating two virtual inputs (protection or automation). This setting allows configuration of 0 to 32 binary output paired controls. The paired control mapping is

reverse paired order, meaning that it starts backward from the end of the Control Outputs List. For example, when the DNP Number of Paired Controls setting is configured as 4, the DNP Points Lists web page shows Automation Virtual Inputs 121 to 128 are paired, as shown in the figure.

Figure 89: Paired points list

181	Aut Virtual Input 118	-
182	Aut Virtual Input 119	-
183	Aut Virtual Input 120	-
184	Aut Virtual Input 121 and Aut Virtual Input 122	-
185	Aut Virtual Input 123 and Aut Virtual Input 124	-
186	Aut Virtual Input 125 and Aut Virtual Input 126	-
187	Aut Virtual Input 127 and Aut Virtual Input 128	-
Counter Points		
Point	Description	
0	Digital Counter 1 Value	-

Points not configured as paired operate on a one-to-one basis.

DNP TCP Connection Timeout

Range: 10 to 300 seconds in steps of 1

Default: 120 seconds

This setting specifies a time delay for the detection of dead network TCP connections. If there is no data traffic on a DNP TCP connection for greater than the time specified by this setting, the connection is aborted by the D90^{PLUS}. This frees the connection to be re-used by a client.

Changes to this setting takes effect after power has been cycled to the relay.

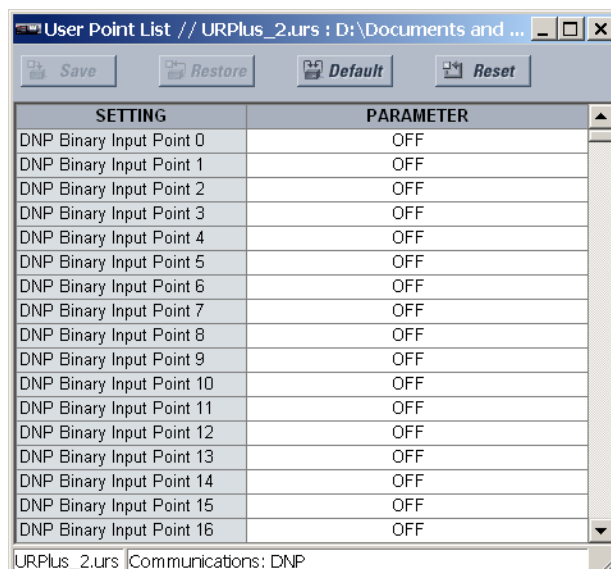
DNP user point list

The binary and analog inputs points for the DNP protocol can be configured to a maximum of 256 points. The value for each point is user-programmable and can be configured by assigning FlexLogic operands for binary inputs or FlexAnalog parameters for analog inputs.

The DNP point lists always begin with point 0 and end at the first “Off” value. Since DNP point lists must be in one continuous block, any points assigned after the first “Off” point are ignored.

Select the **Settings > Communications > DNP > User Point List** menu to open the DNP user point list configuration window.

Figure 90: DNP user point list configuration settings



The following settings are available for points 0 through 255.

DNP Binary Input Point 0, DNP Binary Input Point 1,..., DNP Binary Input Point 255

Range: any FlexLogic operand
Default: Off

These settings represent DNP binary input points and are configured by assigning an appropriate FlexLogic operand to each. Up to 256 binary input points can be configured for the DNP protocol. Changes take effect when the D90^{PLUS} is restarted.

DNP Analog Input Point 0, DNP Analog Input Point 2,..., DNP Analog Input Point 255

Range: any FlexAnalog parameter
Default: Off

These settings represent DNP analog input points and are configured by assigning an appropriate FlexAnalog parameter to each. Up to 256 analog input points can be configured for the DNP protocol. Changes take effect when the D90^{PLUS} is restarted.

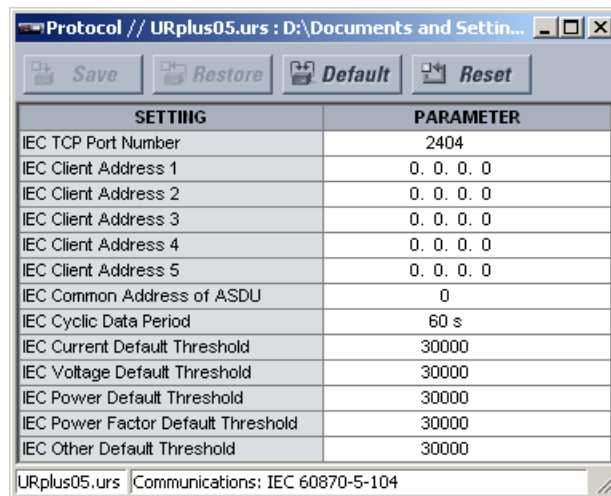
IEC 60870-5-104 communications

The IEC 60870-5-104 server can support two clients simultaneously. It can report any indication or measurement and operate any output present in the device. These point lists are shared with the DNP protocol.

IEC 60870-5-104 protocol

Select the **Settings > Communications > IEC 60870-5-104 > Protocol** menu to open the IEC 60870-5-104 protocol configuration window.

Figure 91: IEC 60870-5-104 protocol configuration settings



SETTING	PARAMETER
IEC TCP Port Number	2404
IEC Client Address 1	0. 0. 0. 0
IEC Client Address 2	0. 0. 0. 0
IEC Client Address 3	0. 0. 0. 0
IEC Client Address 4	0. 0. 0. 0
IEC Client Address 5	0. 0. 0. 0
IEC Common Address of ASDU	0
IEC Cyclic Data Period	60 s
IEC Current Default Threshold	30000
IEC Voltage Default Threshold	30000
IEC Power Default Threshold	30000
IEC Power Factor Default Threshold	30000
IEC Other Default Threshold	30000

The following settings are available.



Do not set more than one protocol to the same TCP/UDP port number, as this results in unreliable operation of those protocols.

IEC TCP Port Number

Range: 0 to 65535 in steps of 1
Default: 2404

This setting specifies the TCP port number to use for IEC 60870-5-104 communications.

IEC Client Address 1, IEC Client Address 2,..., IEC Client Address 5

Range: standard IP address format

Default: 0.0.0.0

These settings specify the IP addresses for five IEC 60870-5-104 clients. These are devices to which the D90^{PLUS} can connect.

IEC Common Address of ASDU

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies the local address of the D90^{PLUS} for IEC 60870-5-104 transactions. The address is common to all data in a single Application Service Data Unit (ASDU). The combination of ASDU common address and Information Object Address (IOA) uniquely identifies each data item in a system.

IEC Cyclic Data Period

Range: 1 to 65535 seconds in steps of 1

Default: 60 seconds

This setting specifies the rate at which the D90^{PLUS} sends updated point data regardless of whether or not a status change has occurred. This data includes binary inputs, binary outputs, and analog inputs.

IEC Current Default Threshold, IEC Voltage Default Threshold, IEC Power Default Threshold, IEC Other Default Threshold

Range: 0 to 100000000 in steps of 1

Default: 30000

These settings are used to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the D90^{PLUS} analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M_ME_NC_1 analog points of that type. For example, to trigger spontaneous responses from the D90^{PLUS} when any current values change by 15 amps, set the **IEC Current Default Threshold** setting to "15." Note that these settings are the default values of the deadbands. P_ME_NC_1 (parameter of measured value, short floating point value) points can be used to change threshold values, from the default, for each individual M_ME_NC_1 analog point. Whenever power is removed and re-applied to the D90^{PLUS}, the default thresholds are in effect.

IEC 60870-5-104 point lists

The MSP and MME points for the IEC 60870-5-104 protocol can be configured to a maximum of 256 points. The value for each point is user-programmable and can be configured by assigning FlexLogic operands for binary MSP points or FlexAnalog parameters for analog MME points.

The IEC 60870-5-104 point lists always begin with point 0 and end at the first "Off" value. Since IEC 60870-5-104 point lists must be in one continuous block, any points assigned after the first "Off" point are ignored.

Select the **Settings > Communications > IEC 60870-5-104 > User Point List** menu to open the IEC 60870-5-104 user point list configuration window.

Figure 92: IEC 60870-5-104 user point list configuration settings

SETTING	PARAMETER
DNP Binary Input Point 0	OFF
DNP Binary Input Point 1	OFF
DNP Binary Input Point 2	OFF
DNP Binary Input Point 3	OFF
DNP Binary Input Point 4	OFF
DNP Binary Input Point 5	OFF
DNP Binary Input Point 6	OFF
DNP Binary Input Point 7	OFF
DNP Binary Input Point 8	OFF
DNP Binary Input Point 9	OFF
DNP Binary Input Point 10	OFF
DNP Binary Input Point 11	OFF
DNP Binary Input Point 12	OFF
DNP Binary Input Point 13	OFF
DNP Binary Input Point 14	OFF
DNP Binary Input Point 15	OFF
DNP Binary Input Point 16	OFF

The following settings are available.

Binary Input Point 0, Binary Input Point 1,..., Binary Input Point 255

Range: any FlexLogic operand

Default: Off

These settings represent the IEC 60870-5-104 binary MSP points and are configured by assigning an appropriate FlexLogic operand. Up to 256 MSP points can be configured for the IEC 60870-5-104 protocol. Changes take effect when the D90^{Plus} is restarted.

Analog Input Point 0, Analog Input Point 1,..., Analog Input Point 255

Range: any FlexAnalog parameter

Default: Off

These settings represent the IEC 60870-5-104 analog MME points and are configured by assigning an appropriate FlexAnalog parameter. Up to 256 MME points can be configured for the IEC 60870-5-104 protocol. Changes take effect when the D90^{Plus} is restarted.

IEC 61850 communications

The D90^{Plus} supports the Manufacturing Message Specification (MMS) protocol as specified by IEC 61850. MMS is supported over the TCP/IP over Ethernet protocol stack. Polling, unbuffered reporting, and buffered reporting are supported. Direct operate and select-before-operate are supported.

GSSE/GOOSE

IEC 61850 provides two fast mechanisms to exchange information between peers in a substation. One is used for transferring status information and is called Generic Substation Status Event (GSSE). The other includes support for a variety of information types, including measured values. It is called the Generic Object Oriented Substation Event (GOOSE) mechanism.

GOOSE or GSSE messages are multicast repeatedly across a substation LAN. All devices on the LAN can receive these messages, but only those devices that require the data are configured to act on them. Because there is no handshaking between devices, GOOSE and GSSE messages can transfer changes very rapidly, making them suitable for performing interlocking and other time-critical substation functions. The IEC 61850 server supports both GOOSE and GSSE protocols in publisher and subscriber roles. In dual-IP redundant configurations, the IED transmits and listens on both ports simultaneously.



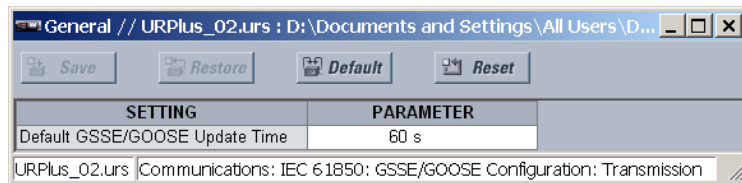
NOTE

Since GSSE/GOOSE messages are multicast Ethernet by specification, they are not usually forwarded by network routers. GOOSE messages can be forwarded by routers if the router has been configured for VLAN functionality.

General transmission

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > General** menu to open the GSSE/GOOSE general transmission configuration window.

Figure 93: General transmission configuration settings



The following setting is available.

Default GSSE/GOOSE Update Time

Range: 1 to 60 seconds
 Default: 60 seconds

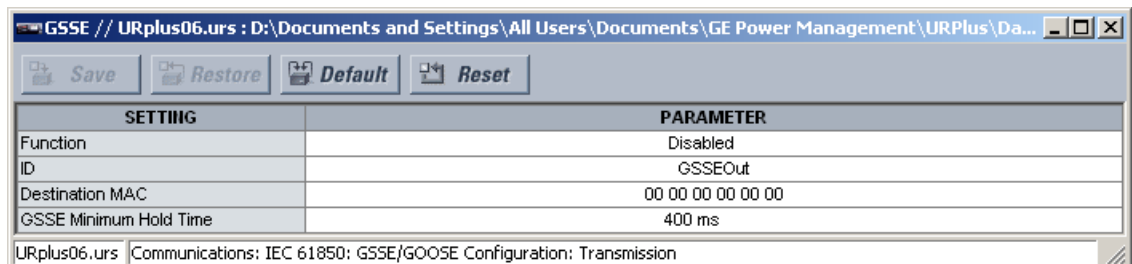
This setting specifies the time between GSSE or GOOSE messages when there are no remote output state changes to be sent. When remote output data changes, GSSE or GOOSE messages are sent immediately. This setting controls the steady-state heartbeat time interval.

This setting is applicable to GSSE, fixed D90^{PLUS} GOOSE, and configurable GOOSE.

GSSE transmission

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > GSSE** menu to open the GSSE transmission configuration window.

Figure 94: GSSE transmission configuration settings



The following settings are available.

Function*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables GSSE transmission.

ID*Range: up to 65 ASCII characters**Default: GSSEOut*

This setting represents the IEC 61850 GSSE application ID name string sent as part of each GSSE message. This name string identifies the GSSE message to the receiving device.

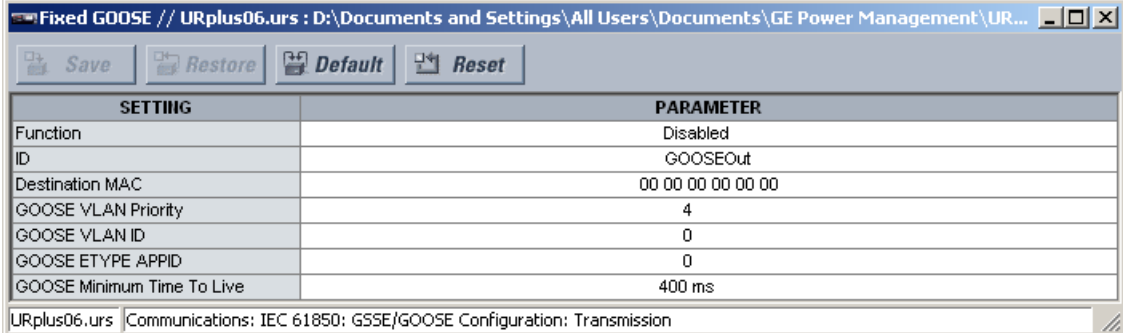
Destination MAC*Range: standard MAC address format**Default: 00 00 00 00 00 00*

This setting specifies the destination Ethernet MAC address for the GSSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

If this setting is specified as "00 00 00 00 00 00" (the default value), then a multicast MAC address is formed based on the MAC address of Ethernet ports 2 and 3. The MAC address of Ethernet port 2 is the MAC address of Ethernet port 1 incremented by 1. The MAC address of Ethernet port 3 is the MAC address of Ethernet port 1 incremented by 2.

GSSE Minimum Hold Time*Range: 50 to 4000 ms in steps of 1**Default: 400 ms*

This setting specifies the minimum hold time for GSSE transmission.

Fixed GOOSE transmissionSelect the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > Fixed GOOSE** menu to open the fixed GOOSE transmission configuration window.**Figure 95: Fixed GOOSE transmission configuration settings**


SETTING	PARAMETER
Function	Disabled
ID	GOOSEOut
Destination MAC	00 00 00 00 00 00
GOOSE VLAN Priority	4
GOOSE VLAN ID	0
GOOSE ETYPE APPID	0
GOOSE Minimum Time To Live	400 ms

URplus06.urs | Communications: IEC 61850: GSSE/GOOSE Configuration: Transmission

The following settings are available.

Function*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables fixed GOOSE transmission.

ID

Range: up to 65 ASCII characters

Default: GOOSEOut

This setting represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message. This name string identifies the GOOSE message to the receiving device.

Destination MAC

Range: standard MAC address format

Default: 00 00 00 00 00 00

This setting specifies the destination Ethernet MAC address for the fixed GOOSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

If this setting is specified as "00 00 00 00 00 00" (the default value), then a multicast MAC address is formed based on the MAC address of Ethernet ports 2 and 3. The MAC address of Ethernet port 2 is the MAC address of Ethernet port 1 incremented by 1. The MAC address of Ethernet port 3 is the MAC address of Ethernet port 1 incremented by 2.

GOOSE VLAN Priority

Range: 0 to 7 in steps of 1

Default: 4

This setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. This setting is required by IEC 61850.

GOOSE VLAN ID

Range: 0 to 4096 in steps of 1

Default: 0

This setting allows the selection of a specific VLAN ID for each GOOSE sending device. This value can be left at its default if the feature is not required.

GOOSE ETYPE APPID

Range: 0 to 16383 in steps of 1

Default: 0

This setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. This setting is required by IEC 61850.

GOOSE Minimum Time to Live

Range: 50 to 4000 ms in steps of 1

Default: 400 ms

This setting specifies the minimum time to live for the GOOSE transmission data set.

Configurable GOOSE transmission

The configurable GOOSE settings allow the D90^{Plus} to be configured to transmit a number of datasets within IEC 61850 GOOSE messages. Up to eight configurable datasets can be configured and transmitted, allowing for optimization of data transfer between devices. This is useful for intercommunication between D90^{Plus} IEDs and devices from other manufacturers that support IEC 61850.

Items programmed for datasets 1 through 8 have changes in their status transmitted once per protection pass for digital data and every 250 ms for analog data.

The integrity GOOSE message is sent at the pre-configured rate for all datasets, even if no changes in the data items are detected.

The configurable GOOSE feature is recommended for applications that require GOOSE data transfer between UR^{Plus}-series IEDs and devices from other manufacturers. Fixed GOOSE is recommended for applications that require GSSE data transfer between UR^{Plus}-series IEDs. IEC 61850 GOOSE messaging contains a number of configurable parameters, all of which must be correct for successful data transfer. It is critical that the configured datasets at the transmission and reception devices are an exact match in terms of data structure, and that the GOOSE addresses and name strings match exactly. Manual configuration is possible, but third-party substation configuration software can be used to automate the process. The UR^{Plus}-series software can produce IEC 61850 ICD files and import IEC 61850 SCD files produced by a substation configurator.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Transmission > Tx Configurable GOOSE** menu to open the configurable GOOSE transmission configuration window.

Figure 96: Configurable GOOSE transmission configuration settings

SETTING	PARAMETER
GOOSEOut 1 Function	Disabled
GOOSEOut 1 ID	GOOSEOut_x_
GOOSEOut 1 Destination MAC	00 00 00 00 00 00
GOOSEOut 1 VLAN Priority	4
GOOSEOut 1 VLAN ID	0
GOOSEOut 1 ETYPE.APPID	0
GOOSEOut 1 ConfRev	1
GOOSEOut 1 Minimum Time To Live	400 ms
GOOSEOut 1 Retrans Profile	STANDARD
GOOSEOut 1 Dataset Item 1	NONE
GOOSEOut 1 Dataset Item 2	NONE
GOOSEOut 1 Dataset Item 3	NONE
GOOSEOut 1 Dataset Item 4	NONE

The following settings are available for each dataset for configurable GOOSE transmission.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables configurable GOOSE transmission.

ID

Range: up to 65 ASCII characters

Default: GOOSEOut_1

This setting represents the IEC 61850 GOOSE application ID (GoID) name string sent as part of each GOOSE message. This name string identifies the GOOSE message to the receiving device.

Destination MAC

Range: standard MAC address format

Default: 00 00 00 00 00 00

This setting specifies the destination Ethernet MAC address for the configurable GOOSE transmission. This address must be a multicast address and the least significant bit of the first byte must be set.

If this setting is specified as "00 00 00 00 00 00" (the default value), then a multicast MAC address is formed based on the MAC address of Ethernet ports 2 and 3. The MAC address of Ethernet port 2 is the MAC address of Ethernet port 1 incremented by 1. The MAC address of Ethernet port 3 is the MAC address of Ethernet port 1 incremented by 2.

VLAN Priority

Range: 0 to 7 in steps of 1

Default: 4

This setting indicates the Ethernet priority of GOOSE messages. This allows GOOSE messages to have higher priority than other Ethernet data. This setting is required by IEC 61850.

VLAN ID

Range: 0 to 4096 in steps of 1

Default: 0

This setting allows the selection of a specific VLAN ID for each GOOSE sending device. This value can be left at its default if the feature is not required.

ETYPE APPID

Range: 0 to 16383 in steps of 1

Default: 0

This setting allows the selection of a specific application ID for each GOOSE sending device. This value can be left at its default if the feature is not required. This setting is required by IEC 61850.

ConfRev

Range: 1 to 16383 in steps of 1

Default: 1

This value changes automatically as described in IEC 61850 part 7-2.

Minimum Time to Live

Range: 50 to 4000 ms in steps of 1

Default: 400 ms

This setting specifies the minimum time to live for the GOOSE transmission data set.

Retransmission Profile

Range: None, Aggressive, Standard, Relaxed

Default: Standard

The D90^{PLUS} supports four retransmission schemes: aggressive, standard, relaxed, and none.

The following retransmission times are specified under these profiles.

- Aggressive — Select for trip schemes — 4, 8, 16, 32, and 64 ms
- Standard — Select for remedial action schemes — 16, 32, 64, 128, and 256 ms (default)
- Relaxed — Select for analog data sets — 100, 200, 400, 800, and 1000 ms
- None — Select for schemes that incorporate a separate confirmation scheme — no retransmission

These selections are available on a transmit dataset-by-dataset basis. For GSSE and fixed GOOSE, the profile is fixed at "Aggressive" and there is no associated setting.

Dataset Item 1, Dataset Item 2, Dataset Item 3,..., Dataset Item 64

Range: all valid MMS data item references for transmitted data

Default: 0

These settings are used to select an MMS data item for each configurable GOOSE dataset item.

To create a configurable GOOSE dataset that contains an IEC 61850 Single Point Status indication and its associated quality flags, the following dataset items can be selected: "GGIO1.ST.Ind1.stVal" and "GGIO1.ST.Ind1.q." The D90^{PLUS} then creates a dataset

containing these two data items. The status value for GGIO1.ST.Ind1.stVal is determined by the operand assigned to GGIO1 indication 1. Changes to this operand result in the transmission of GOOSE messages containing the defined dataset.

Configurable GOOSE reception

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Reception > Rx Configurable GOOSE** menu to open the configurable GOOSE reception configuration window.

Figure 97: Configurable GOOSE reception configuration settings

PARAMETER	GOOSEIN 1	GOOSEIN 2	GOOSEIN 3
Dataset Item 1	None	None	None
Dataset Item 2	None	None	None
Dataset Item 3	None	None	None
Dataset Item 4	None	None	None
Dataset Item 5	None	None	None
Dataset Item 6	None	None	None
Dataset Item 7	None	None	None
Dataset Item 8	None	None	None
Dataset Item 9	None	None	None
Dataset Item 10	None	None	None
Dataset Item 11	None	None	None
Dataset Item 12	None	None	None
Dataset Item 13	None	None	None
Dataset Item 14	None	None	None
Dataset Item 15	None	None	None
Dataset Item 16	None	None	None

The following settings are available for each dataset for configurable GOOSE reception.

Dataset Item 1, Dataset Item 2, Dataset Item 3,..., Dataset Item 64

Range: all valid MMS data item references for transmitted data

Default: 0

These settings are used to select an MMS data item for each configurable GOOSE dataset item.

Remote devices

Remote inputs and outputs provide a means to exchange digital state information between Ethernet-connected devices. The IEC 61850 Generic Substation State Event (GSSE) and Generic Object Oriented Substation Event (GOOSE) standards are used for this purpose.

The sharing of digital point state information between GSSE/GOOSE equipped relays is essentially an extension of FlexLogic, allowing for distributed FlexLogic by making operands available to and from devices on a common communications network. In addition to digital point states, GSSE/GOOSE messages identify the originator of the message and provide other information required by the communication specification. All devices listen to network messages and capture data only from messages that have originated in selected devices.

IEC 61850 GSSE messages are compatible with UCA GOOSE messages and contain a fixed set of digital points. IEC 61850 GOOSE messages can, in general, contain any configurable data items. When used by the remote inputs and outputs feature, IEC 61850 GOOSE messages contain the same data as GSSE messages.

Both GSSE and GOOSE messages are designed to be short, reliable, and have high priority. GOOSE messages have additional advantages over GSSE messages due to their support of virtual LAN (VLAN) and Ethernet priority tagging functionality. The GSSE message structure contains space for 128 bit pairs representing digital point state information. The IEC 61850 specification provides 32 DNA bit pairs that represent the state of two pre-defined events and 30 user-defined events. All remaining bit pairs are UserSt bit pairs, which are status bits representing user-definable events. The D90^{Plus} implementation provides 32 of the 96 available UserSt bit pairs.

The IEC 61850 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device sends a GSSE/GOOSE message upon successful power-up, when the state of any included point changes, or after a specified interval (the default update time) if a change-of-state has not occurred. The transmitting device also sends a hold time that is the GSSE equivalent of “time to live” in IEC GOOSE messages.

Receiving devices constantly monitor the communications network for required messages, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message time allowed to live. The receiving relay sets a timer assigned to the originating device to this time interval, and if it has not received another message from this device at time-out, the remote device is declared to be non-communicating, so it uses the programmed default state for all points from that specific remote device. If a message is received from a remote device before the time allowed to live expires, all points for that device are updated to the states contained in the message and the hold timer restarts. The status of a remote device, where “Offline” indicates non-communicating, can be displayed.

The D90^{Plus} provides for 64 remote inputs and 64 remote outputs.

In a UR^{Plus}-series IED, the device ID that identifies the originator of the message is programmed in the **IED Name** setting.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Devices** menu to open the remote devices configuration window.

Figure 98: Remote devices configuration settings

SETTING	ID	ETYPE APPID	DATASET
Remote Device 1	Remote Device 1	0	Fixed
Remote Device 2	Remote Device 2	0	Fixed
Remote Device 3	Remote Device 3	0	Fixed
Remote Device 4	Remote Device 4	0	Fixed
Remote Device 5	Remote Device 5	0	Fixed
Remote Device 6	Remote Device 6	0	Fixed
Remote Device 7	Remote Device 7	0	Fixed
Remote Device 8	Remote Device 8	0	Fixed
Remote Device 9	Remote Device 9	0	Fixed
Remote Device 10	Remote Device 10	0	Fixed
Remote Device 11	Remote Device 11	0	Fixed
Remote Device 12	Remote Device 12	0	Fixed
Remote Device 13	Remote Device 13	0	Fixed
Remote Device 14	Remote Device 14	0	Fixed
Remote Device 15	Remote Device 15	0	Fixed
Remote Device 16	Remote Device 16	0	Fixed

The following settings are available for each of the 32 remote devices.

ID

Range: up to 65 alphanumeric characters

Default: Remote Device 1

Up to 32 remote devices can be selected for setting purposes. A receiving relay must be programmed to capture messages from the originating remote devices of interest. This setting is used to select specific remote devices by entering an exact identification (ID) assigned to those devices.

ETYPE APPID

Range: 0 to 16383 in steps of 1

Default: 0

This setting is used with GOOSE messages and is not applicable to GSSE messages. It identifies the application identification in the GOOSE message. It needs to match the corresponding settings on the sending device.

DATASET

Range: Fixed, GOOSE 1 through GOOSE 8

Default: Fixed

This setting provides for the choice of the UR^{PLUS}-series fixed (DNA/UserSt) dataset (that is, containing DNA and UserSt bit pairs), or one of the configurable datasets.

The dataset for the received data items must be made up of existing items in an existing logical node. For this reason, logical node GGIO3 is instantiated to hold the incoming data items. GGIO3 is not necessary to make use of the received data. The remote input data item mapping takes care of the mapping of the inputs to remote input FlexLogic operands. However, GGIO3 data can be read by IEC 61850 clients.

Remote inputs

Remote inputs create FlexLogic operands at the receiving relay and are extracted from GSSE/GOOSE messages originating in remote devices. The D90^{PLUS} provides 64 remote inputs, each of which can be selected from a list consisting of 64 selections: DNA-1 through DNA-32 and UserSt-1 through UserSt-32. The function of DNA inputs is defined in the IEC 61850 specification and is presented in the following table. The function of UserSt inputs is defined by the user selection of the FlexLogic operand whose state is represented in the GSSE/GOOSE message. A user must program a DNA point from the appropriate FlexLogic operand.

Table 6: IEC 61850 DNA Assignments

DNA	IEC 61850 definition	FlexLogic operand
1	Test	IEC 61850 TEST MODE
2	ConfRev	IEC 61850 CONF REV

Remote input 1 must be programmed to replicate the logic state of a specific signal from a specific remote device for local use. This programming is performed via the three settings indicated outlined as follows.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Inputs** menu to open the remote inputs configuration window.

Figure 99: Remote inputs configuration settings

SETTING	NAME	DEVICE	BIT PAIR	DEFAULT STATE	EVENTS
Remote Input 1	Remo Ip 1	Remote Device 1	None	Off	Disabled
Remote Input 2	Remo Ip 2	Remote Device 1	None	Off	Disabled
Remote Input 3	Remo Ip 3	Remote Device 1	None	Off	Disabled
Remote Input 4	Remo Ip 4	Remote Device 1	None	Off	Disabled
Remote Input 5	Remo Ip 5	Remote Device 1	None	Off	Disabled
Remote Input 6	Remo Ip 6	Remote Device 1	None	Off	Disabled
Remote Input 7	Remo Ip 7	Remote Device 1	None	Off	Disabled
Remote Input 8	Remo Ip 8	Remote Device 1	None	Off	Disabled
Remote Input 9	Remo Ip 9	Remote Device 1	None	Off	Disabled
Remote Input 10	Remo Ip 10	Remote Device 1	None	Off	Disabled
Remote Input 11	Remo Ip 11	Remote Device 1	None	Off	Disabled
Remote Input 12	Remo Ip 12	Remote Device 1	None	Off	Disabled
Remote Input 13	Remo Ip 13	Remote Device 1	None	Off	Disabled
Remote Input 14	Remo Ip 14	Remote Device 1	None	Off	Disabled
Remote Input 15	Remo Ip 15	Remote Device 1	None	Off	Disabled
Remote Input 16	Remo Ip 16	Remote Device 1	None	Off	Disabled

The following settings are available for each of the 32 remote inputs.

Name

Range: up to 12 alphanumeric characters

Default: Remo Ip 1

This setting allows the user to assign descriptive text to the remote input.

Device

Range: 1 to 32 inclusive

Default: Remote Device 1

This setting selects the number (1 to 32) of the remote device that originates the required signal, as previously assigned to the remote device via the [Remote Device 1 ID](#) setting.

Bit Pair

Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32, Config Item 1 to Config Item 64

Default: None

This setting selects the specific bits of the GSSE/GOOSE message required.

Default State

Range: On, Off, Latest/On, Latest/Off

Default: Off

This setting selects the logic state for this point if the local relay has just completed startup or the remote device sending the point is declared to be non-communicating. The following choices are available:

- On — Defaults the input to logic 1
- Off — Defaults the input to logic 0
- Latest/On — Freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input defaults to logic 1. When communication resumes, the input becomes fully operational.
- Latest/Off — Freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input defaults to logic 0. When communication resumes, the input becomes fully operational.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of remote input events in the sequence of events recorder.

Remote double-point status inputs

Remote double-point status inputs are extracted from GOOSE messages originating in the remote device. The D90^{PLUS} provides 16 remote double-point status inputs. Each remote double-point status input must be programmed to replicate the logic state of a specific signal from a specific remote device for local use.

The configurable GOOSE dataset items must be changed to accept a double-point status item from a GOOSE dataset. Dataset items configured to receive any of “GGIO3.ST.IndPos1.stV” to “GGIO3.ST.IndPos16.stV” accept double-point status information that is decoded by the remote double-point status inputs configured to this dataset item.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote DPS Inputs** menu to open the remote double-point status inputs configuration window.

Figure 100: Remote double-point status inputs configuration settings

SETTING	PARAMETER
Remote DPS Input 1 Name	RemDPS Ip 1
Remote DPS Input 1 Device	Remote Device 1
Remote DPS Input 1 Item	None
Remote DPS Input 1 Default State	LATEST
Remote DPS Input 1 Events	Disabled
Remote DPS Input 2 Name	RemDPS Ip 2
Remote DPS Input 2 Device	Remote Device 1
Remote DPS Input 2 Item	None
Remote DPS Input 2 Default State	LATEST
Remote DPS Input 2 Events	Disabled
Remote DPS Input 3 Name	RemDPS Ip 3
Remote DPS Input 3 Device	Remote Device 1
Remote DPS Input 3 Item	None
Remote DPS Input 3 Default State	LATEST
Remote DPS Input 3 Events	Disabled

The following settings are available for each of the 16 remote double-point status inputs.

Name

Range: up to 12 alphanumeric characters

Default: RemDPS Ip 1

This setting specifies an exact identification (ID) for each remote double-point status input.

Device

Range: Remote Device 1 through Remote Device 32

Default: Remote Device 1

This setting selects a remote device ID to indicate the origin of a GOOSE message.

Item

Range: None, Dataset Item 1 through Dataset Item 64

Default: None

This setting specifies the required bits of the GOOSE message.

Default State

Range: Intermediate, Off, On, Bad, Latest

Default: Latest

This setting selects the default value for the offline remote double-point status input.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of remote double-point status input events in the sequence of events recorder.

Remote outputs: DNA bit pairs

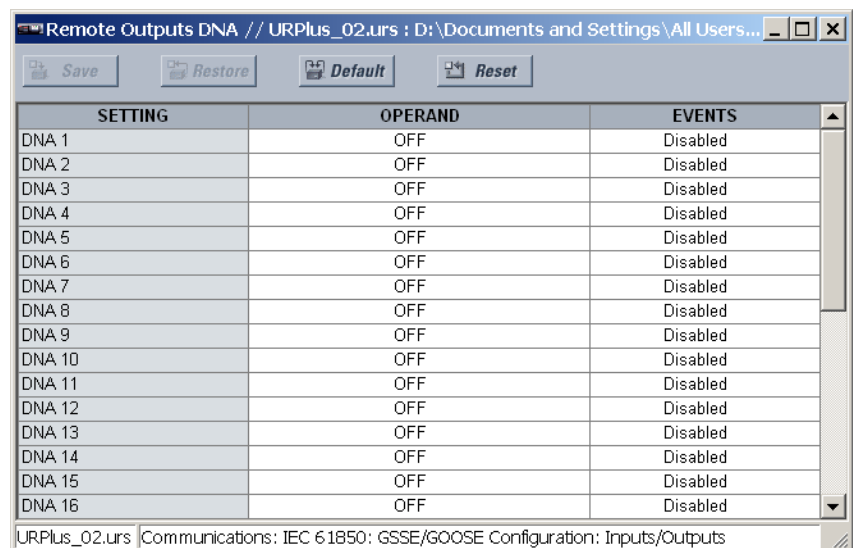
Remote outputs (1 to 32) are FlexLogic operands inserted into GSSE/GOOSE messages that are transmitted to remote devices on a LAN. Each digital point in the message must be programmed to carry the state of a specific FlexLogic operand. This operand setting represents a specific DNA function (as shown in the following table) to be transmitted.

Table 7: IEC 61850 DNA Assignments

DNA	IEC 61850 definition	FlexLogic operand
1	Test	IEC 61850 TEST MODE
2	ConfRev	IEC 61850 CONF REV

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Outputs DNA** menu to open the remote inputs configuration window.

Figure 101: Remote outputs DNA bit pair configuration settings



The following settings are available for each of the 32 remote outputs.

Operand

Range: any automation logic or FlexLogic operand

Default: Off

This setting specifies the FlexLogic operand assigned to DNA point 1.

Events

Range: Enabled, Disabled

Default: Disabled

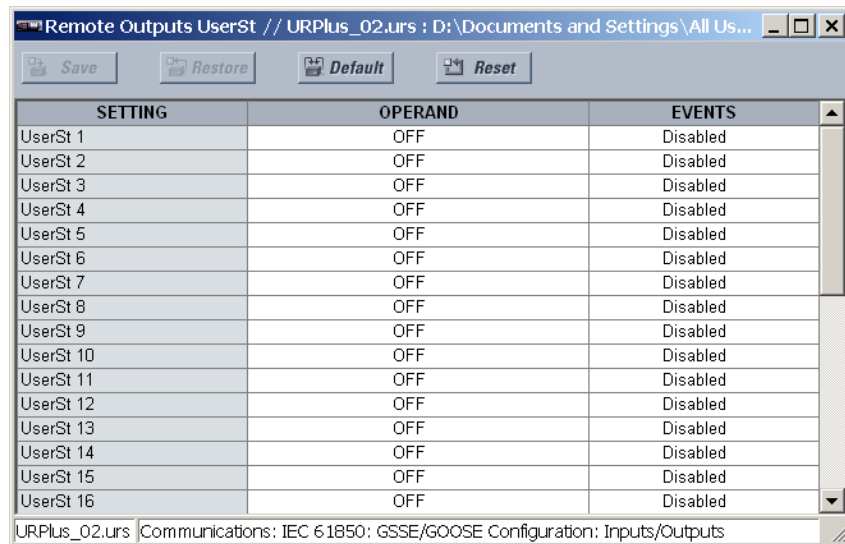
This setting enables and disables the logging of remote output DNA bit pair events in the sequence of events recorder.

Remote outputs: UserSt bit pairs

Remote outputs 1 to 32 originate as GSSE/GOOSE messages to be transmitted to remote devices. Each digital point in the message must be programmed to carry the state of a specific FlexLogic operand. This operand setting is used to select the operand that represents a specific UserSt function (as selected by the user) to be transmitted.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > Remote Outputs UserSt** menu to open the remote inputs configuration window.

Figure 102: Remote output UserSt bit pair configuration settings



SETTING	OPERAND	EVENTS
UserSt 1	OFF	Disabled
UserSt 2	OFF	Disabled
UserSt 3	OFF	Disabled
UserSt 4	OFF	Disabled
UserSt 5	OFF	Disabled
UserSt 6	OFF	Disabled
UserSt 7	OFF	Disabled
UserSt 8	OFF	Disabled
UserSt 9	OFF	Disabled
UserSt 10	OFF	Disabled
UserSt 11	OFF	Disabled
UserSt 12	OFF	Disabled
UserSt 13	OFF	Disabled
UserSt 14	OFF	Disabled
UserSt 15	OFF	Disabled
UserSt 16	OFF	Disabled

The following settings are available for each of the 32 bit pairs.

Operand

Range: any FlexLogic operand

Default: Off

This setting specifies the FlexLogic operand assigned to UserSt point 1.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of remote output UserSt bit pair events in the sequence of events recorder.

IEC 61850 GOOSE analog inputs

The IEC 61850 GOOSE analog inputs feature allows the transmission of analog values between any two UR^{PLUS}-series devices.

Select the **Settings > Communications > IEC 61850 > GSSE/GOOSE Configuration > Inputs/Outputs > IEC 61850 GOOSE Analog Inputs** menu to open the IEC 61850 GOOSE analog inputs configuration window.

Figure 103: IEC 61850 GOOSE analog inputs configuration settings

SETTING	DEFAULT VALUE	MODE	UNITS	PU BASE
IEC61850 Goose Analog Input 1	1000.000	Default Value		1
IEC61850 Goose Analog Input 2	1000.000	Default Value		1
IEC61850 Goose Analog Input 3	1000.000	Default Value		1
IEC61850 Goose Analog Input 4	1000.000	Default Value		1
IEC61850 Goose Analog Input 5	1000.000	Default Value		1
IEC61850 Goose Analog Input 6	1000.000	Default Value		1
IEC61850 Goose Analog Input 7	1000.000	Default Value		1
IEC61850 Goose Analog Input 8	1000.000	Default Value		1
IEC61850 Goose Analog Input 9	1000.000	Default Value		1
IEC61850 Goose Analog Input 10	1000.000	Default Value		1
IEC61850 Goose Analog Input 11	1000.000	Default Value		1
IEC61850 Goose Analog Input 12	1000.000	Default Value		1
IEC61850 Goose Analog Input 13	1000.000	Default Value		1
IEC61850 Goose Analog Input 14	1000.000	Default Value		1
IEC61850 Goose Analog Input 15	1000.000	Default Value		1
IEC61850 Goose Analog Input 16	1000.000	Default Value		1

The following settings are available for each of the 128 IEC 61850 GOOSE analog inputs.

Default Value

Range: -1000000.000 to 1000000.000 in steps of 0.001

Default: 1000.000

This setting specifies the value of the GOOSE analog input when the sending device is offline and the **Default Mode** setting is set to “Default Value.” This setting is stored as an IEEE 754 / IEC 60559 floating point number. Because of the large range of this setting, not all possible values can be stored. Some values are rounded to the closest possible floating point number.

Mode

Range: Default Value, Last Known

Default: Default Value

When the sending device is offline and this setting is “Last Known,” the value of the GOOSE analog input remains at the last received value. When the sending device is offline and this setting value is “Default Value,” then the value of the GOOSE analog input is defined by the **Default Value** setting.

Units

Range: up to 4 alphanumeric characters

Default: ---

This setting specifies a four-character alphanumeric string that is used in the actual values display of the corresponding GOOSE analog input value.

PU Base

Range: 0 to 1000000000 in steps of 1

Default: 1

This setting specifies the per-unit base factor when using the GOOSE analog input FlexAnalog values in other D90^{PLUS} features, such as protection FlexElements. The base factor is applied to the GOOSE analog input FlexAnalog quantity to normalize it to a per-unit quantity. The table outlines the base units.

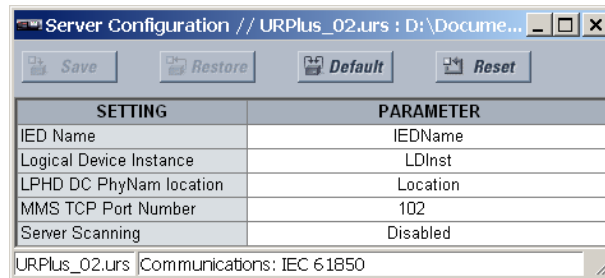
Table 8: Per-unit base units

Element	Base unit
Frequency	1 Hz
Phase angles	360 degrees
Power factor	1.00
Source current	Maximum nominal primary RMS value of the +IN and -IN inputs
Source power	Maximum value of the product of the voltage and current base values for the +IN and -IN inputs
Source voltage	Maximum nominal primary RMS value of the +IN and -IN inputs

The GOOSE analog input FlexAnalog values are available for use in other D90^{Plus} functions that use FlexAnalog values.

IEC 61850 server configuration

Select the **Settings > Communications > IEC 61850 > Server Configuration** menu to open the IEC 61850 server configuration window.

Figure 104: IEC 61850 server configuration settings

The following settings are available.

IED Name

Range: up to 32 alphanumeric characters

Default: IEDName

This setting represents the MMS domain name where all IEC/MMS logical nodes are located. The setting value can be composed of up to 32 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter. Changes to this setting and the GOOSE dataset take effect when the unit is restarted.

Logical Device Instance

Range: up to 32 alphanumeric characters

Default: LDInst

This setting represents the IEC 61850 logical device where all IEC/MMS logical nodes are located. The setting value can be composed of up to 32 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter.

LPHD DC PhyNam Location

Range: up to 80 ASCII characters

Default: Location

This setting represents a string that appears within the PhyName of the LPHD node. It can be up to 80 characters, including upper and lowercase letters, numbers, and the underscore (_) character. The first character in the string must be a letter.

MMS TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 102

This setting specifies the TCP port number for MMS connections.

Server Scanning

Range: Disabled, Enabled

Default: Disabled

Set this option to “Disabled” when IEC 61850 client/server functionality is not required. IEC 61850 has two modes of functionality: GOOSE/GSSE inter-device communication and client/server communication. If the GOOSE/GSSE functionality is required without the IEC 61850 client server feature, then server scanning can be disabled to increase CPU resources. When server scanning is disabled, there is no update to the IEC 61850 logical node status values in the D90^{Plus}. Clients are still able to connect to the server (D90^{Plus} device), but most data values are not updated.

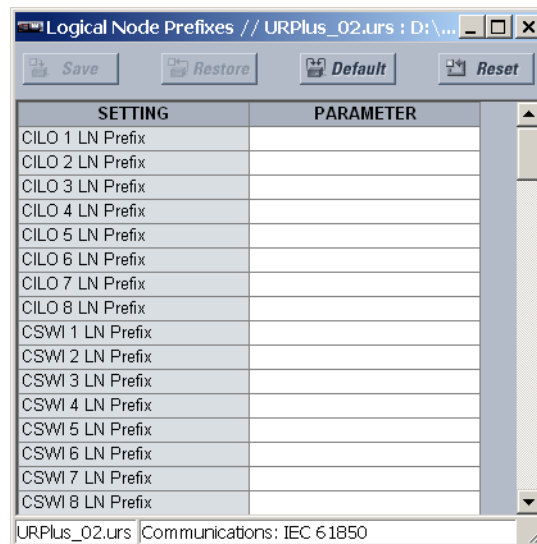
Logical node prefixes

The IEC 61850 logical node name prefix settings are used to create name prefixes to uniquely identify each logical node. For example, the logical node “PTOC1” can have the name prefix “abc”. The full logical node name is then “abcMMXU1”. Valid characters for the logical node name prefixes are upper and lowercase letters, numbers, and the underscore (_) character. The first character in the prefix must be a letter. This conforms to the IEC 61850 standard.

Additional details regarding the logical node naming rules are provided in IEC 61850 standard parts 6 and 7-2. GE Grid Solutions recommends that a consistent naming convention be used for an entire substation project.

Select the **Settings > Communications > IEC 61850 > Logical Node Prefixes** menu item to open the IEC 61850 logical node prefixes configuration window.

Figure 105: IEC 61850 logical node prefix configuration settings



The following IEC 61850 logical node name prefix settings are available for the D90^{Plus}.

CILO1 LN Prefix through CILO8 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the interlocking logical nodes 1 through 8.

CSWI1 LN Prefix through CSWI8 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the switch controller logical nodes 1 through 8.

GGIO1 LN Prefix through GGIO5 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for generic input and output logical nodes 1 through 5.

LPHD1 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the physical device information logical nodes.

MMXU1 LN Prefix through MMXU4 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for measured quantity logical nodes 1 through 4.

PIOC1 LN Prefix through PIOC14 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for instantaneous overcurrent logical nodes 1 through 14.

PDIS1 LN Prefix through PDIS10 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for distance protection logical nodes 1 through 10.

PTOC1 LN Prefix through PTOC18 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for time overcurrent logical nodes 1 through 18.

PTOV1 LN Prefix through PTOV8 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for overvoltage logical nodes 1 through 8.

PTRC1 LN Prefix through PTRC2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for the protection trip conditioning 1 through 2 logical nodes.

PTUV1 LN Prefix through PTUV4 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for undervoltage logical nodes 1 through 4.

RBRF1 LN Prefix, RBRF2 LN Prefix

Range: six character ASCII string

Default: empty

These settings specify the prefixes for breaker failure logical nodes 1 and 2.

RDIR1 LN Prefix, RDIR2 LN Prefix*Range: six character ASCII string**Default: empty*

These settings specify the prefixes for the directional element logical nodes 1 and 2.

RFLO1 LN Prefix*Range: six character ASCII string**Default: empty*

This setting specifies the prefix for the fault locator logical node.

RPSB1 LN Prefix*Range: six character ASCII string**Default: empty*

This setting specifies the prefix for the power swing detection logical node.

RREC1 LN Prefix*Range: six character ASCII string**Default: empty*

This setting specifies the prefix for the autoreclose logical node.

RSYN1 LN Prefix, RSYN2 LN Prefix*Range: six character ASCII string**Default: empty*

These settings specify the prefixes for the synchrocheck logical nodes 1 and 2.

XCBR1 LN Prefix through XCBR2 LN Prefix*Range: six character ASCII string**Default: empty*

These settings specify the prefixes for the circuit breaker 1 through 2 logical nodes.

XSWI1 LN Prefix through XSWI6 LN Prefix*Range: six character ASCII string**Default: empty*

These settings specify the prefixes for the circuit disconnect switch 1 through 6 logical nodes.

ZLIN1 LN Prefix to ZLIN 4 LN Prefix*Range: six character ASCII string**Default: empty*

These settings specify the prefixes for the transmission line data logical nodes 1 through 4.

MMXU deadbands

A deadband is a range in which no action occurs, expressed as a percentage.

The MMXU deadband settings represent the deadband values used to determine when the update the MMXU “mag” and “cVal” values from the associated “instmag” and “instcVal” values. The “mag” and “cVal” values are used for the IEC 61850 buffered and unbuffered reports. These settings correspond to the associated “db” data items in the CF functional constraint of the MMXU logical node, as per the IEC 61850 standard. According to IEC 61850-7-3, the db value “shall represent the percentage of difference between the maximum and minimum in units of 0.00%.” Thus, it is important to know the maximum value for each MMXU measured quantity, since this represents the 100.00% value for the deadband.

Select the **Settings > Communications > IEC 61850 > MMXU Deadbands** menu to open the MMXU deadbands configuration window.

Figure 106: IEC 61850 MMXU deadband configuration settings

PARAMETER	MMXU1	MMXU2	MMXU3
TotW Deadband	10.000 %	10.000 %	10.000 %
TotVAr Deadband	10.000 %	10.000 %	10.000 %
TotVA Deadband	10.000 %	10.000 %	10.000 %
TotPF Deadband	10.000 %	10.000 %	10.000 %
Hz Deadband	10.000 %	10.000 %	10.000 %
PPV phsAB Deadband	10.000 %	10.000 %	10.000 %
PPV phsBC Deadband	10.000 %	10.000 %	10.000 %
PPV phsCA Deadband	10.000 %	10.000 %	10.000 %
PhV phsA Deadband	10.000 %	10.000 %	10.000 %
PhV phsB Deadband	10.000 %	10.000 %	10.000 %
PhV phsC Deadband	10.000 %	10.000 %	10.000 %
A phsA Deadband	10.000 %	10.000 %	10.000 %
A phsB Deadband	10.000 %	10.000 %	10.000 %
A phsC Deadband	10.000 %	10.000 %	10.000 %
A neut Deadband	10.000 %	10.000 %	10.000 %
W phsA Deadband	10.000 %	10.000 %	10.000 %
W phsB Deadband	10.000 %	10.000 %	10.000 %
W phsC Deadband	10.000 %	10.000 %	10.000 %

The following settings are available for each of the four MMXU nodes.

Total Watt Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

This setting specifies the real power deadband value. The maximum value representing 100% of deadband is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times \text{VT ratio}$.

Total Var Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

This setting specifies the reactive power deadband value. The maximum value representing 100% of deadband is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times \text{VT ratio}$.

Total VA Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

This setting specifies the apparent power deadband value. The 100% deadband value is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times \text{VT ratio}$.

Total Power Factor Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

This setting specifies the power factor deadband value. The 100% deadband value is 2.

Hz Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

This setting specifies the frequency deadband value. The 100% deadband value is 90 Hz.

PPV Phase AB Deadband, PPV Phase BC Deadband, PPV Phase CA Deadband

Range: 0.001 to 100.000% in steps of 0.001

Default: 10.000%

These settings specify the V_{ab} , V_{bc} , and V_{ca} per-phase voltage deadband values. The 100% deadband value is $275 \times \text{VT ratio}$.

PhV Phase A Deadband, PhV Phase B Deadband, PhV Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the Va, Vb, and Vc phase voltage deadband values. The 100% deadband value is $275 \times VT$ ratio.

Current Phase A Deadband, Current Phase B Deadband, Current Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the Ia, Ib, and Ic phase current deadband values. The 100% deadband value is $46 \times \text{phase CT secondary} \times \text{phase CT ratio}$.

Current Neutral Deadband*Range: 0.001 to 100.00% in steps of 0.001**Default: 10.000%*

This setting specifies the neutral current deadband value. The 100% deadband value is $46 \times \text{ground CT secondary} \times \text{ground CT ratio}$.

Watt Phase A Deadband, Watt Phase B Deadband, Watt Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the real per-phase power deadband values. The maximum value representing 100% of deadband is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times VT$ ratio.

Var Phase A Deadband, Var Phase B Deadband, Var Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the reactive per-phase power deadband values. The maximum value representing 100% of deadband is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times VT$ ratio.

VA Phase A Deadband, VA Phase B Deadband, VA Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the apparent per-phase power deadband values. The maximum value representing 100% of deadband is $46 \times \text{phase CT secondary} \times \text{phase CT ratio} \times 275 \times VT$ ratio.

Power Factor Phase A Deadband, Power Factor Phase B Deadband, Power Factor Phase C Deadband*Range: 0.001 to 100.000% in steps of 0.001**Default: 10.000%*

These settings specify the per-phase power factor deadband values. The maximum value representing 100% of deadband is 2.

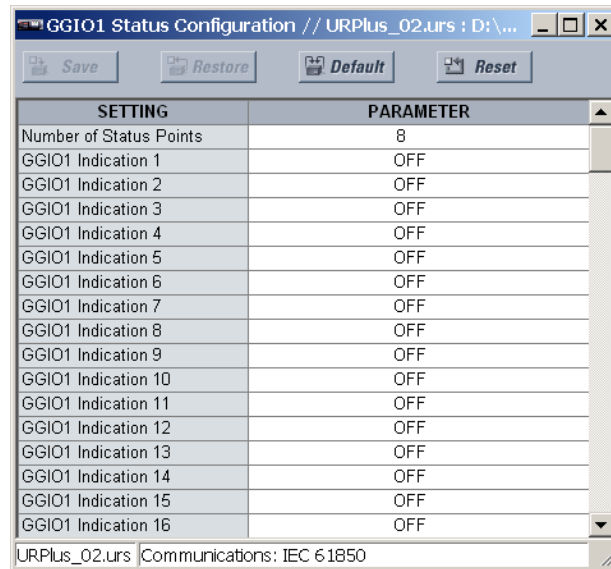
GGIO1 status configuration

The GGIO1 logical node provides access to as many as 128 digital status points and associated timestamps and quality flags. Clients use GGIO1 to access digital status values from the D90^{PLUS}. Configuration settings are provided to select the number of digital status indications available in GGIO1 (8 to 128) and select logic operands to drive the status of the GGIO1 status indications. Clients can utilize the IEC 61850 buffered and unbuffered reporting features available from GGIO1 to build sequence of events (SOE) logs and HMI

display screens. Buffered reporting should generally be used for SOE logs since the buffering capability reduces the chances of missing data state changes. Use unbuffered reporting for local status display.

Select the **Settings > Communications > IEC 61850 > GGIO1 Status Configuration** menu to open the GGIO1 status configuration window.

Figure 107: IEC 61850 GGIO1 status configuration



The following settings are available.

Number of Status Points

Range: 8 to 128 in steps of 8

Default: 8

This setting specifies the number of “Ind” points (single point status indications) instantiated in the GGIO1 logical node. Changes to this setting take effect when the D90^{Plus} is restarted.

GGIO1 Indication 1, GGIO1 Indication 2, ..., GGIO1 Indication 128

Range: any logic operand

Default: OFF

These settings assign logic operands to represent GGIO1 status indications.

GGIO2 control configuration

The GGIO2 logical node provides access to the D90^{Plus} protection virtual inputs. Protection virtual inputs are single-point control (binary) values that can be written by clients. They are generally used as control inputs. GGIO2 provides access to protection virtual inputs through the following IEC 61850 standard control model (ctlModel) services:

- Status only
- Direct control with normal security
- SBO control with normal security

Settings are used to select the control model for each point. Enable each protection virtual input used through GGIO2, and program the corresponding SPSCO ctlModel setting to the appropriate control configuration.

Select the **Settings > Communications > IEC 61850 > GGIO2 Control Configuration** menu to open the GGIO2 control configuration window.

Figure 108: IEC 61850 GGIO2 control configuration

SETTING	PARAMETER
SPCSO 1 ctlModel	1
SPCSO 2 ctlModel	1
SPCSO 3 ctlModel	1
SPCSO 4 ctlModel	1
SPCSO 5 ctlModel	1
SPCSO 6 ctlModel	1
SPCSO 7 ctlModel	1
SPCSO 8 ctlModel	1
SPCSO 9 ctlModel	1
SPCSO 10 ctlModel	1
SPCSO 11 ctlModel	1
SPCSO 12 ctlModel	1
SPCSO 13 ctlModel	1
SPCSO 14 ctlModel	1
SPCSO 15 ctlModel	1
SPCSO 16 ctlModel	1

The following setting is available for each of the 64 GGIO2 control points. Each control point is mapped to a corresponding D90^{Plus} protection virtual input. For example, GGIO2 control point SPCSO 3 is mapped to protection virtual input 3.

SPCSO 1 ctlModel

Range: 0, 1, 2

Default: 1

The GGIO2 control configuration settings are used to set the control model for each input. The available choices are “0” (status only), “1” (direct control), and “2” (SBO with normal security).

GGIO4 analog configuration

The GGIO4 logical node provides access to as many as 32 analog value points, as well as associated timestamps and quality flags. The data content must be configured before the data can be used. GGIO4 provides analog values for access by clients.

It is intended that clients use GGIO4 to access generic analog values from the D90^{Plus}. Settings are used to select the number of analog values available in GGIO4 (4 to 32) as well as FlexAnalog values that determine the value of the GGIO4 analog inputs. Clients can utilize polling or the IEC 61850 unbuffered reporting feature available from GGIO4 to obtain the analog values provided by GGIO4.

Select the **Settings > Communications > IEC 61850 > GGIO4 Analog Configuration** menu item to open the GGIO4 analog configuration window.

Figure 109: IEC 61850 GGIO4 analog configuration

SETTING	PARAMETER
IEC61850 GGIO4 Analogs	4
IEC61850 GGIO4 Analog 1 Value	OFF
IEC61850 GGIO4 Analog 1 db	100.000 %
IEC61850 GGIO4 Analog 1 min	0.000
IEC61850 GGIO4 Analog 1 max	1000000.000
IEC61850 GGIO4 Analog 2 Value	OFF
IEC61850 GGIO4 Analog 2 db	100.000 %
IEC61850 GGIO4 Analog 2 min	0.000
IEC61850 GGIO4 Analog 2 max	1000000.000
IEC61850 GGIO4 Analog 3 Value	OFF
IEC61850 GGIO4 Analog 3 db	100.000 %
IEC61850 GGIO4 Analog 3 min	0.000
IEC61850 GGIO4 Analog 3 max	1000000.000

The following settings are available.

IEC 61850 GGIO4 Analogs

Range: 4 to 32 in steps of 4

Default: 4

This setting specifies how many analog data points exist in GGIO4. When this value is changed, the D90^{Plus} must be restarted to allow the GGIO4 logical node to be re-instantiated and contain the newly configured number of analog points.

IEC 61850 GGIO4 Analog 1 Value

Range: any FlexAnalog value

Default: OFF

These settings select the FlexAnalog value to drive the instantaneous value of each GGIO4 analog status value (GGIO4.MX.AnIn1.instMag.f).

IEC 61850 GGIO4 Analog 1 Deadband

Range: 0.000 to 100.000 in steps of 0.001

Default: 0.000

These settings specify the deadband for each analog value. See IEC 61850-7-1 and IEC 61850-7-3 for details. The deadband is used to determine when to update the deadbanded magnitude from the instantaneous magnitude and is represented as a percentage of the difference between the maximum and minimum values.

IEC 61850 GGIO4 Analog 1 Minimum

Range: -1000000000.000 to 1000000000.000 in steps of 0.001

Default: 0.000

These settings specify the minimum value for each analog value. See IEC 61850-7-1 and IEC 61850-7-3 for details. This minimum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.

These settings are stored as IEEE 754 / IEC 60559 floating point numbers. Because of the large range of these settings, not all values can be stored. Some values are rounded to the closest possible floating point number.

IEC 61850 GGIO4 Analog 1 Maximum

Range: -1000000000.000 to 1000000000.000 in steps of 0.001

Default: 0.000

These settings specify the maximum value for each analog value. See IEC 61850-7-1 and IEC 61850-7-3 for details. This maximum value is used to determine the deadband. The deadband is used in the determination of the deadbanded magnitude from the instantaneous magnitude.

These settings are stored as IEEE 754 / IEC 60559 floating point numbers. Because of the large range of these settings, not all values can be stored. Some values are rounded to the closest possible floating point number.

GGIO5 control configuration

The GGIO5 logical node is available to provide access to the D90^{PLUS} automation virtual inputs. Automation virtual inputs are single-point control (binary) values that can be written by clients. They are generally used as control inputs. GGIO5 provides access to automation virtual inputs through the following IEC 61850 standard control model (ctlModel) services:

- Status only
- Direct control with normal security
- SBO control with normal security

Settings are used to select the control model for each point. Enable each automation virtual input used through GGIO5, and program the corresponding SPCSO ctlModel setting to the appropriate control configuration.

Select the **Settings > Communications > IEC 61850 > GGIO5 Control Configuration** menu to open the GGIO5 control configuration window.

Figure 110: IEC 61850 GGIO5 control configuration

The screenshot shows a software window titled "GGIO5 Control Configuration // URplus06.urs : D:\Doc...". It contains a table with two columns: "SETTING" and "PARAMETER". The table lists 19 rows, each representing an SPCSO point (SPCSO 1 to SPCSO 19) and its corresponding ctlModel setting, which is consistently set to 1. The window also features buttons for "Save", "Restore", "Default", and "Reset".

SETTING	PARAMETER
SPCSO 1 ctlModel	1
SPCSO 2 ctlModel	1
SPCSO 3 ctlModel	1
SPCSO 4 ctlModel	1
SPCSO 5 ctlModel	1
SPCSO 6 ctlModel	1
SPCSO 7 ctlModel	1
SPCSO 8 ctlModel	1
SPCSO 9 ctlModel	1
SPCSO 10 ctlModel	1
SPCSO 11 ctlModel	1
SPCSO 12 ctlModel	1
SPCSO 13 ctlModel	1
SPCSO 14 ctlModel	1
SPCSO 15 ctlModel	1
SPCSO 16 ctlModel	1
SPCSO 17 ctlModel	1
SPCSO 18 ctlModel	1
SPCSO 19 ctlModel	1

URplus06.urs | Communications: IEC 61850

The following setting is available for each of the 128 GGIO5 control points. Each control point is mapped to a corresponding D90^{PLUS} automation virtual input. For example, GGIO5 control point SPCSO 3 is mapped to automation virtual input 3.

SPCSO 1 ctlModel

Range: 0, 1, 2

Default: 1

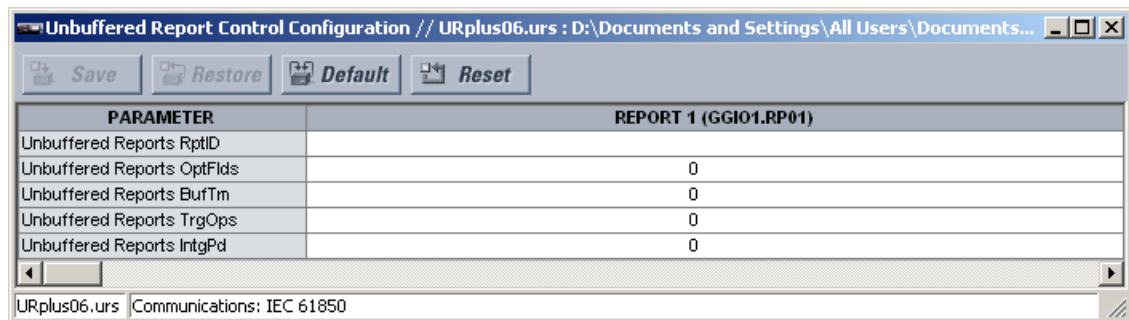
The GGIO5 control configuration settings are used to set the control model for each input. The available choices are “0” (status only), “1” (direct control), and “2” (SBO with normal security).

Unbuffered report control configuration

IEC 61850 unbuffered reporting is provided in the GGIO1 logical nodes (for binary status values), GGIO4 logical nodes (for analog value points), and MMXU1 to MMXU4 (for analog measured values). Report settings can be configured using the EnerVista UR^{Plus} Setup software, substation configurator software, or via an IEC 61850 client.

Select the **Settings > Communications > IEC 61850 > Unbuffered Report Control Configuration** menu to open the IEC 61850 unbuffered report configuration window.

Figure 111: IEC 61850 unbuffered report control configuration



The following settings are available for each unbuffered report. Up to 18 unbuffered reports can be configured. Changes to the report configuration take effect when the D90^{Plus} is restarted.

Disconnect any IEC 61850 client connection to the D90^{Plus} prior to making setting changes to the unbuffered report configuration. Disconnecting the rear Ethernet connection from the D90^{Plus} disconnects the IEC 61850 client connection.

Unbuffered Reports RptID

Range: up to 65 alphanumeric characters

Default: empty

This setting specifies the name for the IEC 61850 unbuffered report.

Unbuffered Reports OptFlds

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the option fields. The following bits are supported by the D90^{Plus}:

- Bit 1 – Sequence-number
- Bit 2 – Report-time-stamp
- Bit 3 – Reason-for-inclusion
- Bit 4 – Data-set-name
- Bit 5 – Data-reference
- Bit 6 – Not supported for unbuffered reports
- Bit 7 – Not supported for unbuffered reports
- Bit 8 – Conf-revision

Unbuffered Reports BufTm

Range: 0 to 4294967295 in steps of 1

Default: 0

This setting specifies the buffer time.

Unbuffered Reports TrgOps

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the trigger options. The following bits are supported by the D90^{PLUS}:

- Bit 1 – Data-change
- Bit 4 – Integrity
- Bit 5 – General interrogation

Unbuffered Reports IntgPd

Range: 0, or 250 to 4294967295 in steps of 1

Default: 0

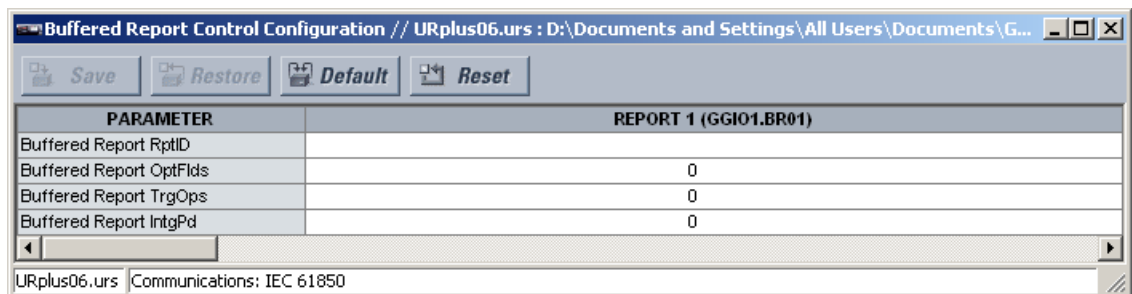
This setting specifies the integrity period for unbuffered reports.

Buffered report control configuration

IEC 61850 buffered reporting is provided in the GGIO1 logical nodes (for binary status values) and MMXU1 to MMXU4 (for analog measured values). Report settings are configured using the EnerVista UR^{PLUS} Setup software, substation configurator software, or via an IEC 61850 client.

Select the **Settings > Communications > IEC 61850 > Buffered Report Control Configuration** menu to open the IEC 61850 buffered report configuration window.

Figure 112: IEC 61850 buffered report control configuration



The following settings are available for each buffered report. Up to six buffered reports can be configured. Changes to the report configuration take effect when the D90^{PLUS} is restarted.

Disconnect any IEC 61850 client connection to the D90^{PLUS} prior to making setting changes to the buffered report configuration. Disconnecting the rear Ethernet connection from the D90^{PLUS} disconnects the IEC 61850 client connection.

Buffered Reports RptID

Range: up to 65 alphanumeric characters

Default: empty

This setting specifies the name for the IEC 61850 buffered report.

Buffered Reports OptFlds

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the option fields. The following bits are supported by the D90^{PLUS}:

- Bit 1 – Sequence-number
- Bit 2 – Report-time-stamp
- Bit 3 – Reason-for-inclusion
- Bit 4 – Data-set-name
- Bit 5 – Data-reference
- Bit 6 – Buffer-overflow
- Bit 7 – EntryID
- Bit 8 – Conf-revision

Buffered Reports TrgOps

Range: 0 to 65535 in steps of 1

Default: 0

This setting specifies a bitmask that selects the trigger options. The following bits are supported by the D90^{PLUS}:

- Bit 1 – Data-change
- Bit 4 – Integrity
- Bit 5 – General interrogation

Buffered Reports IntgPd

Range: 0, or 250 to 4294967295 in steps of 1

Default: 0

This setting specifies the integrity period for buffered reports.

IEC 61850 actual values

Actual values for IEC 61850 are available in two locations. A general IEC 61850 communications actual value is available through the **Actual Values > Communications > Communication** menu. The IEC 61850 GOOSE input and output actual values are available through the **Actual Values > Communications > Inputs/Outputs** menu.

Remote device status

Select the **Actual Values > Communications > Inputs/Outputs > Remote Devices Status** menu to open the remote device status values window.

Figure 113: Remote device status values

The screenshot shows a software window titled "Remote Devices Status // Station 1: IED 2: Actual Values: Communications: Inputs/Outputs". The window contains a table with three columns: REMOTE DEVICE, INAME, and STATUS. The table lists 8 remote devices, all of which are currently "Offline". There are also buttons for Save, Restore, Default, and Reset at the top of the window.

REMOTE DEVICE	INAME	STATUS
All Remote Devices Online	No	No
Remote Device 1	Remote Device 1	Offline
Remote Device 2	Remote Device 2	Offline
Remote Device 3	Remote Device 3	Offline
Remote Device 4	Remote Device 4	Offline
Remote Device 5	Remote Device 5	Offline
Remote Device 6	Remote Device 6	Offline
Remote Device 7	Remote Device 7	Offline
Remote Device 8	Remote Device 8	Offline

IED 2 | Actual Values: Communications: Inputs/Outputs

The following actual values are available for the IEC 61850 remote devices. The name and status are available for each remote device.

All Remote Devices Online

Range: Yes, No

This value indicates whether or not all programmed remote devices are online. If the corresponding state is "No," then at least one required remote device is offline.

Name

Range: up to 65 alphanumeric characters

This value displays the name programmed for the corresponding remote device.

Status

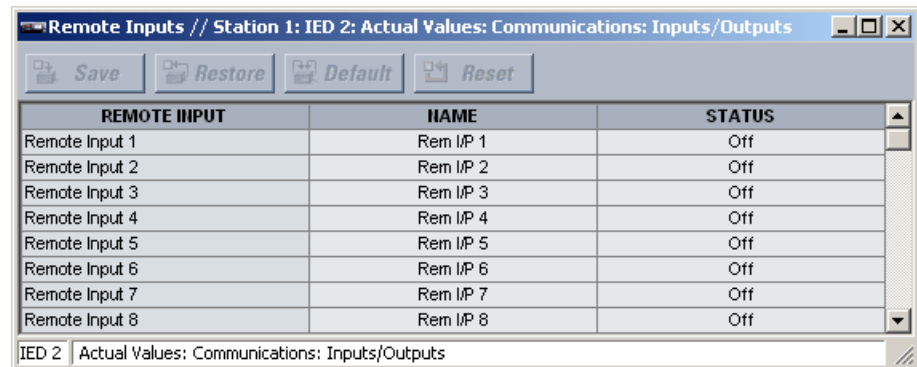
Range: Online, Offline

This value indicates the present state of the corresponding remote device.

Remote input actual values

Select the **Actual Values > Communications > Inputs/Outputs > Remote Inputs** menu to open the remote input actual values window.

Figure 114: Remote input actual values



The screenshot shows a window titled "Remote Inputs // Station 1: IED 2: Actual Values: Communications: Inputs/Outputs". The window contains a table with three columns: REMOTE INPUT, NAME, and STATUS. The table lists eight remote inputs, all with a status of "Off".

REMOTE INPUT	NAME	STATUS
Remote Input 1	Rem I/P 1	Off
Remote Input 2	Rem I/P 2	Off
Remote Input 3	Rem I/P 3	Off
Remote Input 4	Rem I/P 4	Off
Remote Input 5	Rem I/P 5	Off
Remote Input 6	Rem I/P 6	Off
Remote Input 7	Rem I/P 7	Off
Remote Input 8	Rem I/P 8	Off

The following actual values are available for each remote input.

Name

Range: up to 12 alphanumeric characters

This value displays the name programmed for the corresponding remote input.

Status

Range: On, Off

This value indicates the present state of the corresponding remote input. The state displayed is that of the remote point unless the remote device has been established to be "Offline," in which case the value shown is the programmed default state for the remote input.

Remote double-point status input actual values

Select the **Actual Values > Communications > Inputs/Outputs > Remote DPS Inputs** menu to open the remote double-point status input actual values window.

Figure 115: Remote double-point status input actual values

REMOTE DPS INPUT	NAME	STATUS
Remote DPS Input 1	RemDPS Ip 1	BAD
Remote DPS Input 2	RemDPS Ip 2	BAD
Remote DPS Input 3	RemDPS Ip 3	BAD
Remote DPS Input 4	RemDPS Ip 4	BAD
Remote DPS Input 5	RemDPS Ip 5	BAD
Remote DPS Input 6	RemDPS Ip 6	BAD
Remote DPS Input 7	RemDPS Ip 7	BAD
Remote DPS Input 8	RemDPS Ip 8	BAD

The following actual values are available for each remote double-point status input.

Name

Range: up to 12 alphanumeric characters

This value displays the name programmed for the corresponding remote double-point status input.

Status

Range: On, Off, Intermediate, Bad

This value indicates if the corresponding remote double-point status input is in the on (close), off (open), intermediate, or bad state.

Remote device statistics

Select the **Actual Values > Communications > Inputs/Outputs > Remote Devices Statistics** menu to open the remote devices statistics window.

Figure 116: Remote device statistics

REMOTE DEVICE	NAME	STNUM	SQNUM
Remote Device 1	Remote Device 1	---	---
Remote Device 2	Remote Device 2	---	---
Remote Device 3	Remote Device 3	---	---
Remote Device 4	Remote Device 4	---	---
Remote Device 5	Remote Device 5	---	---
Remote Device 6	Remote Device 6	---	---
Remote Device 7	Remote Device 7	---	---
Remote Device 8	Remote Device 8	---	---

The following statistics are available for each remote device.

Name

Range: up to 65 alphanumeric characters

This value displays the name programmed for the corresponding remote device.

StNum

Range: 0 to 4294967295 in steps of 1

This value is obtained from the indicated remote device and is incremented whenever a change of state of at least one DNA or UserSt bit occurs.

SqNum

Range: 0 to 4294967295 in steps of 1

This value is obtained from the indicated remote device and increments whenever a GSSE message is sent. This number rolls over to zero when a count of 4294967295 is incremented.

IEC 61850 GOOSE analog input actual values

Select the **Actual Values > Communications > Inputs/Outputs > IEC61850 GOOSE Analog Inputs** menu to open the IEC 61850 GOOSE analog input actual values window.

Figure 117: IEC 61850 GOOSE analog input actual values

PARAMETER	VALUE
IEC61850 GOOSE Analog Input 1 Actual	0.000
IEC61850 GOOSE Analog Input 2 Actual	0.000
IEC61850 GOOSE Analog Input 3 Actual	0.000
IEC61850 GOOSE Analog Input 4 Actual	0.000
IEC61850 GOOSE Analog Input 5 Actual	0.000
IEC61850 GOOSE Analog Input 6 Actual	0.000
IEC61850 GOOSE Analog Input 7 Actual	0.000
IEC61850 GOOSE Analog Input 8 Actual	0.000
IEC61850 GOOSE Analog Input 9 Actual	0.000
IEC61850 GOOSE Analog Input 10 Actual	0.000
IEC61850 GOOSE Analog Input 11 Actual	0.000
IEC61850 GOOSE Analog Input 12 Actual	0.000
IEC61850 GOOSE Analog Input 13 Actual	0.000
IEC61850 GOOSE Analog Input 14 Actual	0.000
IEC61850 GOOSE Analog Input 15 Actual	0.000
IEC61850 GOOSE Analog Input 16 Actual	0.000

IEC 2 | Actual Values: Communications: Inputs/Outputs

The following actual value is available for each IEC 61850 GOOSE analog input.

IEC 61850 GOOSE Analog Input 1 Actual

Range: Yes, No

This value displays the IEC 61850 GGI03 analog input data point 1. The GGI03 analog data values are received via IEC 61850 GOOSE messages sent from other devices.

FlexStates

The FlexStates feature provides a mechanism where any of 256 selected FlexLogic operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic operand states in the D90^{PLUS}. The state bits are packed so that 16 states can be read in a single Modbus register. The state bits can be configured so that all of the states of interest are available in a minimum number of Modbus registers.

The state bits can be read in the FlexStates register array beginning at Modbus address 0900h. Sixteen states are packed into each register, with the lowest-numbered state in the lowest-order bit. There are 16 registers in total to accommodate the 256 state bits.

FlexState settings

Select the **Settings > Communications > FlexStates** menu to open the FlexStates configuration window.

Figure 118: FlexStates configuration settings

SETTING	PARAMETER
Parameter 1	OFF
Parameter 2	OFF
Parameter 3	OFF
Parameter 4	OFF
Parameter 5	OFF
Parameter 6	OFF
Parameter 7	OFF
Parameter 8	OFF
Parameter 9	OFF
Parameter 10	OFF
Parameter 11	OFF
Parameter 12	OFF
Parameter 13	OFF
Parameter 14	OFF
Parameter 15	OFF
Parameter 16	OFF

The following settings are available.

Parameter 1 through Parameter 256

Range: any FlexLogic operand

Default: Off

These settings assign FlexLogic parameters to each of the 256 FlexStates. The FlexState register array begins at Modbus address 0900h.

FlexState actual values

Select the **Actual Values > Communications > FlexStates** menu to open the FlexStates actual values window.

Figure 119: FlexStates actual values

PARAMETER	NAME	VALUE
Parameter 1	OFF	Off
Parameter 2	OFF	Off
Parameter 3	OFF	Off
Parameter 4	OFF	Off
Parameter 5	OFF	Off
Parameter 6	OFF	Off
Parameter 7	OFF	Off
Parameter 8	OFF	Off
Parameter 9	OFF	Off
Parameter 10	OFF	Off
Parameter 11	OFF	Off
Parameter 12	OFF	Off
Parameter 13	OFF	Off
Parameter 14	OFF	Off
Parameter 15	OFF	Off
Parameter 16	OFF	Off

The following actual values are available for each FlexState parameter.

Name

Range: any FlexLogic operand

This actual value indicates the FlexLogic operand assigned to the FlexState parameter.

Value

Range: OFF, ON

This actual value indicates the logic state (ON, OFF) of the FlexState parameter.

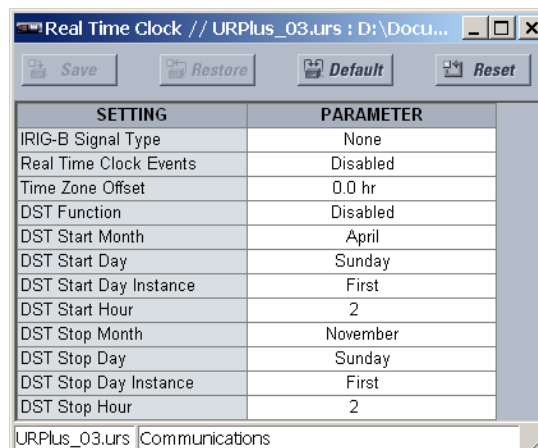
Real-time clock

The date and time can be synchronized to a known time base and to other devices using an IRIG-B signal. If an IEEE 1344 compliant IRIG-B generator is connected to the D90^{PLUS}, then no additional information is required. Otherwise, only the current year needs to be entered. To instead set manually the relay clock, use the **Actual Values > Communications > Commands > Set Date and Time** command.

The daylight savings time (DST) settings can be used to have the D90^{PLUS} clock follow the DST rules of the local time zone. When IRIG-B time synchronization is active, the DST settings are ignored. The DST settings are used when the D90^{PLUS} is synchronized with SNTP, or when neither SNTP nor IRIG-B is used.

Select the **Settings > Communications > Real Time Clock** menu to open the real-time clock configuration window.

Figure 120: Real-time clock configuration settings



SETTING	PARAMETER
IRIG-B Signal Type	None
Real Time Clock Events	Disabled
Time Zone Offset	0.0 hr
DST Function	Disabled
DST Start Month	April
DST Start Day	Sunday
DST Start Day Instance	First
DST Start Hour	2
DST Stop Month	November
DST Stop Day	Sunday
DST Stop Day Instance	First
DST Stop Hour	2

The following settings are available to configure the clock.

IRIG-B Signal Type

Range: None, DC Shift, Amplitude Modulated

Default: None

This setting selects the type of IRIG-B signal. Select “None” to disable IRIG-B.

Real Time Clock Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of real-time clock events in the sequence of events recorder.

Time Zone Offset

Range: -24.0 to 24.0 hours in steps of 0.5

Default: 0.0 hours

This setting specifies the local time zone offset from Greenwich Mean Time (GMT) in hours. This setting has two uses. When the D90^{PLUS} is time synchronized with IRIG-B, or has no permanent time synchronization, the offset is used to calculate Universal Coordinated Time (UTC) time for IEC 61850 features. When the D90^{PLUS} is time synchronized with SNTP, the offset is used to determine the local time for the D90^{PLUS} clock, since SNTP provides UTC time.

DST Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the daylight saving time function.

DST Start Month

Range: January through December (all months of the year)

Default: April

This setting specifies the start month for daylight saving time.

DST Start Day

Range: Sunday through Saturday (all days of the week)

Default: Sunday

This setting specifies the day of the week to start daylight saving time.

DST Start Day Instance

Range: First, Second, Third, Fourth, Last

Default: First

This setting specifies which instance of the day of the week to start daylight saving time. For example, if daylight saving time begins on the second Monday in April, program this setting to "Second."

DST Start Hour

Range: 0 to 23 in steps of 1

Default: 2

This setting specifies the hour to start daylight saving time. For example, if daylight saving time begins at 2:00 AM, program this setting to "2."

DST Stop Month

Range: January through December (all months of the year)

Default: November

This setting specifies the stop month for daylight saving time.

DST Stop Day

Range: Sunday through Saturday (all days of the week)

Default: Sunday

This setting specifies the day of the week to stop daylight saving time.

DST Stop Day Instance

Range: First, Second, Third, Fourth, Last

Default: First

This setting specifies which instance of the day of the week to stop daylight saving time. For example, if daylight saving time ends on the fourth Monday in November, program this setting to "Fourth."

DST Stop Hour

Range: 0 to 23 in steps of 1

Default: 2

This setting specifies the hour at which daylight saving time ends. For example, if daylight saving time ends at 4:00 AM, program this setting to “4.”

User-programmable self-tests

All major self-test alarms are reported automatically with their corresponding FlexLogic operands. And most of the minor alarms can be disabled.

Select the **Settings > Communications > User-Programmable Self-Tests** menu to open the user-programmable self-test configuration window.

Figure 121: User-programmable self-test configuration settings

SETTING	PARAMETER
Ethernet Port 1 Fail Function	Disabled
Ethernet Port 2 Fail Function	Disabled
Ethernet Port 3 Fail Function	Disabled
SNTP Fail Function	Enabled
IRIG B Fail Function	Enabled
Ch 1 Direct Ring Break Function	Enabled
Ch 2 Direct Ring Break Function	Enabled
Ch 1 Direct Device Off Function	Enabled
Ch 2 Direct Device Off Function	Enabled

The following settings are available to configure the self-tests.

Ethernet Port 1 Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is “Disabled,” the ETHERNET PORT 1 FAILURE alarm does not assert a FlexLogic operand or write to the event recorder. Moreover, it does not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is “Enabled,” the ETHERNET PORT 1 FAILURE alarm continues to function along with other major and minor alarms. See the Self-Tests section in the Testing chapter for information on alarms.

Ethernet Port 2 Fail Function

Range: Enabled, Disabled

Default: Disabled

When this setting is “Disabled,” the ETHERNET PORT 2 FAILURE alarm does not assert a FlexLogic operand or write to the event recorder. Moreover, it does not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is “Enabled,” the ETHERNET PORT 2 FAILURE alarm continues to function along with other major and minor alarms. See the Self-Tests section in the Testing chapter for information on alarms.

Ethernet Port 3 Fail Function

Range: Enabled, Disabled

Default: Disabled

When this setting is “Disabled,” the ETHERNET PORT 3 FAILURE alarm does not assert a FlexLogic operand or write to the event recorder. Moreover, it does not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is “Enabled,” the ETHERNET PORT 3 FAILURE alarm continues to function along with other major and minor alarms. See the Self-Tests section in the Testing chapter for information on alarms.

SNTP Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is “Disabled,” the SNTP FAILURE alarm does not assert a FlexLogic operand or write to the event recorder. Moreover, it does not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is “Enabled,” the SNTP FAILURE alarm continues to function along with other major and minor alarms. See the Self-Tests section in the Testing chapter for information on alarms.

IRIG-B Fail Function

Range: Enabled, Disabled

Default: Enabled

When this setting is “Disabled,” the IRIG-B FAILURE alarm does not assert a FlexLogic operand or write to the event recorder. Moreover, it does not trigger the ANY MINOR ALARM or ANY SELF-TEST messages. When this setting is “Enabled,” the IRIG-B FAILURE alarm continues to function along with other major and minor alarms. See the Self-Tests section in the Testing chapter for information on alarms.

Ch 1 Direct Ring Break Function

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” the CH1 DIRECT RING BREAK self-test alarm indicates that direct output messages sent from channel 1 of the D90^{PLUS} are not being received back by the device.

Ch 2 Direct Ring Break Function

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” the CH2 DIRECT RING BREAK self-test alarm indicates that direct output messages sent from channel 2 of the D90^{PLUS} are not being received back by the device.

Ch 1 Direct Device Off Function

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” the CH1 DIRECT DEVICE OFF self-test alarm indicates that direct output messages from at least one direct device on channel 1 are not being received.

Ch 2 Direct Device Off Function

Range: Enabled, Disabled

Default: Disabled

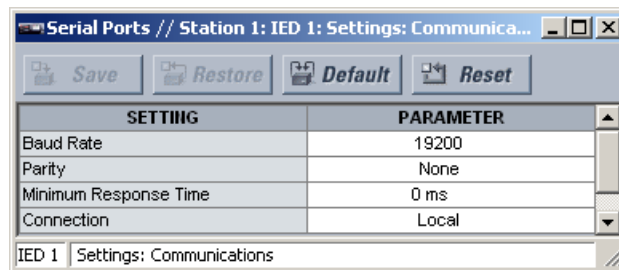
When this setting is “Enabled,” the CH2 DIRECT DEVICE OFF self-test alarm indicates that direct output messages from at least one direct device on channel 2 are not being received.

Serial port

The D90^{Plus} is equipped with one serial RS485 communication port, located on the main processor module in slot D at the back of the unit. The RS485 port has settings for baud rate and parity. It is important that these parameters agree with the settings used on the computer or other equipment that is connected to these ports. This port can be connected to a computer running the EnerVista UR^{Plus} Setup software. This software can download and upload setting files, view measured parameters, and upgrade the device firmware. A maximum of 32 D90^{Plus} devices can be daisy-chained and connected to a DCS, PLC, or computer using the RS485 port.

Select the **Settings > Communications > Serial Ports** menu to open the serial port configuration window.

Figure 122: Serial port configuration settings



The following settings are available to configure the RS485 port.

Baud Rate

Range: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200

Default: 19200

This setting specifies the baud rate (bits per second) for the RS485 port.

Parity

Range: None, Odd, Even

Default: None

This setting specifies the parity for the RS485 port.

Minimum Response Time

Range: 0 to 1000 ms in steps of 10

Default: 0 ms

The minimum time before the port transmits after receiving data from a host can be set. This allows operation with hosts that hold the RS485 transmitter active for some time after each transmission.

Connection

Range: Local, Remote

Default: Local

This setting selects whether the serial RS485 connection is classified as local access or remote access for security purposes.

Direct inputs and outputs

Direct inputs and outputs are available when an inter-relay communications card is installed in the D90^{Plus}. They provide a means of sharing digital point states among a number of UR or UR^{Plus}-series IEDs over a dedicated fiber, RS422, or G.703 interface. No

additional switching equipment is required as the IEDs are connected directly in a ring or redundant (dual) ring configuration. This feature is optimized for speed and intended for pilot-aided schemes, distributed logic applications, or the extension of the input/output capabilities of a single device.

The D90^{Plus} provides 96 direct inputs and 96 direct outputs per communication channel.

Direct inputs and outputs are intended for exchange of status information (inputs and outputs) between UR^{Plus}-series devices connected directly via inter-relay communications cards. The mechanism is very similar to IEC 61850 GSSE, except that communications takes place over a non-switchable isolated network and is optimized for speed. All inter-relay communication cards support two channels, allowing direct output messages to be sent from both channels simultaneously. This effectively sends direct output messages both ways around a ring configuration. Messages are resent (forwarded) when it is determined that the message did not originate at the receiver.

Direct output message timing is similar to GSSE message timing. Integrity messages (with no state changes) are sent at least every 1000 ms at 64 kbps or 500 ms at 128 kbps. Messages with state changes are sent within the main pass scanning the inputs and asserting the outputs unless the communication channel bandwidth has been exceeded. Two self-tests are performed and signaled by the following FlexLogic operands:

- **CH1 DIR IO RING BREAK** and **CH2 DIR IO RING BREAK** — These operands indicate that direct output messages sent from a UR^{Plus}-series device are not being received back by the device.
- **CH1 DIR DEV 1 OFF** to **CH1 DIR DEV 16 OFF** and **CH2 DIR DEV 1 OFF** to **CH2 DIR DEV 16 OFF** — These operands indicate that direct output messages from the corresponding direct device are not being received.

Direct input and output settings are similar to remote input and output settings. The equivalent of the remote device name strings for direct inputs and outputs is the **Direct Device ID**. Delivery time for direct input and output messages is approximately 0.2 of a power system cycle at 128 kbps and 0.4 of a power system cycle at 64 kbps, per each "bridge."



Direct inputs and outputs exchange between UR^{Plus}-series IEDs is supported over the inter-relay communication card's G.703, C37.94, direct fiber, and RS422 interfaces. Direct inputs and outputs exchange with UR-series IEDs is supported on the C37.94, direct fiber, and RS422 interfaces.

Direct input and output configuration

Select the **Settings > Communications > Direct I/O** menu to open the direct inputs and outputs configuration window.

Figure 123: Direct inputs/outputs configuration settings

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Disabled	Disabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	1	

The following setting is available and applicable to both channels in all direct inputs and direct outputs.

Direct Device ID

Range: 1 to 16 in steps of 1

Default: 1

This setting identifies the D90^{Plus} in all direct output messages. Assign a unique number to each UR^{Plus}-series IEDs in a ring. Each ID is used to identify the sender of the direct input/output message.

The following settings are available for each channel and are applicable to all direct inputs and direct outputs.

Ring Configuration

Range: Enabled, Disabled

Default: Disabled

These settings configure the direct input/output scheme to operate in a ring. If set to "Enabled," all direct output messages are received back. If not, the direct input/output ring break self-test is triggered. The self-test error is signaled by the [CH1 DIR IO RING BRK](#) and [CH2 DIR IO RING BRK](#) FlexLogic operands.

CRC Alarm Function

Range: Enabled, Disabled

Default: Disabled

The D90^{Plus} checks integrity of the incoming direct input/output messages using a 32-bit CRC. The CRC alarm function is available for monitoring the communication medium noise by tracking the rate of messages failing the CRC check. The monitoring function counts all incoming messages, including messages that failed the CRC check. A separate counter adds up messages that failed the CRC check.

The CRC check can fail if one or more bits in a packet are corrupted. Therefore, an exact correlation between the CRC fail rate and the bit error rate (BER) is not possible. Under certain assumptions an approximation can be made as follows. A direct input/output packet containing 20 bytes results in 160 bits of data being sent and therefore, a transmission of 63 packets is equivalent to 10000 bits. A BER of 10^{-4} implies 1 bit error for every 10000 bits sent/received. Assuming the best case of only 1 bit error in a failed packet, having one failed packet for every 63 received is about equal to a BER of 10^{-4} .

The CRC alarm function is available on a per-channel basis. The total number of direct input/output messages that failed the CRC check is available as an actual value.

CRC Alarm Count*Range: 100 to 10000 in steps of 1**Default: 600*

When the total message counter reaches the user-defined maximum specified by this setting, both the counters reset and the monitoring process is restarted.

To monitor communications integrity, the D90^{PLUS} sends one message per second (at 64 kbps) or two messages per second (128 kbps) even if there is no change in the direct outputs. For example, setting the **CRC Alarm Count** to “10000” corresponds to a time window of about 160 minutes at 64 kbps and 80 minutes at 128 kbps. If the messages are sent faster as a result of direct outputs activity, the monitoring time interval shortens. Take this into account when determining this setting. For example, if the requirement is a maximum monitoring time interval of 10 minutes at 64 kbps, then the setting is $10 \times 60 \times 1 = 600$.

CRC Alarm Threshold*Range: 1 to 1000 in steps of 1**Default: 10*

When the failed CRC counter reaches the user-defined level specified by this setting within the user-defined message count specified by **CRC Alarm Count**, the **DIR IO CH1 CRC ALARM** or **DIR IO CH2 CRC ALARM** FlexLogic operand is set. The operand can be configured to drive an output contact, annunciator alarm, or selected communication-based output. Program latching and acknowledging conditions, if required, accordingly in the annunciator settings.

CRC Alarm Events*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables the logging of CRC alarm events in the sequence of events recorder.

Message Alarm Function*Range: Enabled, Disabled**Default: Disabled*

The D90^{PLUS} checks integrity of the direct input/output communication ring by counting unreturned messages. In the ring configuration, all messages originating at a given device are to return within a pre-defined period of time. The unreturned messages alarm function is available for monitoring the integrity of the communication ring by tracking the rate of unreturned messages. This function counts all outgoing messages and a separate counter adds the messages have failed to return.

The unreturned messages alarm function is available on a per-channel basis and is active only in the ring configuration. The total number of unreturned input/output messages is available as an actual value.

Message Alarm Count*Range: 100 to 10000 in steps of 1**Default: 600*

When the total message counter reaches the user-defined maximum specified by this setting, both the counters reset and the monitoring process restarts.

Message Alarm Threshold*Range: 1 to 1000 in steps of 1**Default: 10*

When the unreturned messages counter reaches the user-definable level specified by this setting and within the user-defined message count specified by **Channel 1 Msg Alarm Count**, the **DIR IO CH1 UNRET ALM** FlexLogic operand is set. The operand needs to be

configured to drive an output contact, annunciator alarm, or selected communication-based output. Latching and acknowledging conditions, if required, need to be programmed accordingly in the annunciator settings.

Message Alarm Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of unreturned message alarm events in the sequence of events recorder.

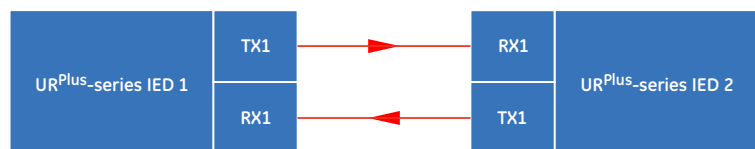
Direct input and output examples

The following application examples illustrate direct input and output configuration.

Direct inputs and outputs to extend input/output capabilities

Consider an application that requires additional contact inputs or outputs or lines of programmable logic that exceed the capabilities of a single UR^{Plus}-series device. The problem is solved by adding an extra UR^{Plus}-series IED to satisfy the additional input and output and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown.

Figure 124: Input and output extension via direct inputs and outputs



869740A1.CDR

The following settings are applied to implement this application. For both IEDs, set the inter-relay baud rate for channel 1 to 128 kbps in the **Settings > Communications > Inter-Relay** menu.

For UR^{Plus}-series IED 1:

Figure 125: Inter-relay communications settings for IED 1

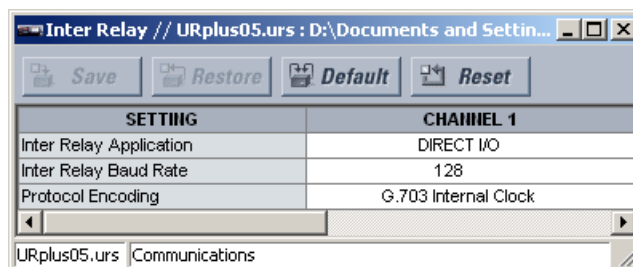


Figure 126: Direct input and output settings for IED 1

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Disabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	1	

For UR^{Plus}-series IED 2:

Figure 127: Inter-relay communications settings for IED 2

SETTING	CHANNEL 1
Inter Relay Application	DIRECT I/O
Inter Relay Baud Rate	128
Protocol Encoding	G.703 External Clock

Figure 128: Direct input and output settings for IED 2

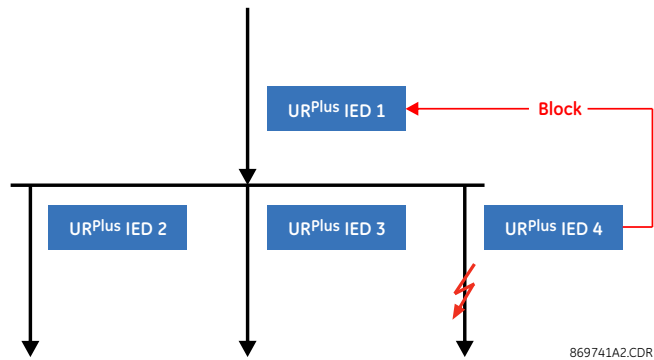
SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Disabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	2	

The message delivery time is about 0.2 of power cycle in both ways (at 128 kbps); that is, from device 1 to device 2, and from device 2 to device 1. Different communication cards can be selected by the user for this back-to-back connection (for example: fiber, G.703, or RS422).

Direct inputs and outputs for interlocking busbar protection

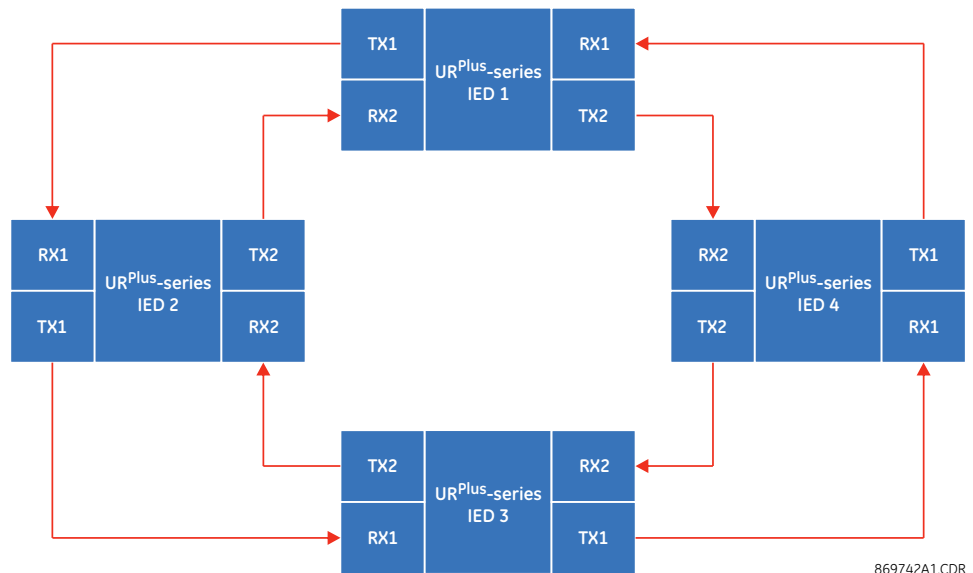
A simple interlocking busbar protection scheme can be accomplished by sending a blocking signal from downstream devices, say 2, 3, and 4, to the upstream device that monitors a single incomer of the busbar.

Figure 129: Interlocking busbar protection scheme example



For increased reliability, a dual-ring configuration is recommended for this application, shown as follows.

Figure 130: Interlocking busbar protection scheme via direct inputs and outputs



The following settings are applied to implement this application. For IED 1, set the inter-relay application for both channels as follows in the **Settings > Communications > Inter-Relay** menu. If there are more than two IEDs in a ring configuration, then one device (for example, IED 1) must have its protocol encoding set as an internal clock and the remaining devices have their protocol encoding set as external clock if no multiplexer is used.

Figure 131: Inter-relay communications settings for IED 1

Inter Relay // Station 1: IED 1: Settings: Communications				
	Save	Restore	Default	Reset
SETTING	CHANNEL 1	CHANNEL 2		
Inter Relay Application	DIRECT I/O REDUNDANT	DIRECT I/O REDUNDANT		
Inter Relay Baud Rate	128	128		
Protocol Encoding	C37.94 Internal Clock	C37.94 Internal Clock		

IED 1 | Settings: Communications

For IEDs 2 through 4, set the inter-relay application for both channels as follows in the **Settings > Communications > Inter-Relay** menu.

Figure 132: Inter-relay communications settings for IEDs 2 through 4

SETTING	CHANNEL 1	CHANNEL 2
Inter Relay Application	DIRECT I/O REDUNDANT	DIRECT I/O REDUNDANT
Inter Relay Baud Rate	128	128
Protocol Encoding	C37.94 External Clock	C37.94 External Clock

IED 2 | Settings: Communications

For UR^{Plus}-series IED 1:

Figure 133: Direct input and output settings for IED 1

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	1	

IED 1 | Settings: Communications

For UR^{Plus}-series IED 2:

Figure 134: Direct input and output settings for IED 2

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	2	

IED 2 | Settings: Communications

For UR^{Plus}-series IED 3:

Figure 135: Direct input and output settings for IED 3

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	3	

For UR^{Plus}-series IED 4:

Figure 136: Direct input and output settings for IED 4

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	4	

Message delivery time is approximately 0.2 of power system cycle (at 128 kbps) multiplied by the number of bridges between the origin and destination. Dual-ring configuration effectively reduces the maximum communications distance by a factor of two.

In this configuration, the following delivery times are expected (at 128 kbps) when both rings are healthy.

Table 9: Delivery times for healthy rings

Path	Delivery time
IED 1 to IED 2	0.2 of a power system cycle
IED 1 to IED 3	0.4 of a power system cycle
IED 1 to IED 4	0.2 of a power system cycle
IED 2 to IED 3	0.2 of a power system cycle
IED 2 to IED 4	0.4 of a power system cycle
IED 3 to IED 4	0.2 of a power system cycle

If one ring is broken (say TX2-RX2), then the delivery times are as follows.

Table 10: Delivery times for rings with break in TX2-RX2

Path	Delivery time
IED 1 to IED 2	0.2 of a power system cycle

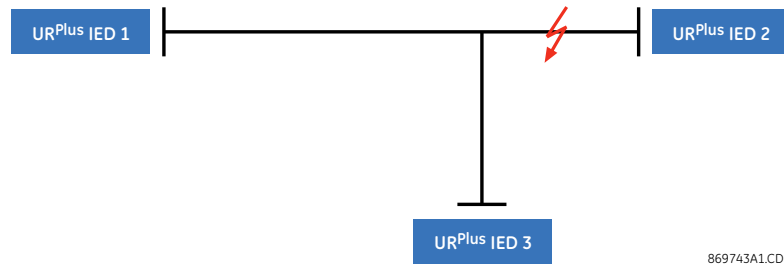
Path	Delivery time
IED 1 to IED 3	0.4 of a power system cycle
IED 1 to IED 4	0.6 of a power system cycle
IED 2 to IED 3	0.2 of a power system cycle
IED 2 to IED 4	0.4 of a power system cycle
IED 3 to IED 4	0.6 of a power system cycle

A coordinating timer for this bus protection scheme can be selected to cover the worst case scenario (0.4 of a power system cycle). Upon detecting a broken ring, the coordination time should be adaptively increased to 0.6 of a power system cycle. The complete application requires addressing a number of issues, such as failure of both the communications rings, failure, or out-of-service conditions of one of the IEDs. Self-monitoring flags of the direct inputs and outputs feature is used to address these concerns.

Direct inputs and outputs for pilot-aides schemes

Consider the three-terminal line protection application shown.

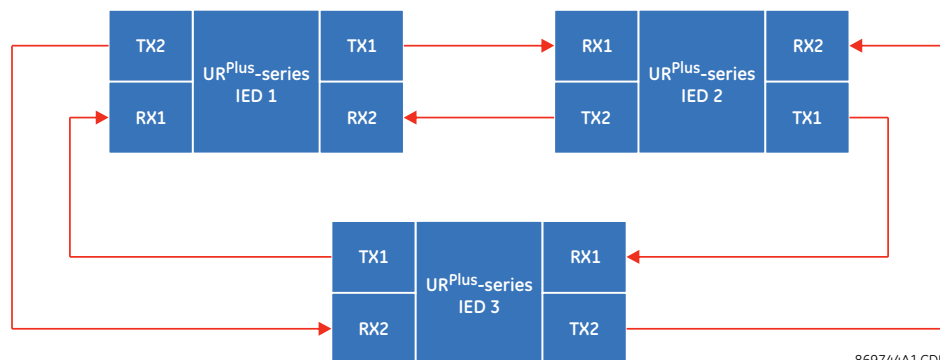
Figure 137: Three-terminal line application



869743A1.CDR

A permissive pilot-aided or blocking scheme can be accomplished using a dual-ring configuration, shown as follows.

Figure 138: Dual-channel closed loop (dual-ring) configuration



869744A1.CDR

Apply the following settings to implement this application. For all IEDs, set the inter-relay application for both channels as follows in the **Settings > Communications > Inter-Relay** menu.

Figure 139: Inter-relay communications settings for IED 1

SETTING	CHANNEL 1	CHANNEL 2
Inter Relay Application	DIRECT I/O REDUNDANT	DIRECT I/O REDUNDANT
Inter Relay Baud Rate	128	128
Protocol Encoding	C37.94 Internal Clock	C37.94 Internal Clock

IED 1 | Settings: Communications

Figure 140: Inter-relay communications settings for IEDs 2 through 3

SETTING	CHANNEL 1	CHANNEL 2
Inter Relay Application	DIRECT I/O REDUNDANT	DIRECT I/O REDUNDANT
Inter Relay Baud Rate	128	128
Protocol Encoding	C37.94 External Clock	C37.94 External Clock

IED 2 | Settings: Communications

For UR^{Plus}-series IED 1:

Figure 141: Direct input and output settings for IED 1

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	1	

IED 1 | Settings: Communications

For UR^{Plus}-series IED 2:

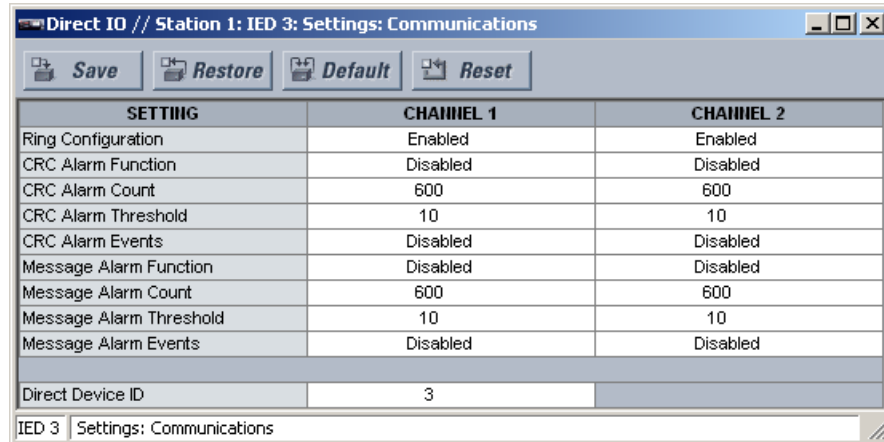
Figure 142: Direct input and output settings for IED 2

SETTING	CHANNEL 1	CHANNEL 2
Ring Configuration	Enabled	Enabled
CRC Alarm Function	Disabled	Disabled
CRC Alarm Count	600	600
CRC Alarm Threshold	10	10
CRC Alarm Events	Disabled	Disabled
Message Alarm Function	Disabled	Disabled
Message Alarm Count	600	600
Message Alarm Threshold	10	10
Message Alarm Events	Disabled	Disabled
Direct Device ID	2	

IED 2 | Settings: Communications

For UR^{Plus}-series IED 3:

Figure 143: Direct input and output settings for IED 3



In this configuration the following delivery times are expected (at 128 kbps) when both rings are healthy.

Table 11: Expected delivery times for healthy rings

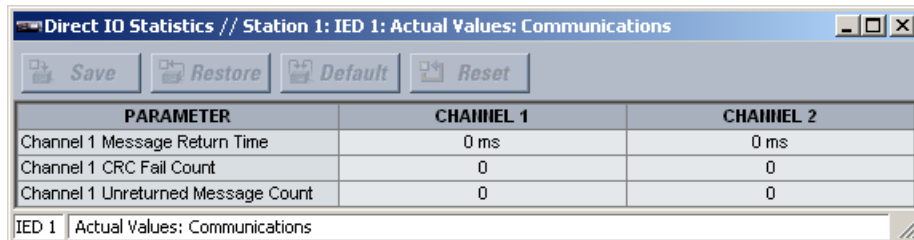
Path	Delivery time
IED 1 to IED 2	0.2 of a power system cycle
IED 1 to IED 3	0.2 of a power system cycle
IED 2 to IED 3	0.2 of a power system cycle

This configuration can be applied to both permissive and blocking schemes.

Direct input and output statistics

Select the **Actual Values > Communications > Direct IO Statistics** menu to open the direct inputs and outputs statistics window.

Figure 144: Direct inputs and outputs statistics



The following actual values are available for each channel and are applicable to all direct inputs and direct outputs.

Message Return Time

Range: 0 to 10000 ms in steps of 1

This actual value displays the time taken for direct output messages to return to the sender. There are two return times (one for each channel) for dual-channel communications modules. The value is defaulted to the maximum “10000 ms” if the message is not received or if the ring configuration function setting is “Disabled.”

CRC Fail Count

Range: 0 to 65535 in steps of 1

These actual values (one per communications channel) display the number of direct output messages that have been received but fail the CRC check. High values can indicate a problem with wiring or the communication channel on one or more devices. This value can be reset to zero using the Clear Direct I/O Counters command.

Unreturned Message Count

Range: 0 to 65535 in steps of 1

These actual values (one per communications channel) display the number of direct output messages that do not complete the trip around the communications ring. High values can indicate a problem with wiring or the communication channel on one or more devices. This value can be reset to zero using the Clear Direct I/O Counters command. If the **Message Alarm Function** setting is changed to "Disabled," then this value is frozen to the value at the time of change.

Direct input and output commands

Select the **Actual Values > Communications > Commands > Commands** menu to open the inter-relay communications commands.

Figure 145: Inter-relay communications commands



The following command is available for direct inputs and outputs.

Clear Direct I/O Counters

This command clears the statistic counters for the direct input/output CRC fail count and the unreturned message count.

Teleprotection inputs and outputs

Digital teleprotection transfers protection commands between two or three IEDs in a secure, fast, dependable, and deterministic fashion. Possible applications are permissive or blocking pilot schemes and direct transfer trip (DTT). Teleprotection can be applied over any analog or digital channels and any communications media, such as direct fiber, copper wires, optical networks, or microwave radio links. A mixture of communication media is possible.

Once teleprotection is enabled and the teleprotection inputs and outputs are configured, data packets are transmitted continuously every $\frac{1}{4}$ cycle ($\frac{3}{8}$ cycle if using C37.94 modules) from peer-to-peer. Security of communication channel data is achieved by using CRC-32 on the data packet. The baud rate between the peers must be the same for proper operation of the teleprotection feature.

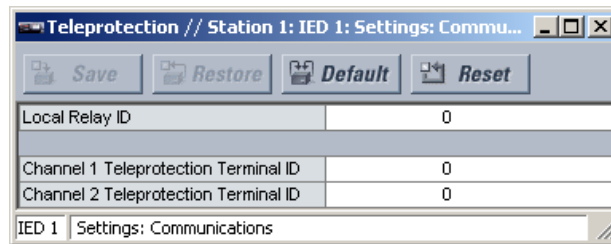


Teleprotection communication is supported between UR^{Plus}-series IEDs or between a UR^{Plus}-series and a UR-series IED over the G.703, C37.94, and RS422 communication interfaces.

Teleprotection settings

Select the **Settings > Communications > Teleprotection** menu item to open the main teleprotection configuration window.

Figure 146: Teleprotection configuration settings



The following teleprotection settings are available.

Local Relay ID

Range: 0 to 255 in steps of 1

Default: 0

In installations that use multiplexers or modems, a good practice is to ensure that the data used by the devices protecting a given line is from the correct device. The teleprotection function performs this check by reading the message ID sent by transmitting UR^{Plus}-series devices and comparing it to the programmed terminal IDs in the receiving device. Where redundancy is necessary the terminal IDs of both channels must be identical. Three-terminal applications can be achieved by programming distinct terminal IDs for each channel. The default value of “0” indicates that the relay ID is not to be checked. The same local relay ID is transmitted over both channels.

Channel 1 Teleprotection Terminal ID

Range: 0 to 255 in steps of 1

Default: 0

This setting specifies the ID of the transmitting device for channel 1. See the description for the [Local Relay ID](#) for details.

Channel 2 Teleprotection Terminal ID

Range: 0 to 255 in steps of 1

Default: 0

This setting specifies the ID of the transmitting device for channel 2. See the description for the [Local Relay ID](#) for details.

Teleprotection channel test actual values

Select the **Actual Values > Communications > Teleprotection Channel Tests** menu to open the teleprotection actual values window.

Figure 147: Teleprotection actual values

PARAMETER	CHANNEL 1	CHANNEL 2
Status	n/a	n/a
Number of lost packets	0	0

The following actual values are available for each channel.

Status

Range: n/a, Fail, OK

This actual value is the receiver status for each channel. If the value is “OK,” teleprotection is enabled and data is being received from the remote terminal. If the value is “Fail,” teleprotection is enabled and data is not being received from the remote terminal. If the value is “n/a,” then teleprotection is disabled.

Number of Lost Packets

Range: 0 to 65535 in steps of 1

This actual value represents data packets lost in transmission. This number can be reset to zero using the Clear Teleprotection Counters command.

Teleprotection commands

Select the **Actual Values > Communications > Commands > Commands** menu to open the inter-relay communications commands window.

Figure 148: Inter-relay communications commands



The following teleprotection command is available.

Clear Teleprotection Counters

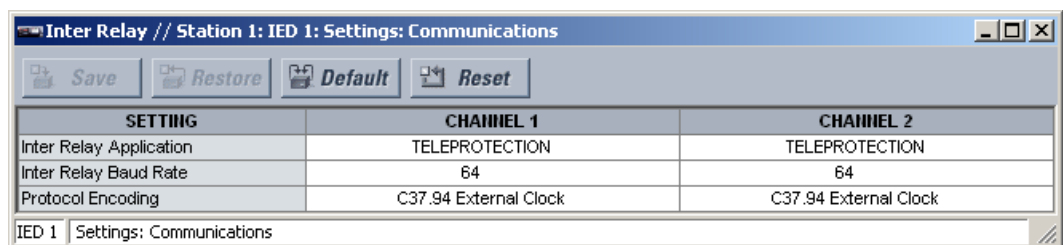
This command clears the number of teleprotection lost packets count.

Inter-relay communications

The inter-relay communications settings configure inter-relay communication for direct inputs and outputs and teleprotection inputs and outputs.

Select the **Settings > Communications > Inter-Relay** menu to open the inter-relay communications configuration window.

Figure 149: Inter-relay communications settings



The following settings are available for each inter-relay communications channel.

Inter-Relay Application

Range: None, Direct I/O, Teleprotection, Direct I/O Redundant
Default: None

This setting selects the inter-relay communications application for each channel.

This setting can be selected as “Direct I/O,” “Direct I/O Redundant,” or “Teleprotection” to enable direct inputs and outputs. If a channel is set to “None,” then that transmitter’s output is disabled.

If the application is different for a channel pair (channels 1 and 2), then the channels are treated independently and provide 96 inputs and outputs per channel.

Select one of the redundancy values in cases where redundancy is important. Redundancy works on channel pairs (1 and 2). To enable redundancy for a channel pair, both channels 1 and 2 must be set to the same application setting and redundancy specified. Otherwise, the channels are treated independently. If channel redundancy is enabled, then channel 1 becomes the primary channel and channel 2 the secondary channel. In the event the primary channel fails, the data is accepted from the channel pair twin (channel 2).

In redundancy mode, the secondary channels become dormant and report their direct input states as off. In this case, only the primary channel is active and the use of the secondary channel operands is not recommended. You program all logic to use the primary channel operands when using redundant mode. In redundancy setting mode, the channel 1 direct inputs and outputs are transmitted and received by both channels when the IEDs are configured in a redundant ring. This provides a greater level of security if one of the rings become disconnected. Use this mode when interfacing with UR-series devices.

Inter-Relay Baud Rate

*Range: 64 kbps, 128 kbps
Default: 64 kbps*

This setting selects the baud rate for each inter-relay communications channel. All interconnected devices must use the same baud rate for communications to operate properly.

Protocol Encoding

*Range: Default, G.703 Octet Internal Clock, G.703 Octet External Clock, G.703 Internal Clock, G.703 External Clock, Diff. Manchester, C37.94 Internal Clock, C37.94 External Clock
Default: Default*

For RS422 communications, only the "Default" value is available. For channels with G.703 communications, the "Default," "G.703 Internal Clock," "G.703 Octet Internal Clock," "G.703 External Clock," and "G.703 Octet External Clock" values are available. For channels with fiber communications, the "Default," "Diff. Manchester," "C37.94 Internal Clock," and "C37.94 External Clock" values are available.

The "Default" value defaults the communications to a connection in a higher order system as shown in the table.

Table 12: Default value encoding

Protocol encoding	Channel type		
	G.703	Fiber	RS422
Octet timing	Enabled	N/A	N/A
Timing	External clock	External clock	N/A
Fiber protocol	N/A	C37.94	N/A

When an internal value is selected, the inter-relay communications card supplies the clock for communications. When an external value is selected, the clock is supplied by the external device connected to the inter-relay communications card.

Inter-relay communication actual values

The inter-relay actual values provide diagnostics to troubleshoot the inter-relay card when there is a problem. These values are useful for the factory and the user if the inter-relay card is not functioning properly. Each fiber transceiver contains a digital diagnostic monitoring interface (DDMI) that provides the transceiver actual values.

Select the **Actual Values > Communications > Inter-Relay Transceivers** menu to open the inter-relay communication actual values window.

Figure 150: Inter-relay communication actual values

PARAMETER	CHANNEL 1	CHANNEL 2
Tranceiver Temperature	0.00 °C	0.00 °C
Tranceiver Temperature Trouble	Off	Off
Tranceiver Voltage	0.0000 V	0.0000 V
Voltage Trouble	Off	Off
Transmit Bias Current	0 µA	0 µA
Transmit Bias Current Trouble	Off	Off
Transmit Power Level	0.0 Dbm	0.0 Dbm
Transmit Power Trouble	Off	Off
Receive Power Level	0.0 Dbm	0.0 Dbm
Receive Power Trouble	Off	Off
Tranceiver Diagnostic Trouble	Off	Off
Loss Of Signal	0	0
Soft Tx Disable Status	0	0
Transmitter Tx Fault	0	0
Yellow Bit Alarm	Off	Off

The following actual values are available for each channel.

Tranceiver Temperature

Range: -99.99 to 300.00 °C

This value indicates the fiber transceiver temperature.

Tranceiver Temperature Trouble

Range: On, Off

This value indicates whether the fiber transceiver temperature has exceeded the manufacturer's limit.

Tranceiver Voltage

Range: 0.0000 to 6.5535 V in steps of 0.0001

This value indicates the fiber transceiver voltage.

Voltage Trouble

Range: On, Off

This value indicates whether the fiber transceiver voltage level is outside the manufacturer's limit.

Transmit Bias Current

Range: 0 to 65535 µA in steps of 1

This value indicates the fiber transceiver bias current level.

Transmit Bias Current Trouble

Range: On, Off

This value indicates whether the fiber transceiver bias current is outside the manufacturer's limit.

Transmit Power Level

Range: -3276.8 to 3276.8 dBm in steps of 0.1

This value indicates the fiber transceiver transmitter power level.

Transmit Power Level Trouble*Range: On, Off*

This value indicates whether the fiber transceiver transmit power level is outside the manufacturer's limit.

Receive Power Level*Range: -3276.8 to 3276.8 dBm in steps of 0.1*

This value indicates the fiber transceiver receive power level.

Receive Power Level Trouble*Range: On, Off*

This value indicates the fiber transceiver receive power level is outside the manufacturer's limit.

Transceiver Diagnostic Trouble*Range: On, Off*

This value indicates the fiber transceiver diagnostics module is not working properly.

Loss of Signal*Range: On, Off*

This value indicates the loss of signal status for fiber and G.703 options. For the RS422 option, this indicates no clock or incorrect clock.

Soft Tx Disable Status*Range: On, Off*

This value indicates whether the fiber transceiver transmitter has been disabled. This occurs if the **Inter-Relay Application** is set to "None," causing the fiber transmitter to be disabled.

Transmitter Tx Fault*Range: On, Off*

This value indicates there is a hardware problem with the fiber transmitter.

Yellow Bit Alarm*Range: On, Off*

This indicates the yellow bit alarm status for the C37.94 protocol encoding if fiber is used.

Inter-relay communication commands

Select the **Actual Values > Communications > Commands > Commands** menu to open the inter-relay communications commands window.

Figure 151: Inter-relay communication commands



The following commands are available for inter-relay communications.

Clear Teleprotection Counters

This command clears the **Number of Lost Packets** teleprotection actual value.

Clear Direct I/O Counters

This command clears all counters for the **CRC Fail Count** and **Unreturned Message Count** direct input and output actual values.

Communication logic operands

The following communication logic operands are available for the D90^{Plus}. They are listed alphabetically by operand syntax. If required, these operands can be assigned user-defined names through the **Settings > Configure FlexOperands** menu.

Direct device operands

CH 1 DIR DEV 1 OFF.....	Asserted when direct device 1 on channel 1 is off.
CH 1 DIR DEV 1 ON.....	Asserted when direct device 1 on channel 1 is on.
CH 2 DIR DEV 1 OFF.....	Asserted when direct device 1 on channel 2 is off.
CH 2 DIR DEV 1 ON.....	Asserted when direct device 1 on channel 2 is on.
CH 1 DIR DEV 2.....	The operands listed above are available for direct devices 2 through 16 on channel 1.
CH 2 DIR DEV 2.....	The operands listed above are available for direct devices 2 through 16 on channel 2.

Direct input and output operands

DIRECT INPUT 1 ON.....	Asserted when direct input 1 is on.
DIRECT INPUT 2.....	The operands listed above are available for direct inputs 2 through 96.

Remote double-point status input operands

RemDPS Ip 1 BAD.....	Asserted when remote double-point status input 1 is in the bad state.
RemDPS Ip 1 INTERM.....	Asserted when remote double-point status input 1 is in the intermediate state.
RemDPS Ip 1 OFF.....	Asserted when remote double-point status input 1 is in the off (open) state.
RemDPS Ip 1 ON.....	Asserted when remote double-point status input 1 is in the on (closed) state.
RemDPS Ip 2.....	The operands listed above are also available for remote double-point status inputs 2 through 16.

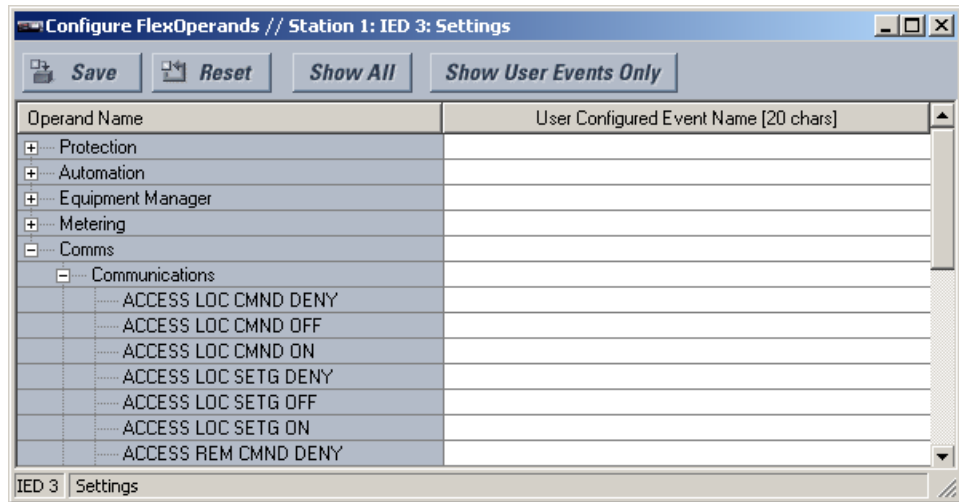
Teleprotection input and output operands

TELEPRO CH1 CRC FAIL.....	Asserted when the CRC detects packet corruption on teleprotection channel 1.
TELEPRO CH1 FAIL.....	Asserted when teleprotection inputs are not received for more than four cycles on channel 1.
TELEPRO CH1 FAIL OFF.....	Asserted when teleprotection has failed for channel 1.
TELEPRO CH1 PKT LOST.....	Asserted when the CRC detects a lost packet on teleprotection channel 1.
TELEPRO CH2 CRC FAIL.....	Asserted when the CRC detects packet corruption on teleprotection channel 2.
TELEPRO CH2 FAIL.....	Asserted when teleprotection inputs are not received for more than four cycles on channel 2.
TELEPRO CH2 FAIL OFF.....	Asserted when teleprotection has failed for channel 2.
TELEPRO CH2 PKT LOST.....	Asserted when the CRC detects a lost packet on teleprotection channel 2.

Customize the operands

Select the **Settings > Configure FlexOperands** menu to open the user-configurable operands window.

Figure 152: User-configurable communication logic operands window



The left side of this screen displays all operands that are currently available to the D90^{Plus}. The communication logic operands are displayed by expanding the **Comms** menu.

User Configured Event Name

Range: up to 20 alphanumeric characters

Default: ---

Each available communications logic operand can be renamed to a user-specified value. This feature allows for clearer identification or to match specific applications. The new operand name appears in protection and automation logic, in settings that take operands as their value, and in event reports.

Communication FlexAnalog parameters

The following communication FlexAnalog parameters (analog operands) are available for the D90^{Plus}. They are listed alphabetically by operand syntax.

Real-time clock analog operands

Day of Month..... Real-time clock day of month value

Day of Week..... Real-time clock day of week value

Day of Year..... Real-time clock day of year value

Hour of Day..... Real-time clock hour of day value

Minute of Hour..... Real-time clock minutes of hour value

Month of Year..... Real-time clock month of year value

Second of Minute..... Real-time clock second of minute value

Year..... Real-time clock year value

GOOSE analog inputs analog operands

GOOSE Analog In 1..... Metered value for GOOSE analog input 1

GOOSE Analog In 2..... The value above is available for GOOSE analog input 2 to 128

D90^{Plus} Line Distance Protection System

Chapter 7: Protection

This chapter outlines how to program the D90^{Plus} protection features.

Protection overview

The D90^{Plus} is intended for use on transmission lines of any voltage level, without, with, and in the vicinity of series compensation, in three-pole and single-pole tripping applications. The distance elements are optimized to provide good measurement accuracy with a sub-cycle operating time, even when used with capacitive voltage transformers, and can be supervised by detection of power swings. The primary function of the relay consists of five phase and ground distance zones of protection, either mho or quadrilateral as per user selection, with built-in logic for the six common pilot aided schemes. The relay also provides directional ground overcurrent elements, which are commonly used as part of an overall line protection system.

The phase distance zones can be configured to work with voltages and currents fed from VTs and CTs located independently from one another on either side of a three-phase power transformer. The relay compensates accordingly to preserve reach and correct target information regardless of the location and type of fault. This feature allows backup protection applications for generators and power transformers.

A close-into-fault, or switch-on-to-fault, function is performed by the line pickup element. Out-of-step tripping, three-pole and single-pole dual-breaker autoreclosing, load encroachment, and many other functions are also available. In addition, overcurrent and undervoltage protection, fault diagnostics, power metering, and RTU functions are provided. The D90^{Plus} provides phase, neutral, and ground time overcurrent protection. The time overcurrent functions can be programmed with multiple curve shapes or FlexCurves for optimum coordination.

Introduction to protection elements

In the UR^{Plus}-series, the term *element* is used to describe a feature based around a comparator. The comparator is provided with an input (or set of inputs) that is tested against a programmed setting (or group of settings) to determine if the input is within the defined range that sets the output to logic 1, also referred to as *setting the flag*. A single comparator can make multiple tests and provide multiple outputs. For example, the time overcurrent comparator sets a pickup flag when the current input is above the setting and

sets an operate flag when the input current has been at a level above the pickup setting for the time specified by the time-current curve settings. All comparators use analog actual values as the input.

Protection elements are arranged into two classes, *grouped* and *control*. Each element classed as a grouped element is provided with six alternate sets of settings, in setting groups numbered 1 through 6. The performance of a grouped element is defined by the setting group that is active at a given time. The performance of a control element is independent of the selected active setting group.

The main characteristics of an element are shown on a logic diagram. This includes the inputs, settings, fixed logic, and the output operands generated.

Some settings for current and voltage elements are specified in per-unit (pu) calculated quantities. Per-unit quantities are calculated as follows.

$$\text{pu quantity} = \frac{\text{actual quantity}}{\text{base quantity}} \tag{Eq. 1}$$

For current elements, the base quantity is the nominal secondary or primary current of the CT. Where the current source is the sum of two CTs with different ratios, the base quantity is the common secondary or primary current to which the sum is scaled (that is, normalized to the larger of the two rated CT inputs). For example, if CT1 is 300 / 5 A and CT2 is 100 / 5 A, then CT2 is scaled to the CT1 ratio for summation. In this case, the base quantity is 5 A secondary or 300 A primary.

For voltage elements, the base quantity is the nominal primary voltage of the protected system that corresponds (based on VT ratio and connection) to secondary VT voltage applied to the device. For example, on a system with a 13.8 kV nominal primary voltage and with 14400:120 V delta-connected VTs, the secondary nominal voltage (1 pu) is:

$$\frac{13800 \text{ V}}{14400 \text{ V}} \times 120 \text{ V} = 115 \text{ V} \tag{Eq. 2}$$

For wye-connected VTs, the secondary nominal voltage (1 pu) is:

$$\frac{13800 \text{ V}}{14400 \text{ V}} \times \frac{120 \text{ V}}{\sqrt{3}} = 66.4 \text{ V} \tag{Eq. 3}$$

Many settings are common to most elements, outlined as follows:

- **Function** settings — These settings program the element to operate when selected as “Enabled.” The factory default is “Disabled.” Once “Enabled,” any element associated with the function becomes active and all options become available.
- **Name** settings — These settings are used to uniquely identify an element.
- **Source** settings — These settings select the parameter or set of parameters to be monitored.
- **Pickup** settings — For simple elements, these settings are used to program the level of the measured parameter above or below which the pickup state is established. In more complex elements, a set of settings can be provided to define the range of the measured parameters that cause the element to pickup.
- **Pickup Delay** setting — This setting sets a time-delay-on-pickup, or on-delay, for the duration between the pickup and operate output states.
- **Reset Delay** setting — This setting is used to set a time-delay-on-dropout, or off-delay, for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.
- **Block** setting — The default output operand state of all comparators is a logic 0 or *flag not set*. The comparator remains in this default state until a logic 1 is asserted at the RUN input, allowing the test to be performed. If the RUN input changes to logic 0 at any time, the comparator returns to the default state. The RUN input is used to supervise the comparator. The BLOCK input is used as one of the inputs to RUN control.

- **Events** setting — This setting is used to control whether the pickup, dropout, or operate states are recorded by the event recorder. When set to “Disabled,” element pickup, dropout, or operate are not recorded as events. When set to “Enabled,” events are created for
 - **<Element> PKP** (pickup)
 - **<Element> DPO** (dropout)
 - **<Element> OP** (operate)

The DPO event is created when the measure and decide comparator output transits from the pickup state (logic 1) to the dropout state (logic 0). This can happen when the element is in the operate state if the reset delay time is not zero.

Power system

This section outlines settings relevant to the D90^{Plus} power system.

Installation settings

Select the **Settings > Protection > Power System > Installation** menu to open the installation settings window.

Figure 153: Installation settings

SETTING	PARAMETER
Relay Settings	Programmed
Relay Name	gab RELAY
User Configuration Name	Initial
User Configuration Date	Tuesday, August 19, 2008 11:58:26

The following settings are available.

Relay Settings

Range: Programmed, Not Programmed

Default: Not Programmed

To safeguard against the installation of a device without any entered settings, the D90^{Plus} does not allow signaling of any output relay until this setting value is “Programmed.” This setting is “Not Programmed” by default. The **UNIT NOT PROGRAMMED** self-test error message displays until the relay is put into the “Programmed” state.

Relay Name

Range: up to 20 alphanumeric characters

Default: ----

This setting allows the user to uniquely identify a relay. This name appears on generated reports.

User Configuration Name

Range: up to 20 alphanumeric characters
 Default: Initial

This setting allows the user to provide a description for the settings that are loaded at a particular time (for example, “Spring-summer settings”). This description is displayed on the Product Information page of the front panel annunciator under the **Configuration** field.

User Configuration Date

Range: up to 20 alphanumeric characters
 Default: ----

This setting records the date of last setting change through the EnerVista UR^{Plus} Setup software. Each time any settings are changed or a new settings file loaded, this value is updated. This description is also displayed on the Product Information page of the front panel annunciator under the **Date** field directly to the right of the **Configuration** field.

AC input modules

CT and VT input channels are contained in AC modules. The following input channel types are available:

- Three-phase voltage
- Single-phase auxiliary voltage
- Three-phase current
- Single-phase ground current

The AC modules calculate total waveform RMS levels, fundamental frequency phasors, and symmetrical components, as allowed by the hardware in each channel. These modules can calculate other parameters as directed by the CPU module.

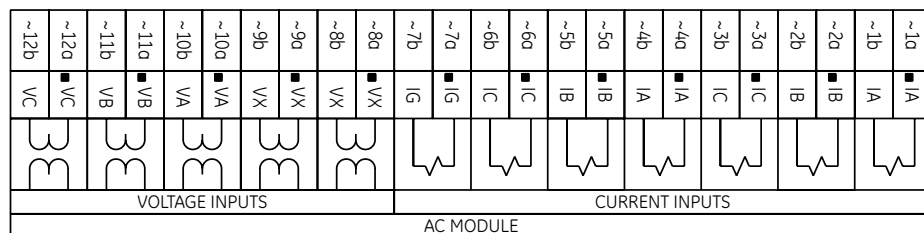
An AC module contains 12 input channels, numbered 1 through 12. The channel numbering corresponds to the module terminal numbering 1 through 12 and is arranged as follows:

- Channels 1, 2, and 3 form a three-phase current input
- Channels 4, 5, and 6 form a second three-phase current input
- Channel 7 is a single-phase current input
- Channels 8 and 9 are single-phase voltage inputs
- Channels 10, 11, and 12 form a three-phase voltage input

Channel groups are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the AC module with the lowest slot position letter to the module with the highest slot position letter, as follows.

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the AC module with the lowest slot position letter to the module with the highest slot position letter, as follows.

Figure 154: AC module bank configuration



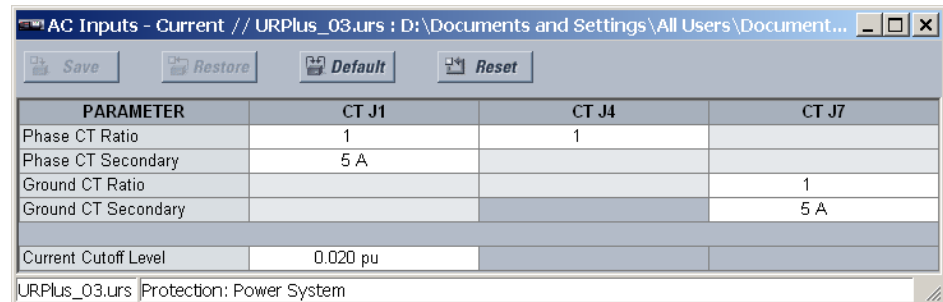
870832A1.CDR

For three-phase channel groups, the number of the lowest numbered channel identifies the group. For example, J1 represents the three-phase channel set of J1, J2, and J3, where J is the slot letter and 1 is the first channel of the set of three channels. The first channel in the group is identified as phase A, the second channel as phase B, and the third channel as phase C.

Current inputs

Select the **Settings > Protection > Power System > AC Inputs - Current** menu to open the current inputs configuration window.

Figure 155: Current inputs configuration settings



PARAMETER	CT J1	CT J4	CT J7
Phase CT Ratio	1	1	
Phase CT Secondary	5 A		
Ground CT Ratio			1
Ground CT Secondary			5 A
Current Cutoff Level	0.020 pu		

The current inputs window sets the parameters for each current input (represented by the module slot position letter). The **Phase CT Ratio** and **Ground CT Ratio** settings are used for calculation of primary metering values and for ratio matching when multiple CT inputs are added within a source. The **Phase CT Secondary** and **Ground CT Secondary** settings are used to derive secondary current values from per-unit settings used in protection elements. This setting is “1 A” or “5 A,” depending on the hardware.

Since the phase CTs are connected in a wye (star) configuration, the calculated phasor sum of the three phase currents ($I_A + I_B + I_C = \text{neutral current} = 3I_0$) is used as the input for the neutral overcurrent elements. In addition, a zero-sequence (core-balance) CT that senses current in all of the circuit primary conductors, or a CT in a neutral grounding conductor, can be used.

The following current input settings are available.

Phase CT Ratio

Range: 1 to 65000 in steps of 1

Default: 1

This setting specifies the phase CT ratio for the corresponding current input. It is used for calculation of primary metering values and for ratio matching when multiple CT inputs are added within a source.

Phase CT Secondary

Range: 1 A, 5 A

Default: 5 A

This setting selects the phase CT secondary value. It is used to derive secondary current values from per-unit settings used in protection elements.

Ground CT Ratio

Range: 1 to 65000 in steps of 1

Default: 1

This setting specifies the ground CT ratio for the corresponding current input. It is used for calculation of primary metering values and for ratio matching when multiple CT inputs are added within a source.

Ground CT Secondary

Range: 1 A, 5 A

Default: 5 A

This setting selects the ground CT secondary value. It is used to derive secondary current values from per-unit settings used in protection elements.

Current Cutoff Level

Range: 0.002 to 0.020 pu in steps of 0.001

Default: 0.020 pu

This setting modifies the current cut-off threshold. Very low currents (1 to 2% of the rated value) are very susceptible to noise. Some users prefer very low currents to display as zero, while others prefer the current be displayed even when the value reflects noise rather than the actual signal. The D90^{Plus} applies a cut-off value to the magnitudes and angles of the measured currents. If the magnitude is below the cut-off level, it is substituted with zero. This applies to phase and ground current phasors as well as true RMS values and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw current samples available via oscillography are not subject to cut-off.



Lower the **Current Cutoff Level** setting with care because the D90^{Plus} accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default setting of “0.020 pu” is recommended.

Voltage inputs

Select the **Settings > Protection > Power System > AC Inputs - Voltage** menu to open the voltage input configuration window.

Figure 156: Voltage input configuration settings

PARAMETER	VT J8	VT J9	VT J10
Phase VT Connection			Wye
Phase VT Secondary			66.4 V
Phase VT Ratio			1.00 :1
Auxiliary VT Connection	Vag	Vag	
Auxiliary VT Secondary	66.4 V	66.4 V	
Auxiliary VT Ratio	1.00 :1	1.00 :1	
Voltage Cutoff Level	1.0 V		

URPlus_03.urs | Protection: Power System

This menu sets the parameters for each voltage input. The **Phase VT Ratio** and **Auxiliary VT Ratio** settings are used to calculate primary metering values or matching primary voltage in a synchrocheck application. The **Phase VT Secondary** and **Auxiliary VT Secondary** settings are used to derive secondary voltage values from the per-unit settings used in protection elements. Protection functions that require phase-to-neutral or zero-sequence quantities do not function correctly for delta VT configurations.

The following voltage input settings are available.

Phase VT Connection

Range: Wye, Delta

Default: Wye

This setting specifies the phase VT connection type for the corresponding voltage input. Enter an open-delta source VT connection as “Delta”.

Phase VT Secondary

Range: 50.0 to 240.0 volts in steps of 0.1

Default: 66.4 volts

This setting specifies the nominal phase VT voltage for the corresponding voltage input. It is used typically to derive secondary voltage values from the per-unit settings used in protection elements.

The typical **Phase VT Secondary** setting is the phase-to-phase secondary voltage appearing at the relay input terminals when nominal voltage is applied to the VT primary. For example, on a system with a 13.8 kV nominal primary voltage and with a 14400:120 V VT in a delta connection, the secondary voltage is $(13800 \text{ V} / 14400) \times 120 = 115 \text{ V}$. Thus, the **Phase VT Secondary** setting is 115 volts.

Phase VT Ratio

Range: 1.00 to 24000.00 in steps of 0.01

Default: 1.00

This setting specifies the phase VT ratio for the corresponding voltage input. It is used typically for calculation of primary metering values or matching primary voltage in a synchrocheck application.

Auxiliary VT Connection

Range: Vag, Vbg, Vcg, Vab, Vbc, Vca, Vn

Default: Vag

This setting specifies the auxiliary VT connection type for the corresponding voltage input.

Auxiliary VT Secondary

Range: 50.0 to 240.0 volts in steps of 0.1

Default: 66.4 volts

This setting specifies the nominal auxiliary VT voltage for the corresponding voltage input. It is used typically to derive secondary voltage values from the per-unit settings used in protection elements.

Auxiliary VT Ratio

Range: 1.00 to 2400.00 in steps of 0.001

Default:

This setting specifies the auxiliary VT ratio for the corresponding voltage input. It is used typically for calculation of primary metering values or matching primary voltage in a synchrocheck application.

Voltage Cutoff Level

Range: 0.1 to 1.0 volts secondary in steps of 0.1

Default: 1.0 volts secondary

This setting specifies the voltage cut-off threshold. Very low secondary voltage measurements (at the fractional volt level) can be affected by noise. Some users prefer these low voltages to display as zero, while others prefer the voltage to display even when the value reflects noise rather than the actual signal. The D90^{PLUS} applies a cut-off value to the magnitudes and angles of the measured voltages. If the magnitude is below the cut-off level, it is substituted with zero. This operation applies to phase voltages, auxiliary voltages, and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw samples of the voltages available via oscillography are not subject cut-off.



NOTE

Lower the **Voltage Cutoff Level** setting with care because the D90^{PLUS} accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default setting of "1.0 V" is recommended.

Calculating the power cut-off level

The **Current Cutoff Level** and the **Voltage Cutoff Level** settings are used to determine the metered power cut-off levels. The power cut-off level is calculated as shown here. For delta connections, the power cut-off is calculated as follows:

$$\text{Three-phase power cut-off} = \frac{\sqrt{3} \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{Eq. 4}$$

where VT primary = VT secondary × VT ratio and CT primary = CT secondary × CT ratio.

For wye connections, the three-phase and per-phase power cut-off values are calculated as follows:

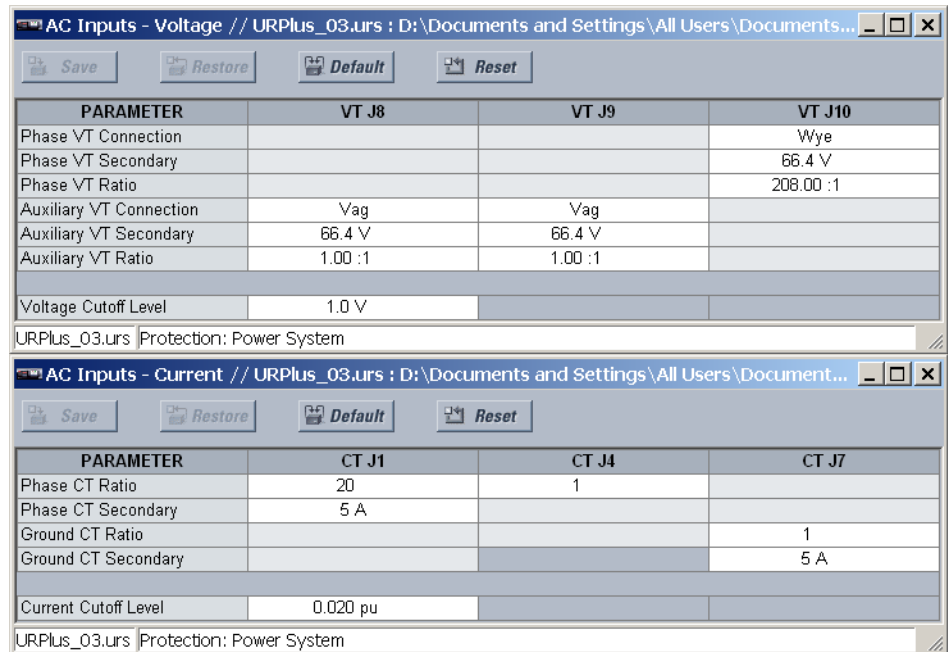
$$\text{Three-phase power cutoff} = \frac{3 \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{Eq. 5}$$

$$\text{Per-phase power cutoff} = \frac{\text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \quad \text{Eq. 6}$$

where VT primary = VT secondary × VT ratio and CT primary = CT secondary × CT ratio.

For example, given the following settings:

Figure 157: Typical power system settings



we have:

- CT primary = **Phase CT Ratio** × **Phase CT Secondary** = 20 × 5 A = 100 A.
- VT primary = **Phase VT Ratio** × **Phase VT Secondary** = 208 × 66.4 V = 13811.2 V.

The power cut-off is therefore:

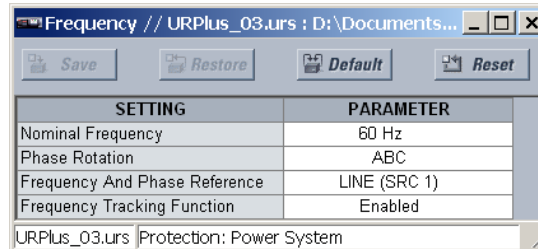
$$\begin{aligned} \text{Three-phase power cut-off} &= \frac{\sqrt{3} \times \text{Current Cutoff Level} \times \text{Voltage Cutoff Level} \times \text{VT primary} \times \text{CT primary}}{\text{VT secondary}} \\ &= \frac{\sqrt{3} \times 0.02 \text{ pu} \times 1.0 \text{ V} \times 100 \text{ A} \times 13811.2 \text{ V}}{66.4 \text{ V}} \\ &= 720.5 \text{ W} \end{aligned} \quad \text{Eq. 7}$$

Any calculated power value below this cut-off does not display. As well, the three-phase energy data does not accumulate if the total power from all three phases does not exceed the power cut-off.

Power system frequency

Select the **Settings > Protection > Power System > Frequency** menu to open the power system frequency configuration window.

Figure 158: System frequency configuration settings



The following settings are available.

Nominal Frequency

Range: 50 Hz, 60 Hz

Default: 60 Hz

This value is used as a default to set the digital sampling rate if the system frequency cannot be measured from available signals. This can happen if the signals are not present or are heavily distorted. Before reverting to the nominal frequency, the frequency tracking algorithm holds the last valid frequency measurement for a safe period of time while waiting for the signals to reappear or for the distortions to decay.

Phase Rotation

Range: ABC, ACB

Default: ABC

The phase sequence of the power system is required to properly calculate sequence components and power parameters. This setting matches the power system phase sequence and informs the relay of the actual system phase sequence, either ABC or ACB. The D90^{PLUS} AC inputs (labeled as A, B, and C) must be connected to system phases A, B, and C for correct operation.

Frequency and Phase Reference

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting determines which signal source is used (and hence which AC signal) for phase angle reference. The AC signal used is prioritized based on the AC inputs configured for the signal source. Phase voltages takes precedence, followed by auxiliary voltage, then phase currents, and finally ground current. For three-phase selection, phase A is used for angle referencing ($V_{\text{ANGLE_REF}} = V_A$), while the Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{\text{FREQ}} = (2V_A - V_B - V_C) / 3$) for better performance during fault, open pole, and VT and CT fail conditions.

The phase reference and frequency tracking AC signals are selected based upon the source configuration, regardless of whether or not a particular signal is actually applied to the relay.

The reference signal phase angle always displays zero degrees and all other phase angles are relative to this signal. If the pre-selected reference signal is not measurable at a given time, the phase angles are not referenced.

The phase angle referencing is done via a phase locked loop, which can synchronize independent UR^{PLUS}-series devices if they have the same AC signal reference. This results in very precise correlation of time tagging in the event recorder between different UR^{PLUS}-series devices provided the relays have an IRIG-B connection.

Frequency Tracking

Range: Disabled, Enabled

Default: Enabled

This setting is set to “Disabled” only in unusual circumstances; consult GE Grid Solutions for special variable-frequency applications.

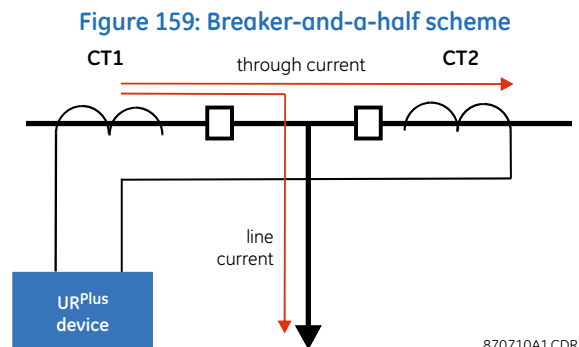
About AC sources

The D90^{Plus} can be used on systems with breaker-and-a-half or ring bus configurations. In these applications, each of the two three-phase sets of individual phase currents (one associated with each breaker) can be used as an input to a breaker failure element. The sum of both breaker phase currents and 3I₀ residual currents can be required for the circuit relaying and metering functions. For a three-winding transformer application, it can be necessary to calculate watts and vars for each of the three windings, using voltage from different sets of VTs. These requirements can be satisfied with a single D90^{Plus} equipped with sufficient CT and VT input channels by selecting the appropriate parameter measurement. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to the protection and control comparators and some metering elements.

Selection of the measurement parameters is performed partially by the design of a measuring element or protection/control comparator by identifying the type of parameter (fundamental frequency phasor, harmonic phasor, symmetrical component, total waveform RMS magnitude, phase-phase or phase-ground voltage, and so on) to measure. The user completes the process by selecting the instrument transformer input channels to use and some of the parameters calculated from these channels. The input parameters available include the summation of currents from multiple input channels. For the summed phase, 3I₀, and ground currents, currents from CTs with different ratios are adjusted to a single ratio before summation.

A mechanism called a *source* configures the routing of CT and VT input channels to measurement sub-systems. Sources, in the context of the UR^{Plus}-series relays, refer to the logical grouping of current and voltage signals such that one source contains all the signals required to measure the load or fault in a particular power apparatus. A given source can contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages, and an auxiliary voltage from a single VT for checking for synchronism.

To illustrate the concept of sources, as applied to current inputs only, consider the breaker-and-a-half scheme shown in the following figure. The current flow is indicated by the arrows. Some current flows through the upper bus bar to some other location or power equipment, and some current flows into transformer winding 1. The current into the line is the phasor sum (or difference) of the currents in CT1 and CT2 (whether the sum or difference is used depends on the relative polarity of the CT connections). The protection elements require access to the net current for line protection, but some elements can need access to the individual currents from CT1 and CT2.



In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all CTs through which any portion of the current for the element being protected can flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the D90^{PLUS}, provisions have been included for all the current signals to be brought to the D90^{PLUS} device where grouping, ratio correction, and summation are applied internally via configuration settings. A major advantage of using internal summation is that the individual currents are available to the protection device, for example as additional information to calculate a restraint current, or to allow the provision of additional protection features that operate on the individual currents such as breaker failure.

Given the flexibility of this approach, it becomes necessary to add configuration settings to the platform to allow the user to select which sets of CT inputs are added to form the net current into the protected device.

The internal grouping of current and voltage signals forms an internal source. This source can be given a specific name through the settings, and becomes available to a protection and metering element in the D90^{PLUS}. Individual names can be assigned to each source to clearly identify them for later use. For example, in the scheme shown, a source configured as the sum of CT1 and CT2 can be assigned the name "Line Current."

Once the sources have been configured, they are available as selections for the choice of input signal for the protection elements and as metered quantities.

CT/VT input channel configuration

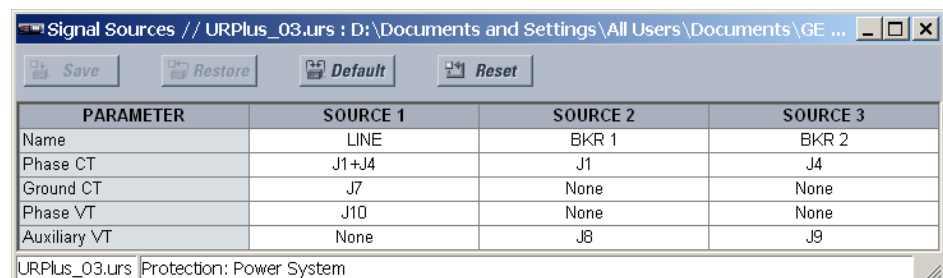
The previous section explains how input channels are identified and configured to the specific transformers and the connections of these transformers. The specific parameters to be used by each measuring element and comparator, and some actual values are controlled by selecting a specific source.

The source is a logical group of current and voltage input channels selected by the user to facilitate this selection. With this mechanism, a user does not have to make multiple selections of voltage and current for those elements that need both parameters, such as a distance element or a watt calculation. It also gathers associated parameters for display purposes. The basic idea of arranging a source is to select a point on the power system where information is of interest. An application example of the grouping of parameters in a source is a transformer winding, on which a three-phase voltage is measured, and the sum of the currents from CTs on each of two breakers is required to measure the winding current flow.

Signal source settings

Select the **Settings > Protection > Power System > Signal Sources** item to open the protection sources configuration window.

Figure 160: Protection sources configuration settings



PARAMETER	SOURCE 1	SOURCE 2	SOURCE 3
Name	LINE	BKR 1	BKR 2
Phase CT	J1+J4	J1	J4
Ground CT	J7	None	None
Phase VT	J10	None	None
Auxiliary VT	None	J8	J9

Settings are available for all three sources. The "LINE," "BKR1," and "BKR2" text items can be replaced with a user-defined name to uniquely identify the associated source.

It is possible to select the sum of two CTs for a protection source. The first channel displayed is the CT to which all others are referred. For example, the selection “J1+J4” indicates the sum of each phase from channels J1 and J4, scaled to whichever CT has the higher ratio.

To configure the protection sources:

1. Specify the ratio and nominal secondary current for each CT input.
2. Specify the connection type, ratio, and nominal secondary voltage for each VT input.
3. Specify the configuration for each source, including the CTs to be summed together.

The following settings are available for each protection source.

Name

Range: up to 20 alphanumeric characters

Default: LINE

This setting specifies a name for the protection source.

Phase CT

Range: None, J1, J4, J1+J4, etc.

Default: J1+J4

This setting selects a phase CT or sum of phase CTs to represent the protection source.

Ground CT

Range: None, J7

Default: J7

This setting selects a ground CT to represent the protection source.

Phase VT

Range: None, J10

Default: J10

This setting selects a phase VT to represent the protection source.

Auxiliary VT

Range: None, J8, J9

Default: None

This setting selects an auxiliary VT to represent the protection source.

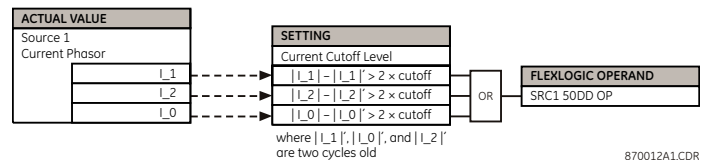
Internal disturbance detection

The disturbance detection element (ANSI 50DD) is a sensitive current disturbance detector that detects any disturbance on the protected system. This element is intended for use in conjunction with measuring elements, blocking of current based elements (to prevent maloperation as a result of the wrong settings), and starting oscillography data capture. A disturbance detector is provided for each source.

The disturbance detector responds to the changes in magnitude of the sequence currents. The disturbance detector also responds to the change in currents of twice the current cut-off level. The default cut-off threshold is 0.02 pu. As such, the disturbance detector responds to a change of 0.04 pu by default. The **Current Cutoff** setting (located in the **Settings > Protection > Power System > AC Input - Current** menu) controls the metering sensitivity of the disturbance detector.

The figure shows the source 1 disturbance detector logic. The logic is identical for all three sources.

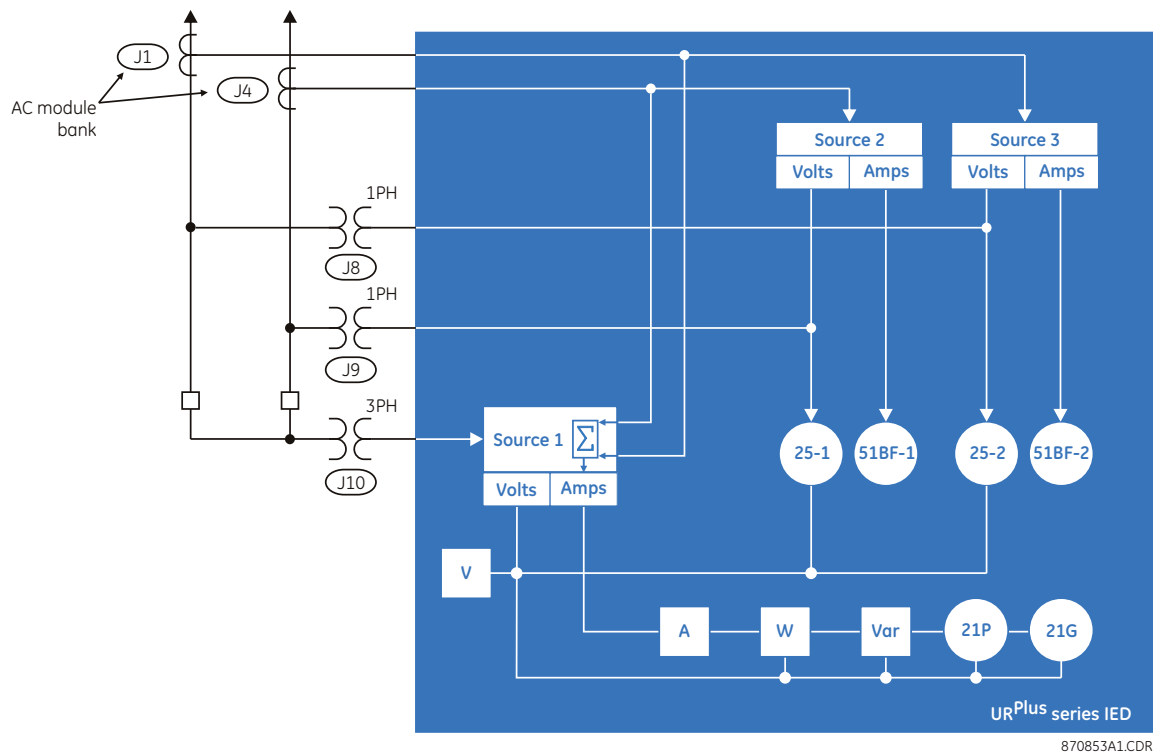
Figure 161: Disturbance detector logic



Use of sources example

Consider a D90^{Plus} connected as shown. This configuration can be used on a transmission line connected into a breaker-and-a-half system. The figure shows the arrangement of sources used to provide the functions required in this application, and the AC module inputs used to provide the data.

Figure 162: Use of sources example



Grouped protection elements

Each protection element can be assigned up to six sets of settings with designations 1 to 6. The performance of these elements is defined by the active setting group at a given time. Multiple setting groups allow the user to conveniently change protection settings for different operating situations (for example, altered power system configuration or season of the year). The active setting group can be preset or selected in the **Settings > Protection > Control > Setting Groups** menu.

Line pickup

The line pickup feature uses a combination of undercurrent and undervoltage to identify a line that has been de-energized (line end open). Alternately assign a FlexLogic operand to the Terminal Open setting that specifies the terminal status. Three instantaneous

overcurrent elements are used to identify a previously de-energized line that has been closed onto a fault. Faults other than close-in faults can be identified satisfactorily with the distance elements.

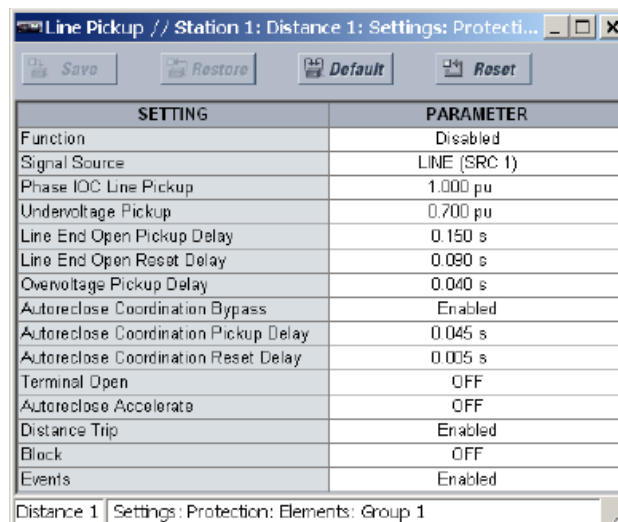
Co-ordination features are included to ensure satisfactory operation when high-speed automatic reclosure is employed. Co-ordination is achieved by all of the line pickup undervoltage elements resetting and blocking the trip path before the autoreclose co-ordination delay times out.

The line pickup protection incorporates zone 1 extension capability. When the line is being re-energized from the local terminal, pickup of an overreaching zone 2 or excessive phase current within eight power cycles after the autorecloser issues a close command results in the **LINE PICKUP RCL TRIP** FlexLogic operand. For security, the overcurrent trip is supervised by an undervoltage condition, which in turn is controlled by the **VT FUSE FAIL OP** operand with a 10 ms coordination timer. Configure the **LINE PICKUP RCL TRIP** operand to perform a trip action if the intent is zone 1 extension.

The zone 1 extension philosophy used here normally operates from an under-reaching zone, and it uses an overreaching distance zone when reclosing the line with the other line end open. The **Autoreclose Accelerate** setting is provided to achieve zone 1 extension functionality if external autoreclosure is employed. Another zone 1 extension approach is to apply permanently an overreaching zone, and reduce the reach when reclosing. This philosophy can be programmed via the autoreclose scheme.

Select the **Settings > Protection > Elements > Group 1 > Line Pickup** menu to open the line pickup configuration window. There is one line pickup element for each setting group.

Figure 163: Line pickup configuration window



SETTING	PARAMETER
Function	Disabled
Signal Source	LINE (SRC 1)
Phase IOC Line Pickup	1.000 pu
Undervoltage Pickup	0.700 pu
Line End Open Pickup Delay	0.150 s
Line End Open Reset Delay	0.090 s
Overvoltage Pickup Delay	0.040 s
Autoreclose Coordination Bypass	Enabled
Autoreclose Coordination Pickup Delay	0.045 s
Autoreclose Coordination Reset Delay	0.005 s
Terminal Open	OFF
Autoreclose Accelerate	OFF
Distance Trip	Enabled
Block	OFF
Events	Enabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the line pickup feature.

Signal Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for line pickup protection.

Phase IOC Line Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the level of line current required to declare a line pickup operation when the line is re-energized.

Undervoltage Pickup

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.700 pu

This setting specifies the level of line voltage required to declare that the line is de-energized, thereby arming the line pickup protection. The overcurrent and distance elements are supervised by the arming logic.

Line End Open Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.150 seconds

This setting specifies the time during which the line is de-energized before the line pickup logic is armed.

Line End Open Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.090 seconds

This setting specifies the time during which the line pickup logic remains armed once the line has been re-energized.

Overvoltage Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.040 seconds

This setting specifies the time during which the line pickup logic remains armed once the line voltage has returned to normal.

Autoreclose Coordination Bypass

Range: Enabled, Disabled

Default: Enabled

The coordination timer allows the overcurrent detector to be set below the expected load current seen after reclose. When this setting is enabled (the default value), the coordination timer is bypassed. Disable this setting (removing the bypass and inserting the timer) if high speed autoreclosure is employed.

Autoreclose Coordination Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.045 seconds

If the setting of the overcurrent detector is less than the load current, then it picks up during a normal re-energization of the line. This setting delays the assertion of the [LINE PICKUP OP](#) operand, allowing the recovery of the line voltage to block the scheme.

Autoreclose Coordination Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.005 seconds

This setting extends the assertion of the line pickup output when autoreclose coordination is not bypassed.

Terminal Open

Range: any FlexLogic operand

Default: OFF

This setting allows the line pickup element to be armed from a status signal (such as breaker position) rather than from current and voltage. The FlexLogic operand assigned to this setting indicates that the terminal is opened. It can be derived by combining the status of several devices in a FlexLogic equation.

Autoreclose Accelerate

Range: any FlexLogic operand

Default: OFF

This setting provides zone 1 extension functionality if external autoreclosure is employed.

Block

Range: any FlexLogic operand

Default: OFF

Assertion of the FlexLogic operand assigned to this setting blocks operation of the line pickup element.

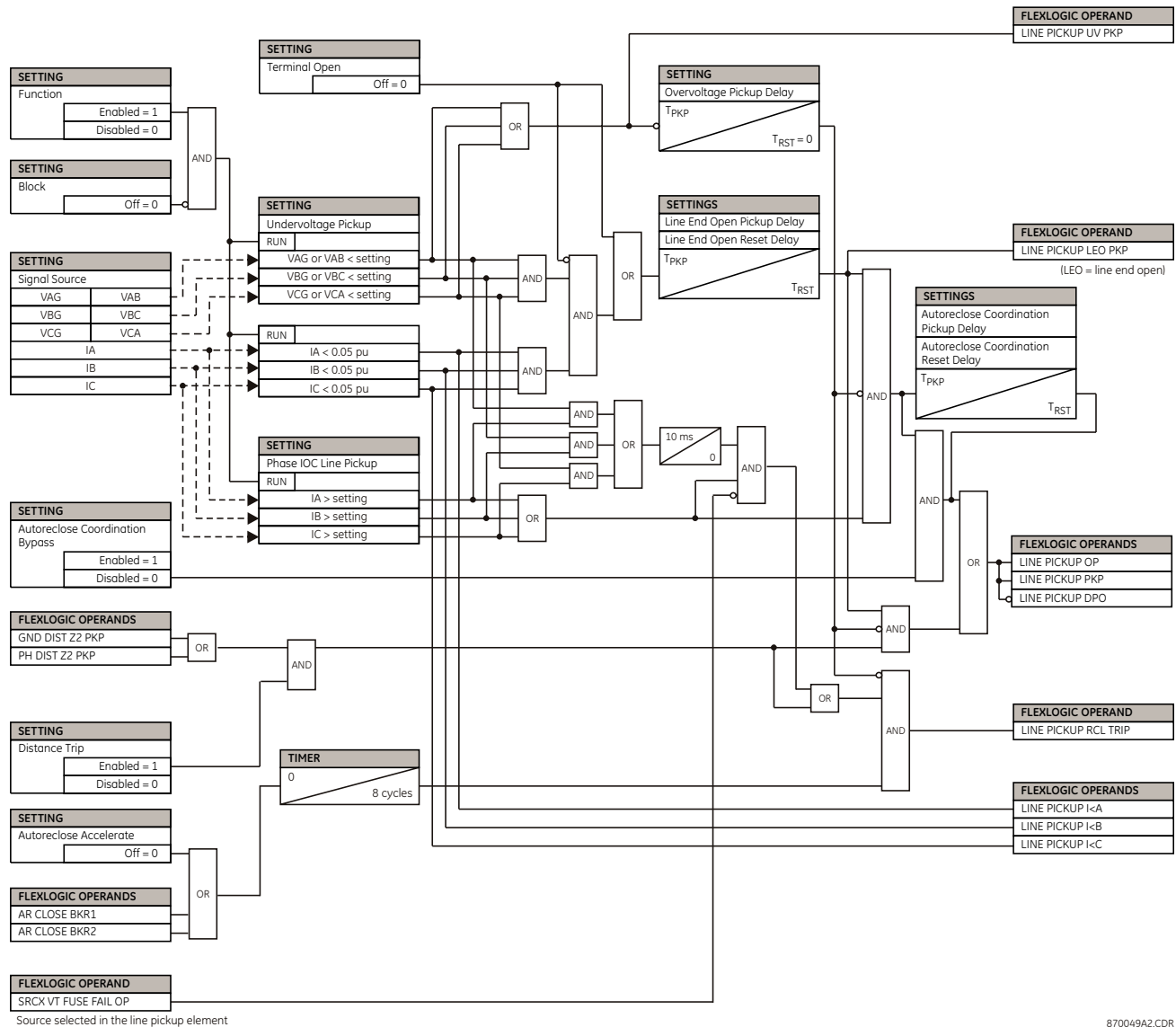
Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of line pickup events in the sequence of events recorder.

Figure 164: Line pickup scheme logic



Source selected in the line pickup element

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Distance elements

Four common settings are available for distance protection. Select the **Settings > Protection > Elements > Group 1 > Distance > Common** menu to open the distance configuration window.

Figure 165: Shared distance settings

SETTING	PARAMETER
Source	SRC 1 (SRC 1)
Memory Duration	10 cycles
Force Self-Polarization	OFF
Force Memory Polarization	OFF
CVT Filter Function	Disabled
CVT Filter T1	1.00 ms
CVT Filter T2	1.00 ms
CVT Filter Tx	1.00 ms

The following settings apply to all phase and ground distance elements. There are five ground distance and five phase distance zones of protection in each setting group.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting identifies the signal source for all distance functions. The mho distance functions use a dynamic characteristic; the positive-sequence voltage—either memorized or actual—is used as a polarizing signal. The memory voltage is also used by the built-in directional supervising functions applied for both the mho and quad characteristics.

Memory Duration

Range: 5 to 25 cycles in steps of 1

Default: 10 cycles

This setting specifies the length of time that a memorized positive-sequence voltage is used in the distance calculations. After this interval expires, the relay checks the magnitude of the actual positive-sequence voltage. If it is higher than 10% of the nominal, the actual voltage is used, and if lower the memory voltage continues to be used.

The memory is established when the positive-sequence voltage stays above 80% of its nominal value for five power system cycles. For this reason it is important to ensure that the nominal secondary voltage of the VT is entered correctly (in the **AC Inputs - Voltage** window).

Set **Memory Duration** long enough to ensure stability on close-in reverse three-phase faults. For this purpose, consider the maximum fault clearing time (breaker fail time) in the substation. On the other hand, the **Memory Duration** cannot be too long as the power system can experience power swing conditions rotating the voltage and current phasors slowly while the memory voltage is static, as frozen at the beginning of the fault. Keeping the memory in effect for too long can eventually lead to incorrect operation of the distance functions.

Force Self-Polarization

Range: any FlexLogic operand

Default: OFF

The distance zones can be forced to become self-polarized through this setting. Any user-selected condition (any FlexLogic operand) can be configured to force self-polarization. When the selected operand is asserted (logic 1), the distance functions become self-polarized regardless of other memory voltage logic conditions. When the selected operand is de-asserted (logic 0), the distance functions follow other conditions of the memory voltage logic shown in the following logic diagram.

Force Memory Polarization*Range: any FlexLogic operand**Default: OFF*

The distance zones can be forced to become memory-polarized through this setting. Any user-selected condition (any FlexLogic operand) can be configured to force memory polarization. When the selected operand is asserted (logic 1), the distance functions become memory-polarized regardless of the positive-sequence voltage magnitude at this time. When the selected operand is de-asserted (logic 0), the distance functions follow other conditions of the memory voltage logic.

CVT Filter Function*Range: Disabled, Enabled**Default: Disabled*

The CVT filter removes the transient response introduced by capacitively coupled voltage transformers (CVT), restoring the voltage waveforms to a faithful representation of the primary system voltage. This allows the distance element to achieve operating times comparable to those obtained when using magnetic VTs.

The CVT filter function is not required for the distance element operation but produces a considerable improvement in operating time.

Disable the CVT filter function if the T1, T2, and Tx parameters are not known (do not use the default values). Contact GE Grid Solutions for assistance in determining these settings.

CVT Filter T1*Range: 0.25 to 10.00 ms in steps of 0.01**Default: 1.00 ms*

This setting specifies the T1 parameter of the CVT filter. Disable the CVT filter function if this parameter is not known (do not use the default value). Contact GE Grid Solutions for assistance in determining this setting.

CVT Filter T2*Range: 0.25 to 10.00 ms in steps of 0.01**Default: 1.00 ms*

This setting specifies the T2 parameter of the CVT filter. Disable the CVT filter function if this parameter is not known (do not use the default value). Contact GE Grid Solutions for assistance in determining this setting.

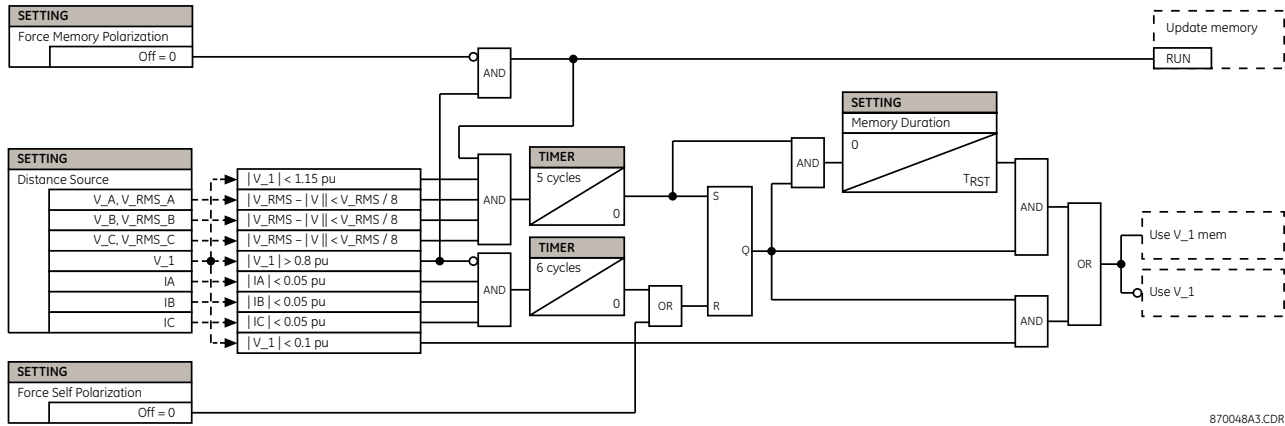
CVT Filter Tx*Range: 0.25 to 10.00 ms in steps of 0.01**Default: 1.00 ms*

This setting specifies the Tx parameter of the CVT filter. Disable the CVT filter function if this parameter is not known (do not use the default value). Contact GE Grid Solutions for assistance in determining this setting.

**NOTE**

Never let the **Force Self-Polarization** and **Force Memory Polarization** settings to be asserted simultaneously. If this happens, the logic gives higher priority to forcing self-polarization as indicated in the logic diagram. This is consistent with the overall philosophy of distance memory polarization. The memory polarization cannot be applied permanently but for a limited time only. The self-polarization can be applied permanently and therefore takes higher priority.

Figure 166: Memory voltage logic



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Impact of memory polarization

The D90^{Plus} uses a memorized positive sequence voltage as a polarizing signal in order to achieve dependable operation for forward faults and secure non-operation for reverse faults.

The dynamic shift of the characteristic ensures improved directionality, but it also means that if a backup function is required for a reverse fault on the bus, then it is appropriate to reverse zone 4 so that a time delayed backup function can be obtained. As mentioned earlier, it can be beneficial to also avoid extremely large reach settings by setting a remote backup so that it is reverse looking. This strategy can be beneficial if the reduced reach enhances the discrimination between the load and fault conditions.

Phase distance

The phase mho distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, and overcurrent supervising characteristics.

The phase quadrilateral distance function has a reactance characteristic, right and left blinders, and 100% memory-polarized directional and current supervising characteristics. When set as “Non-directional,” the mho function becomes an offset mho with the reverse reach controlled independently from the forward reach, and all the directional characteristics removed. When set to “Non-directional,” the quadrilateral function applies a reactance line in the reverse direction instead of the directional comparators.

Each phase distance zone is configured individually through its own setting menu. All of the settings can be independently modified for each of the zones except the common distance settings specified in the previous section.

The common distance settings must be properly chosen for correct operation of the phase distance elements.

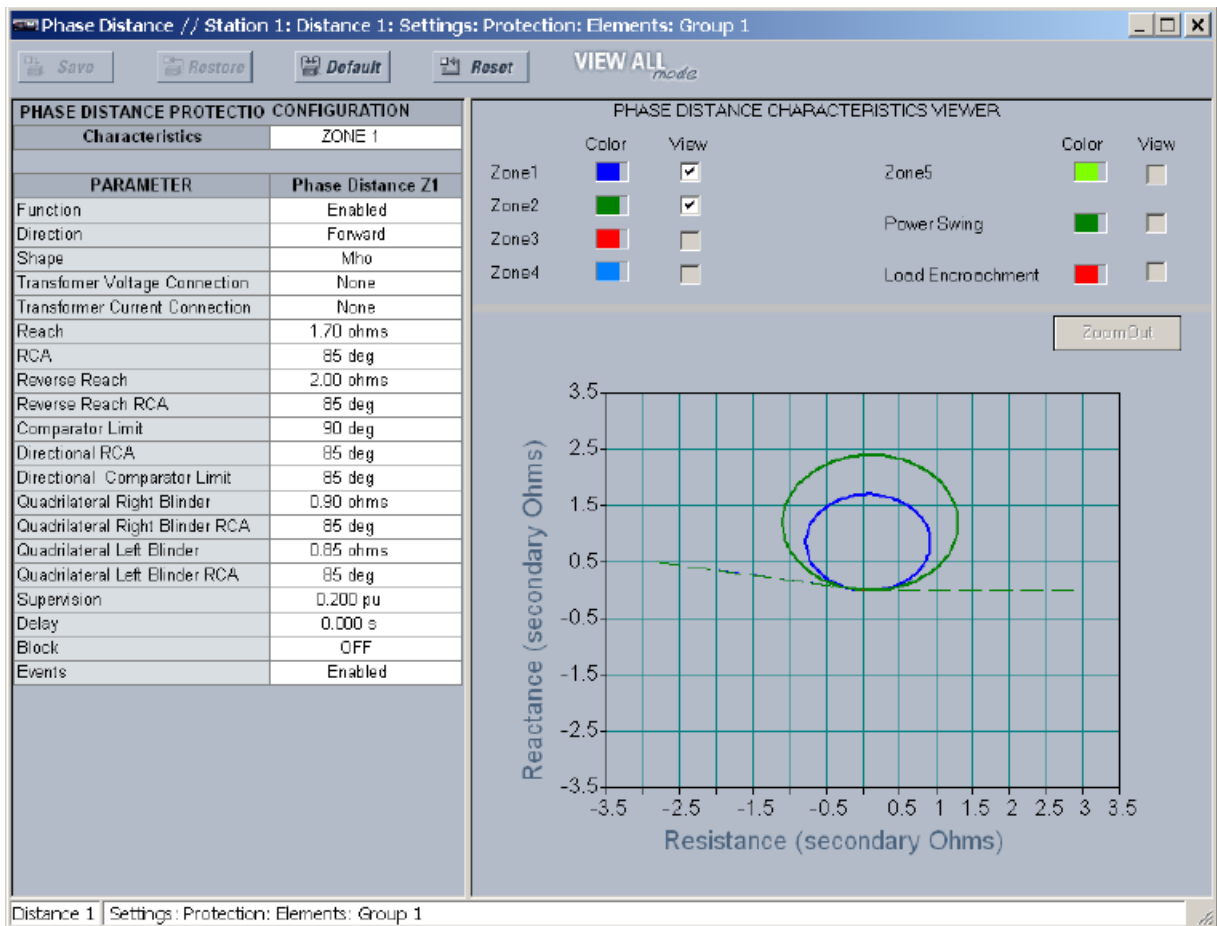
Although all zones can be used as either instantaneous elements (pickup [PKP] and dropout [DPO] FlexLogic operands) or time-delayed elements (operate [OP] FlexLogic operands), only zone 1 is intended for the instantaneous under-reaching tripping mode.

NOTICE

Ensure that the **Phase VT Secondary Voltage** setting is set correctly to prevent improper operation of the associated memory action.

Select the **Settings > Protection > Elements > Group 1 > Phase Distance** menu to open the phase distance configuration window.

Figure 167: Phase distance configuration window (example)



The following settings are available for each phase distance zone. There are five phase distance zones of protection in each setting group.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the phase distance protection feature.

Direction

Range: Forward, Reverse, Non-Directional

Default: Forward

All phase distance zones are reversible. The forward direction is defined by the **RCA** setting, whereas the reverse direction is shifted 180° from that angle. The non-directional zone spans between the forward reach impedance defined by the **Reach** and **RCA** settings, and the reverse reach impedance defined by **Reverse Reach** and **Reverse Reach RCA** settings as illustrated in the following figures.

Shape

Range: Mho, Quad

Default: Mho

This setting selects the shape of the phase distance function between the mho and quadrilateral characteristics. The selection is available on a per-zone basis. The two characteristics and their possible variations are shown in the following figures.

Figure 168: Directional mho phase distance characteristic

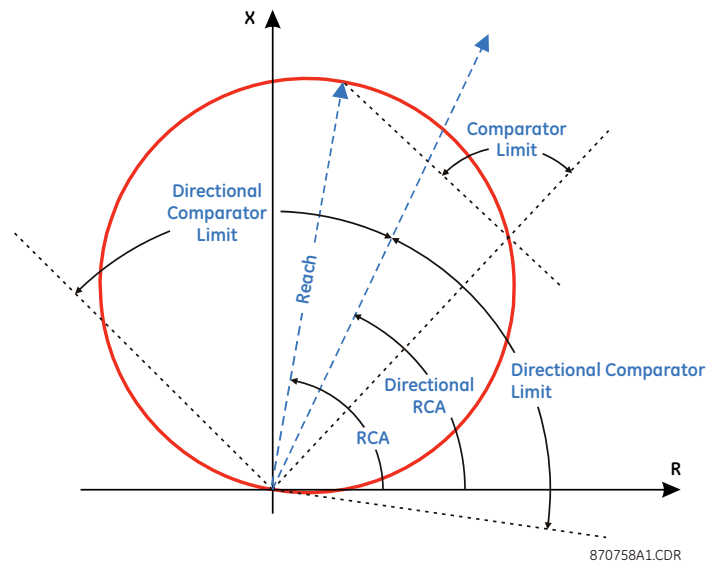


Figure 169: Non-directional mho phase distance characteristic

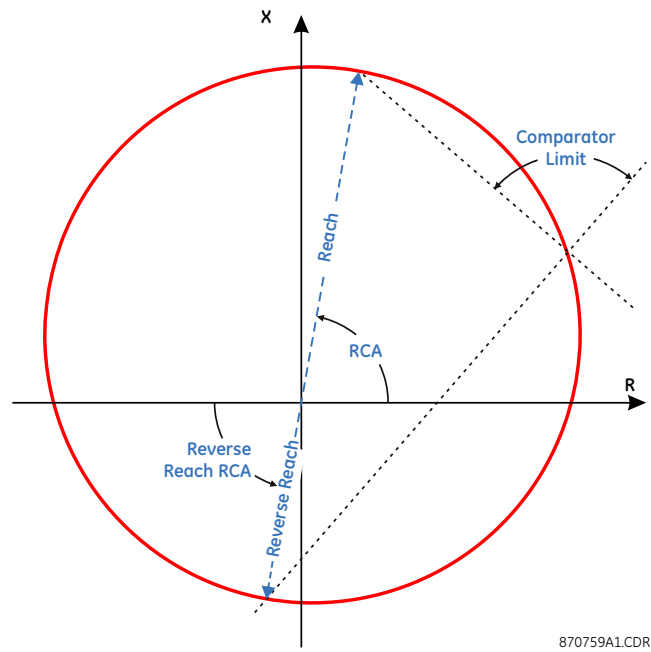
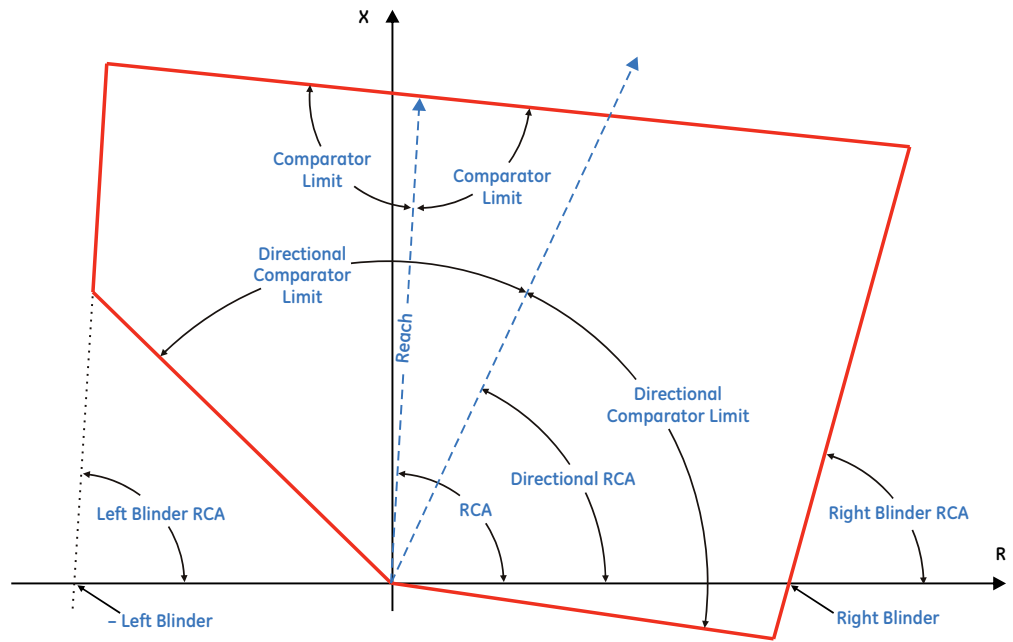
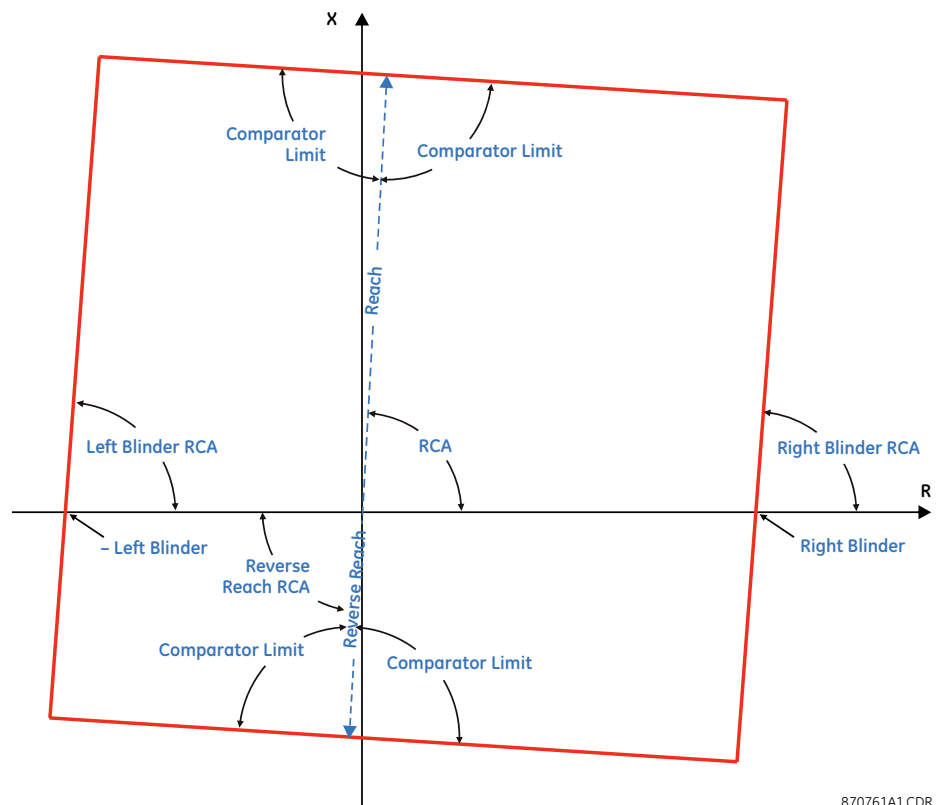


Figure 170: Directional quadrilateral phase distance characteristic



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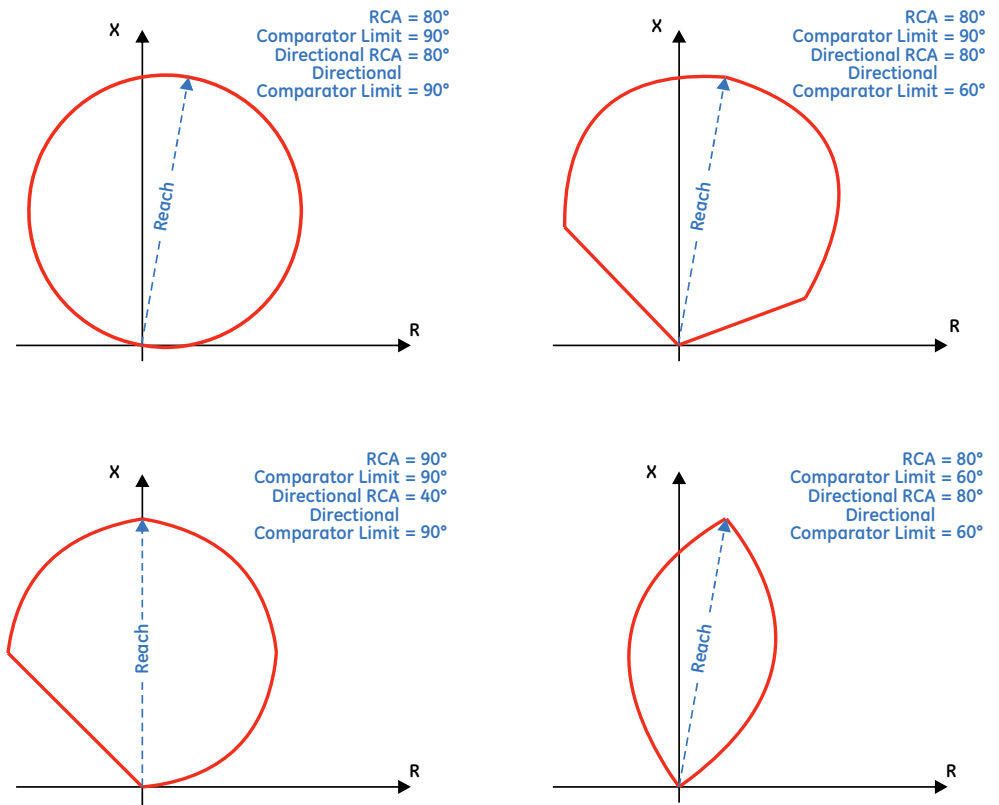
Figure 171: Non-directional quadrilateral phase distance characteristic



870761A1.CDR

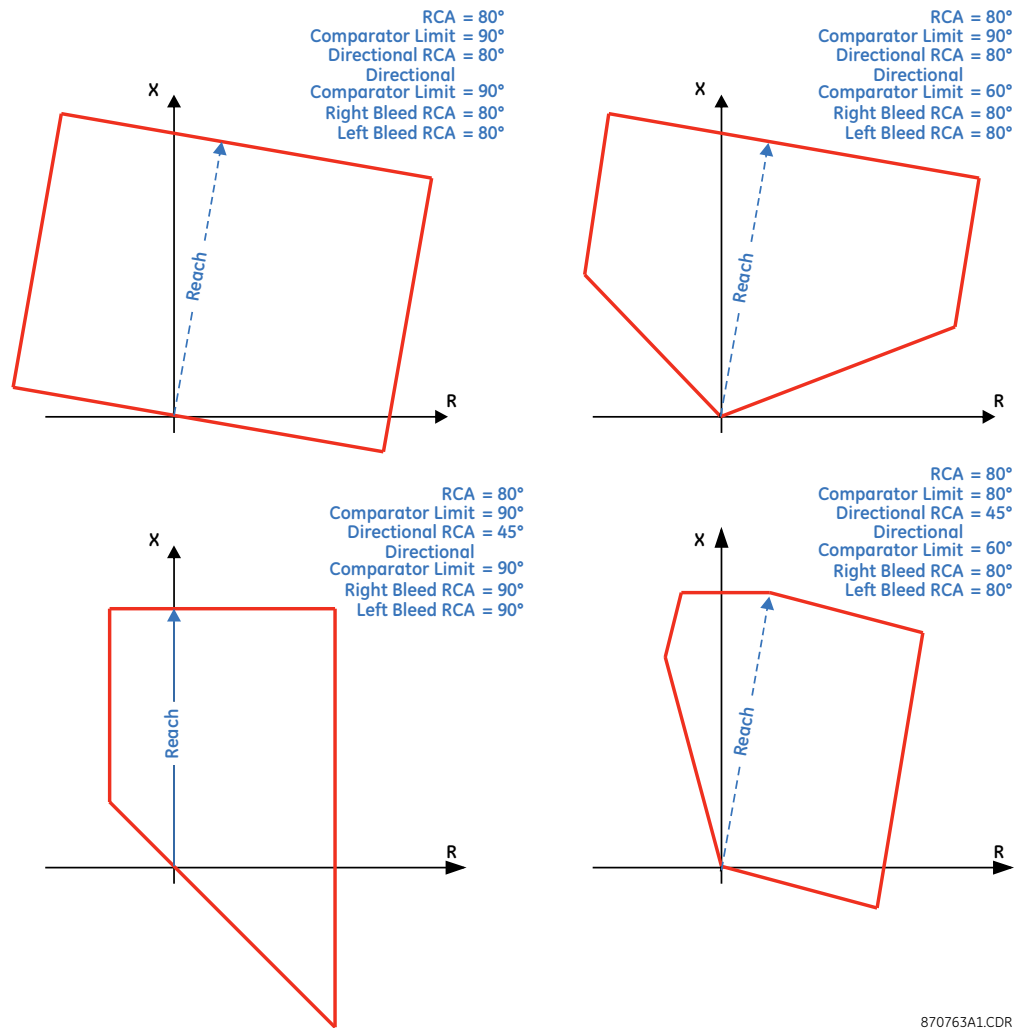
Sample shapes for the mho and quadrilateral distance characteristics are shown as follows.

Figure 172: Mho distance characteristic sample shapes



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Figure 173: Quadrilateral distance characteristic sample shapes



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Transformer Voltage Connection

Range: None, Dy1, Dy3, Dy5, Dy7, Dy9, Dy11, Yd1, Yd3, Yd5, Yd7, Yd9, Yd11

Default: None

The phase distance elements can be applied to look through a three-phase delta-wye or wye-delta power transformer. In addition, VTs and CTs can be located independently from one another at different windings of the transformer. If the potential source is located at the correct side of the transformer, set this value to "None."

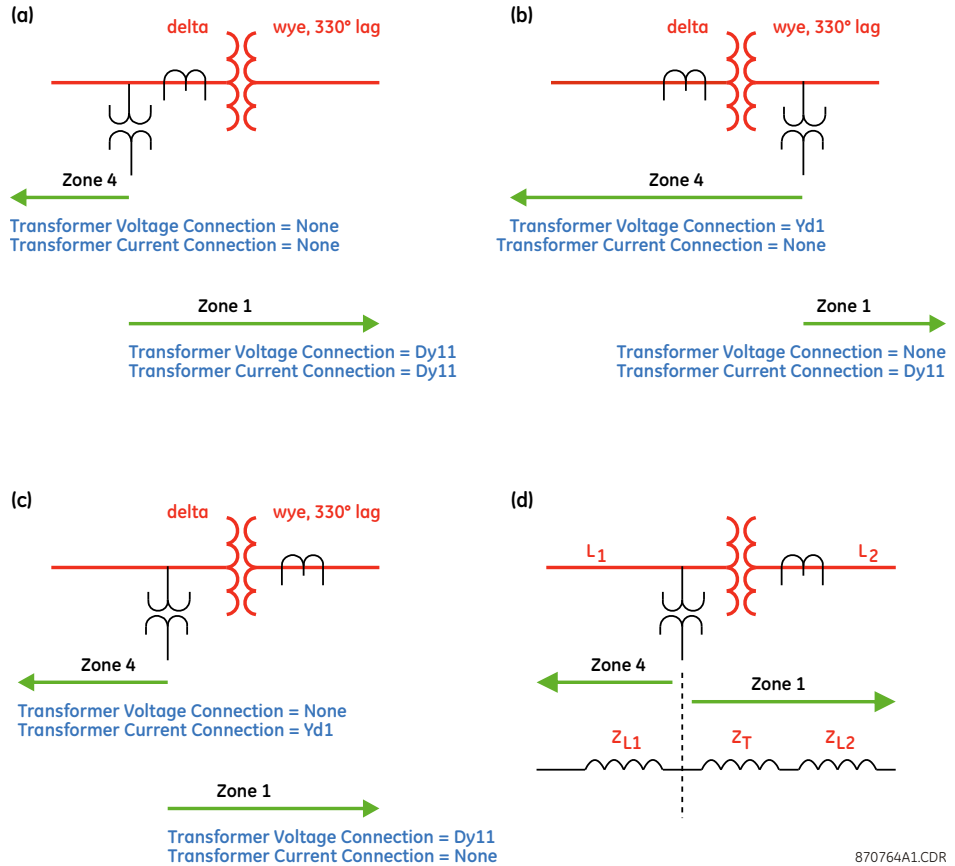
This setting specifies the location of the voltage source with respect to the involved power transformer in the direction of the zone. The following figure illustrates the usage of this setting. In section (a), zone 1 is looking through a transformer from the delta into the wye winding. Therefore, the zone 1 **Transformer Voltage Connection** is set to "Dy11." In section (b), zone 4 is looking through a transformer from the wye into the delta winding. Therefore, the zone 4 **Transformer Voltage Connection** is set to "Yd1". The zone is restricted by the potential point (location of the VTs) as illustrated in section (d).

Transformer Current Connection

Range: None, Dy1, Dy3, Dy5, Dy7, Dy9, Dy11, Yd1, Yd3, Yd5, Yd7, Yd9, Yd11
 Default: None

This setting specifies the location of the current source with respect to the involved power transformer in the direction of the zone. In section (a) of the following figure, zone 1 is looking through a transformer from the delta into the wye winding. Therefore, the zone 1 **Transformer Current Connection** is set to "Dy11." In section (b), the CTs are located at the same side as the read point. Therefore, the zone 4 **Transformer Current Connection** is set to "None."

Figure 174: Applications of the transformer voltage and current connection settings



Reach

Range: 0.02 to 500.00 ohms in steps of 0.01
 Default: 1.70 ohms

This setting specifies the zone reach for the forward and reverse applications. In the non-directional applications, this setting defines the forward reach of the zone. The reverse reach impedance in non-directional applications is set independently. The reach impedance is entered in secondary ohms. The reach impedance angle is entered as the **RCA** setting.

Zone 1 is characterized by transient overreach of less than 5% under source impedance ratios of up to 30. When setting an under-reaching zone 1 for direct tripping and under-reaching pilot schemes (DUTT, PUTT), also consider other factors as per rules of distance relaying. In non-directional applications, this 5% transient accuracy applies to the forward reach only.

RCA

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the characteristic angle (similar to the “maximum torque angle” in previous technologies) of the phase distance characteristic for the forward and reverse applications. In the non-directional applications, this setting defines the angle of the forward reach impedance. The reverse reach impedance in the non-directional applications is set independently. The setting is an angle of reach impedance as shown in the distance characteristic figures shown earlier. This setting is independent from the **Directional RCA** setting, the characteristic angle of an extra directional supervising function.

Reverse Reach

Range: 0.02 to 500.00 ohms in steps of 0.01

Default: 2.00 ohms

This setting specifies the reverse reach of the non-directional zone. The value must be entered in secondary ohms. This setting does not apply when the zone direction is set to “Forward” or “Reverse.”

Reverse Reach RCA

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the angle of the reverse reach impedance of the non-directional zone. This setting does not apply when the zone direction is set to “Forward” or “Reverse.”

Comparator Limit

Range: 30 to 90° in steps of 1

Default: 90°

This setting specifies the shape of the operating characteristic. In particular, it produces the lens-type characteristic of the mho function and a tent-shaped characteristic of the reactance boundary of the quadrilateral function. If the mho shape is selected, the same limit angle applies to both the mho and supervising reactance comparators. In conjunction with the mho shape selection, the setting improves loading of the protected line. In conjunction with the quadrilateral characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

Directional RCA

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the characteristic angle (or maximum torque angle) of the directional supervising function. If the mho shape is applied, the directional function is an extra supervising function as the dynamic mho characteristic is itself directional. In conjunction with the quadrilateral shape, this setting defines the only directional function built into the phase distance element. The directional function uses the memory voltage for polarization. This setting typically equals the distance characteristic angle specified by the **RCA** setting.

Directional Comparator Limit

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the comparator limit angle for the directional supervising function.

Quadrilateral Right Blinder

Range: 0.02 to 500.00 ohms in steps of 0.01

Default: 0.90 ohms

This setting specifies the right blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Phase Distance Characteristic figures). The angular position of the blinder is adjustable with the use of the **Quadrilateral Right Blinder RCA** setting. This setting applies only to the quadrilateral characteristic and is set giving consideration to the maximum load current and required resistive coverage.

Quadrilateral Right Blinder RCA

Range: 60 to 90° in steps of 1

Default: 85°

This setting specifies the angular position of the right blinder of the quadrilateral characteristic (see the Quadrilateral Phase Distance Characteristic figures).

Quadrilateral Left Blinder

Range: 0.02 to 500.00 ohms in steps of 0.01

Default: 0.85 ohms

This setting specifies the left blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Phase Distance Characteristic figures). The angular position of the blinder is adjustable with the use of the **Quadrilateral Left Blinder RCA** setting. This setting applies only to the quadrilateral characteristic and is set with consideration to the maximum load current.

Quad Left Blinder RCA

Range: 60 to 90° in steps of 1

Default: 85°

This setting specifies the angular position of the left blinder of the quadrilateral characteristic (see the Quadrilateral Phase Distance Characteristic figures).

Supervision

Range: 0.050 to 30.000 pu in steps of 0.001

Default: 0.200 pu

The phase distance elements are supervised by the magnitude of the line-to-line current (fault loop current used for the distance calculations). For convenience, $\sqrt{3}$ is accommodated by the pickup (that is, before being used, the entered value of the threshold setting is multiplied by $\sqrt{3}$).

If the minimum fault current level is sufficient, set the current supervision pickup above maximum full load current preventing maloperation under VT fuse fail conditions. This requirement can be difficult to meet for remote faults at the end of zones 2 through 5. If this is the case, set the current supervision pickup below the full load current, but this can result in maloperation during fuse fail conditions.

Zone 1 is sealed-in with current supervision.

Voltage Level

Range: 0.000 to 5.000 pu in steps of 0.001

Default: 0.000 pu

This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point where the zone does not overreach. For plain (non-compensated) lines, set to zero. Otherwise, the setting is entered in per unit of the phase VT bank configured in the distance **Source** setting. Effectively, this setting facilitates dynamic current-based reach reduction. In non-directional applications (the **Direction** is set to "Non-directional"), this setting applies only to the forward reach of the non-directional zone.



The use of dynamic reach control by selection of a non-zero value for the **Voltage Level** setting disables the subcycle operating time for that particular zone.

Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
Default: 0.000 seconds

This setting allows the user to delay operation of the distance elements and implement stepped distance protection. The distance element timers for zones 2 through 5 apply a short dropout delay to cope with faults located close to the zone boundary when small oscillations in the voltages or currents can inadvertently reset the timer. Zone 1 does not need any drop-out delay since it is sealed-in by the presence of current.

Block

Range: any FlexLogic operand
Default: OFF

This setting enables the user to select a FlexLogic operand to block a given distance element. VT fuse fail detection is one of the applications for this setting.

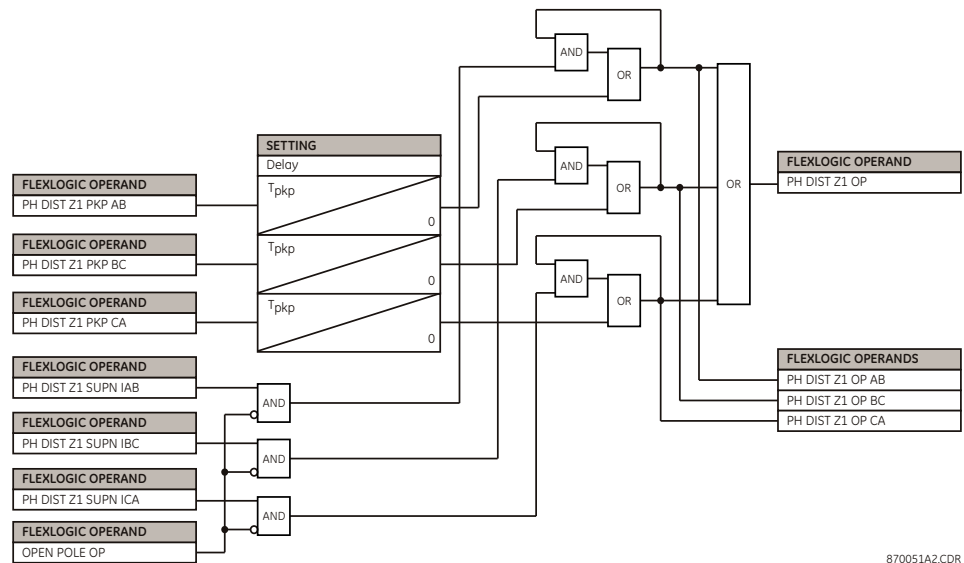
Events

Range: Enabled, Disabled
Default: Enabled

This setting enables and disables the logging of phase distance events in the sequence of events recorder.

The following figure shows phase distance operation scheme logic for zone 1.

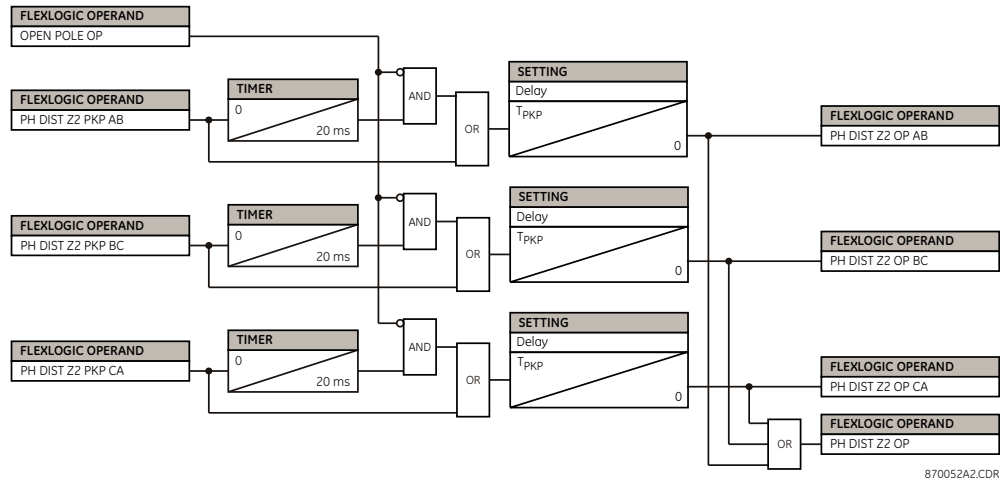
Figure 175: Phase distance zone 1 operation logic



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The following figure shows the phase distance operation scheme logic for zone 2. The logic is analogous for zones 3 through 5.

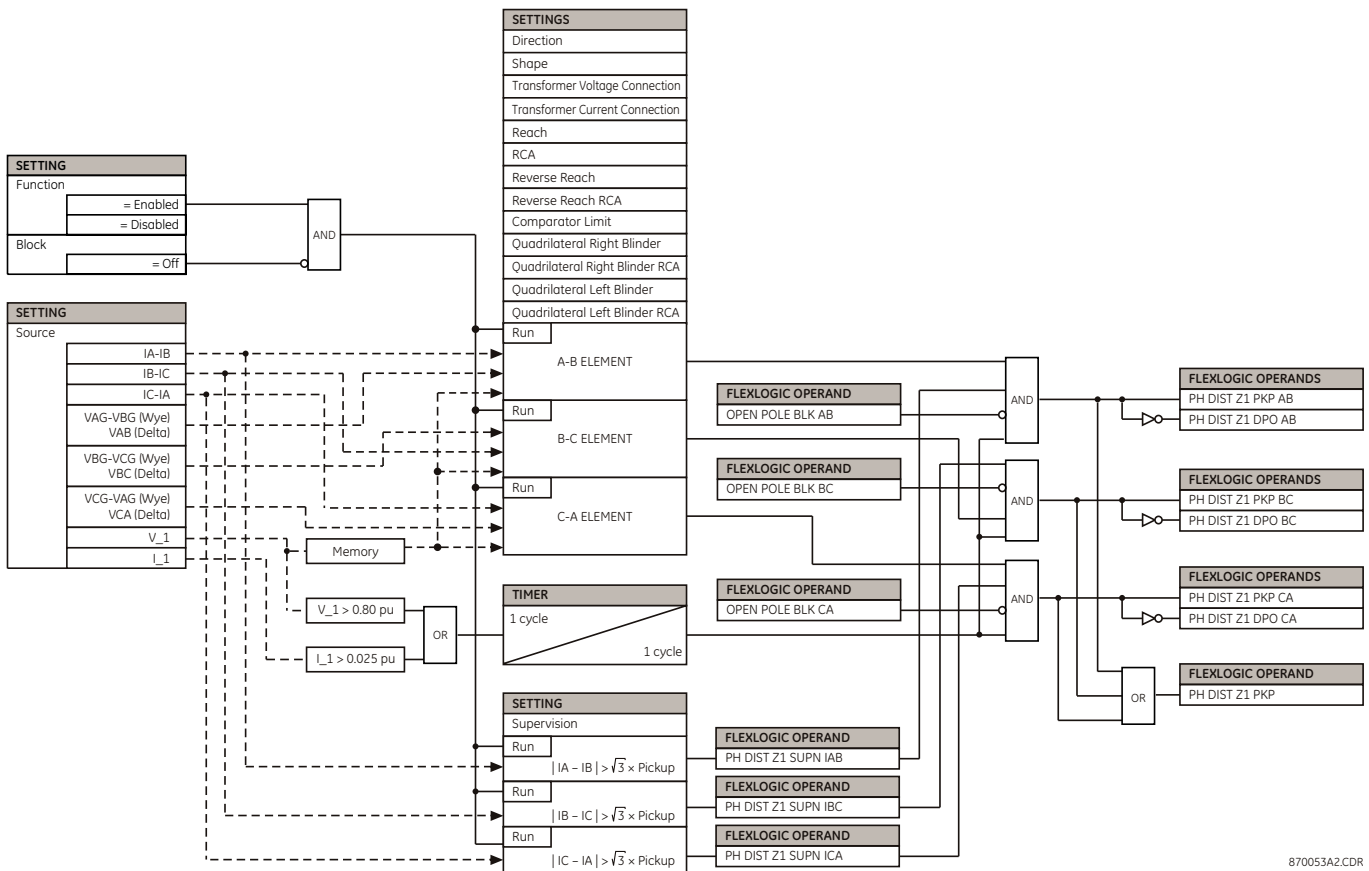
Figure 176: Phase distance zone 2 operation logic



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The following figure shows the phase distance scheme logic for zone 1. The logic is analogous for zones 2 through 5.

Figure 177: Phase distance logic



870052A2.CDR

Ground distance settings

The ground mho distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, current, and phase selection supervising characteristics. The ground quadrilateral distance function is composed of a reactance characteristic, right and left blinders, and 100% memory-polarized directional, overcurrent, and phase selection supervising characteristics.

When set to non-directional, the mho function becomes an offset mho with the reverse reach controlled independently from the forward reach, and all the directional characteristics removed. When set to non-directional, the quadrilateral function applies a reactance line in the reverse direction instead of the directional comparators.

The reactance supervision for the mho function uses the zero-sequence current for polarization. The reactance line of the quadrilateral function uses either zero-sequence or negative-sequence current as a polarizing quantity. The selection is controlled by a user setting and depends on the degree of non-homogeneity of the zero-sequence and negative-sequence equivalent networks.

The directional supervision uses memory voltage as polarizing quantity and both zero- and negative-sequence currents as operating quantities.

The phase selection supervision restrains the ground elements during double-line-to-ground faults as they, by the principles of distance relaying, can be inaccurate in such conditions. Ground distance zones 2 through 5 apply additional zero-sequence directional supervision.

Each ground distance zone is configured individually through its own setting menu.

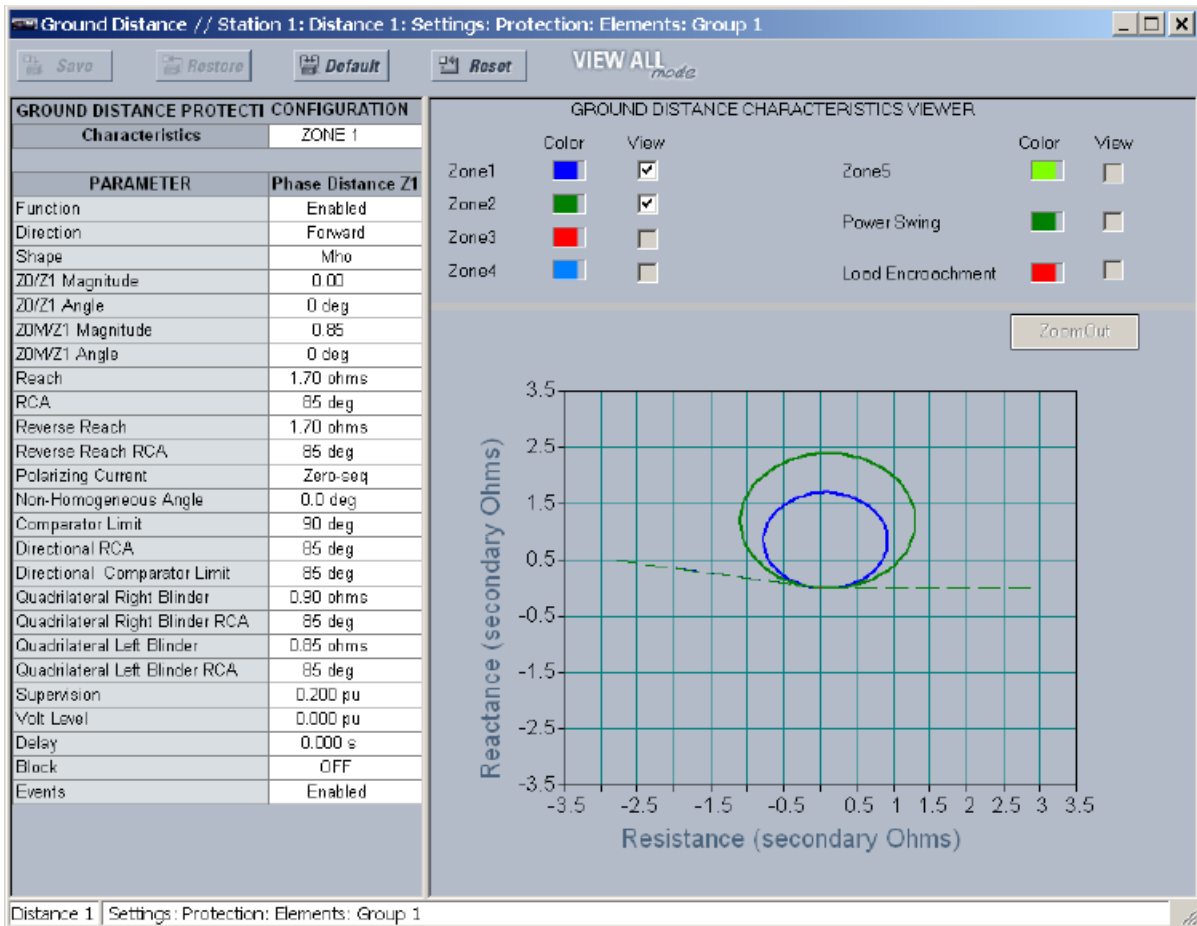
Although all ground distance zones can be used as either instantaneous elements (pickup [PKP] and dropout [DPO] FlexLogic signals) or time-delayed elements (operate [OP] FlexLogic signals), only zone 1 is intended for the instantaneous under-reaching tripping mode.

NOTICE

Ensure that the **Phase VT Secondary Voltage** setting is programmed correctly to prevent improper operation of associated memory action.

Select the **Settings > Protection > Elements > Group 1 > Ground Distance** menu to open the ground distance configuration window. There are five zones of ground distance protection for each setting group.

Figure 178: Ground distance settings configuration



The following settings are available for each ground distance zone. There are five ground distance zones of protection in each setting group.

Function

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the phase distance protection feature.

Direction

Range: Forward, Reverse, Non-directional
 Default: Forward

All ground distance zones are reversible. The forward direction is defined by the **RCA** setting and the reverse direction is shifted by 180° from that angle. The non-directional zone spans between the forward reach impedance defined by the **Reach** and **RCA** settings, and the reverse reach impedance defined by the **Reverse Reach** and **Reverse Reach RCA** settings.

Shape

Range: Mho, Quad
 Default: Mho

This setting selects the shape of the ground distance characteristic between the mho and quadrilateral characteristics. The selection is available on a per-zone basis.

The figures show the directional and non-directional mho and quadrilateral ground distance characteristics.

Figure 179: Directional mho ground distance characteristic

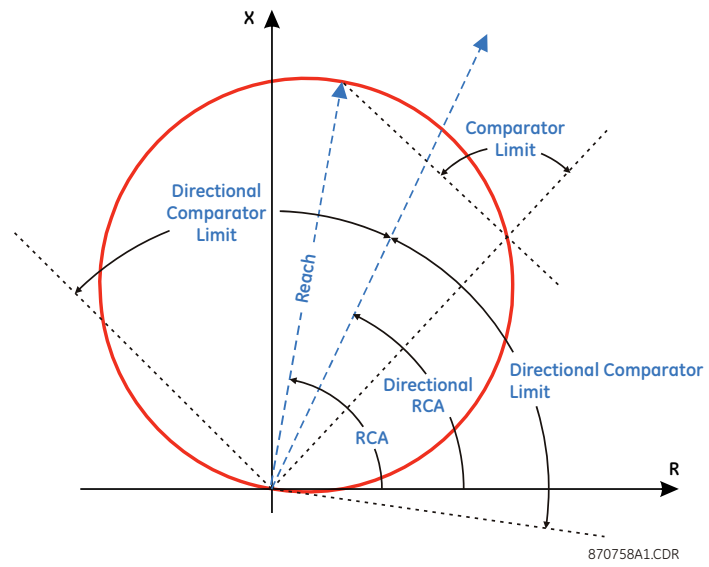


Figure 180: Non-directional mho ground distance characteristic

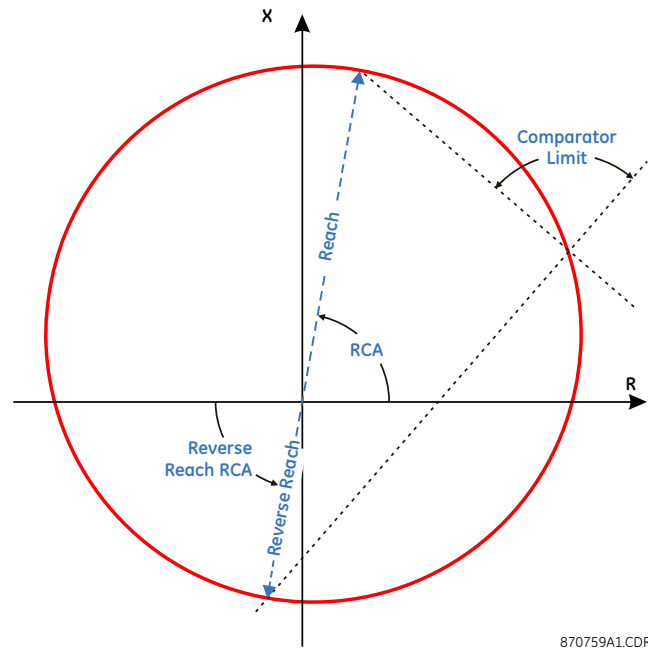
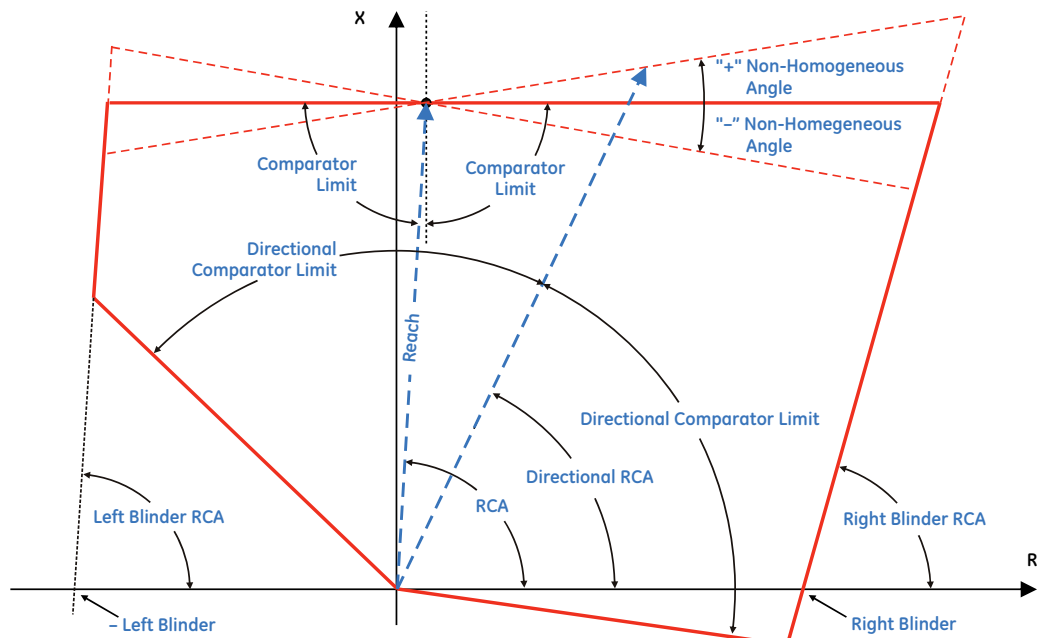
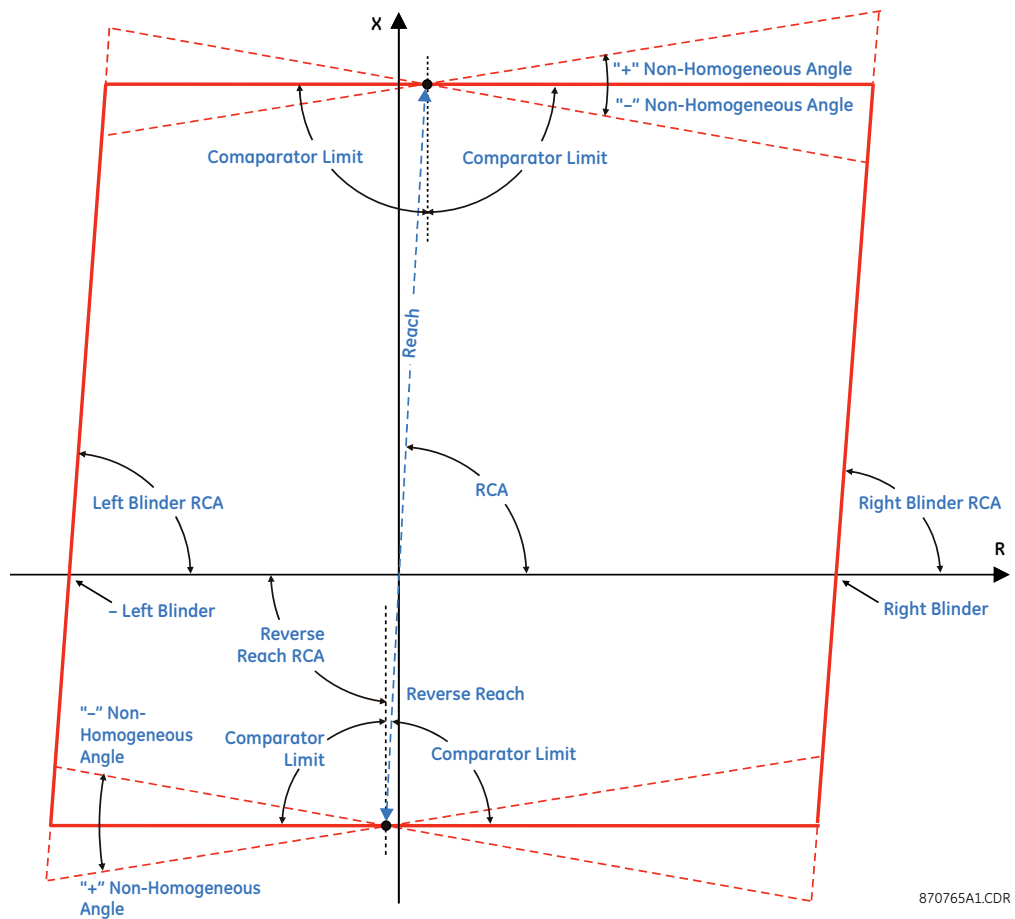


Figure 181: Directional quadrilateral ground distance characteristic



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Figure 182: Non-directional quadrilateral ground distance characteristic



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Z0/Z1 Magnitude

Range: 0.00 to 10.00 in steps of 0.01

Default: 2.70

This setting specifies the ratio between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. This setting is available on a per-zone basis, enabling precise settings for tapped, non-homogeneous, and series compensated lines.

Z0/Z1 Angle

Range: -90 to 90° in steps of 1

Default: 0°

This setting specifies the angle difference between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. The entered value is the zero-sequence impedance angle minus the positive-sequence impedance angle. This setting is available on a per-zone basis, enabling precise values for tapped, non-homologous, and series-compensated lines.

Z0M/Z1 Magnitude

Range: 0.00 to 7.00 in steps of 0.01

Default: 0.00

The ground distance elements can be programmed to apply compensation for the zero-sequence mutual coupling between parallel lines. If this compensation is required, the ground current from the parallel line (3I₀) measured in the direction of the zone being compensated must be connected to the ground input CT of the CT bank configured in the **Distance > Common > Source** setting. This setting specifies the ratio between the magnitudes of the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line. Set this setting to zero if the compensation is not to be performed.

Z0M/Z1 Angle

Range: -90 to 90° in steps of 1

Default: 0°

This setting specifies the angle difference between the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line.

Reach

Range: 0.02 to 500.00 ohms in steps of 0.01

Default: 2.00 ohms

This setting specifies the reach of the zone for the forward and reverse applications. In non-directional applications, this setting defines the forward reach of the zone. The reverse reach impedance in non-directional applications is set independently. The angle of the reach impedance is entered as the **RCA** setting. The reach impedance is entered in secondary ohms.

RCA

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the characteristic angle (similar to the maximum torque angle in previous technologies) of the ground distance characteristic for the forward and reverse applications. In the non-directional applications, this setting defines the forward reach of the zone. The reverse reach impedance in the non-directional applications is set independently. This setting is independent from the **Directional RCA** setting (the characteristic angle of an extra directional supervising function).

The relay internally performs zero-sequence compensation for the protected circuit based on the values entered for the **Z0/Z1 Magnitude** and **Z0/Z1 Angle** settings, and if configured to do so, zero-sequence compensation for mutual coupling based on the values entered for the **Z0M/Z1 Magnitude** and **Z0M/Z1 Angle** settings. As such, enter the **Reach** and **RCA** settings in terms of positive-sequence quantities.

Reverse Reach

Range: 0.02 to 500.00 ohms in steps of 0.01

Default: 2.00 ohms

This setting specifies the reverse reach of the zone set as non-directional. The value must be entered in secondary ohms. This setting does not apply when the zone direction is set to "Forward" or "Reverse."

Reverse Reach RCA

Range: 30 to 90° in steps of 1

Default: 85°

This setting specifies the angle of the reverse reach impedance if the zone is set to non-directional. This setting does not apply when the zone direction is set to "Forward" or "Reverse."

Polarizing Current

Range: Zero-sequence, Negative-Sequence

Default: Zero-sequence

This setting applies only if the **Shape** is set to "Quad" and controls the polarizing current used by the reactance comparator of the quadrilateral characteristic. Either the zero-sequence or negative-sequence current can be used. In general, a variety of system conditions must be examined to select an optimum polarizing current. This setting becomes less relevant when the resistive coverage and zone reach are set conservatively. Also, this setting is more relevant in lower voltage applications such as on distribution lines or cables, as compared with high-voltage transmission lines. This setting applies to both the zone 1 and reverse reactance lines if the zone is set to non-directional.

Non-Homogeneous Angle

Range: -40.0 to 40.0° in steps of 0.1

Default: 0.0°

This setting applies only if the **Shape** is set to "Quad" and provides a method to correct the angle of the polarizing current of the reactance comparator for non-homogeneity of the zero-sequence or negative-sequence networks. In general, a variety of system conditions must be examined to select this setting. In many applications this angle is used to reduce the reach at high resistances in order to avoid overreaching under far-out reach settings and/or when the sequence networks are greatly non-homogeneous. This setting applies to both the forward and reverse reactance lines if the zone is set to non-directional.

Comparator Limit

Range: 30 to 90° in steps of 1

Default: 90°

This setting shapes the operating characteristic. In particular, it enables a lens-shaped characteristic of the mho function and a tent-shaped characteristic of the quadrilateral function reactance boundary. If the mho shape is selected, the same limit angle applies to mho and supervising reactance comparators. In conjunction with the mho shape selection, this setting improves loadability of the protected line. In conjunction with the quadrilateral characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

Directional RCA*Range: 30 to 90° in steps of 1**Default: 85°*

The setting specifies the characteristic angle (or maximum torque angle) of the directional supervising function. If the mho shape is applied, the directional function is an extra supervising function, as the dynamic mho characteristic itself is a directional one. In conjunction with the quadrilateral shape selection, this setting defines the only directional function built into the ground distance element. The directional function uses memory voltage for polarization.

Directional Comparator Limit*Range: 30 to 90° in steps of 1**Default: 90°*

This setting specifies the comparator limit angle for the directional supervising function.

Quadrilateral Right Blinder*Range: 0.02 to 500.00 ohms in steps of 0.01**Default: 10.00 ohms*

This setting specifies the right blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane. The angular position of the blinder is adjustable with the use of the [Quadrilateral Right Blinder RCA](#) setting. This setting applies only to the quadrilateral characteristic; set it with consideration to the maximum load current and required resistive coverage.

Quadrilateral Right Blinder RCA*Range: 60 to 90° in steps of 1**Default: 85°*

This setting specifies the angular position of the right blinder of the quadrilateral characteristic.

Quadrilateral Left Blinder*Range: 0.02 to 500.00 ohms in steps of 0.01**Default: 10.00 ohms*

This setting specifies the left blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane. The angular position of the blinder is adjustable with the use of the [Quadrilateral Left Blinder RCA](#) setting. This setting applies only to the quadrilateral characteristic; set it with consideration to the maximum load current.

Quadrilateral Left Blinder RCA*Range: 60 to 90° in steps of 1**Default: 85°*

This setting specifies the angular position of the left blinder of the quadrilateral characteristic.

Supervision*Range: 0.050 to 30.000 pu in steps of 0.001**Default: 0.200 pu*

The ground distance elements are supervised by the magnitude of the neutral (3I₀) current. Set the current supervision pickup to be less than the minimum 3I₀ current for the end of the zone fault, taking into account the required fault resistance coverage to prevent maloperation due to VT fuse failure. Settings less than 0.2 pu are not recommended, so apply them with caution. To enhance ground distance security against spurious neutral current during switch-off transients, three-phase faults, and phase-to-phase faults, a positive-sequence current restraint of 5% is applied to the neutral current supervision magnitude.

Set this setting at least three times the **Current Cutoff Level** setting specified in the **Settings > Protection > Power System > AC Inputs - Current** menu. Zone 1 is sealed in with the current supervision.

Voltage Level

Range: 0.000 to 5.000 pu in steps of 0.001
 Default: 0.000 pu

This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point for which the zone shall not overreach. For plain (non-compensated) lines, set it to zero. Otherwise, the setting is entered in per unit of the VT bank configured under the distance **Source** setting. Effectively, this setting facilitates dynamic current-based reach reduction. In non-directional applications, this setting applies only to the forward reach of the non-directional zone.



The use of dynamic reach control by selection of a non-zero value for the **Voltage Level** setting disables the subcycle operating time for that particular zone.

Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
 Default: 0.000 seconds

This setting enables the user to delay operation of the distance elements and implement a stepped distance backup protection. The distance element timer applies a short drop-out delay to cope with faults located close to the boundary of the zone when small oscillations in the voltages or currents can inadvertently reset the timer.

Block

Range: any FlexLogic operand
 Default: Off

This setting enables the user to select a FlexLogic operand to block the given ground distance element. VT fuse fail detection is one of the applications for this setting.

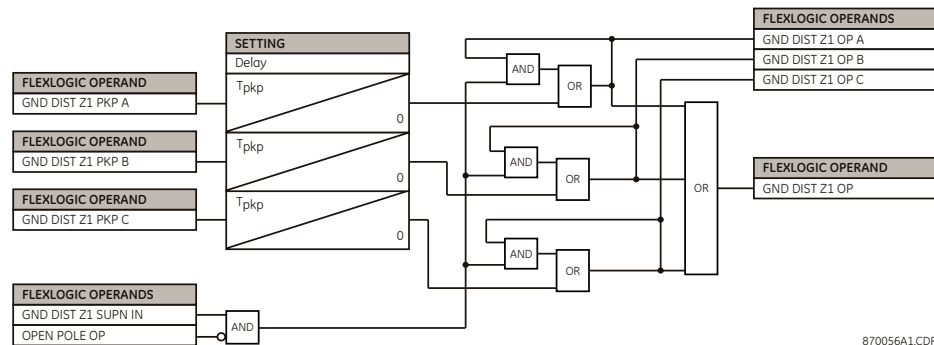
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of ground distance events in the sequence of events recorder.

The following figure shows the ground distance operation scheme for zone 1.

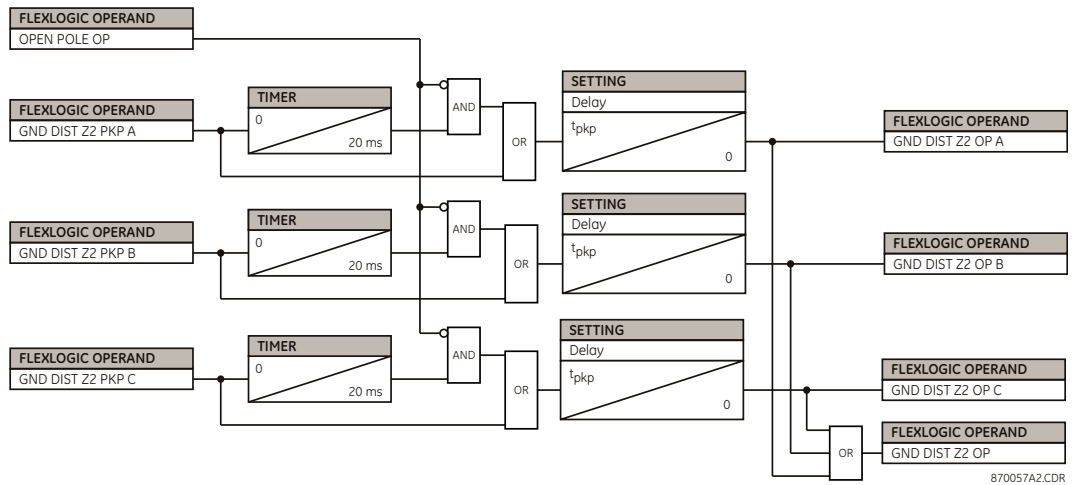
Figure 183: Ground distance zone 1 operation logic



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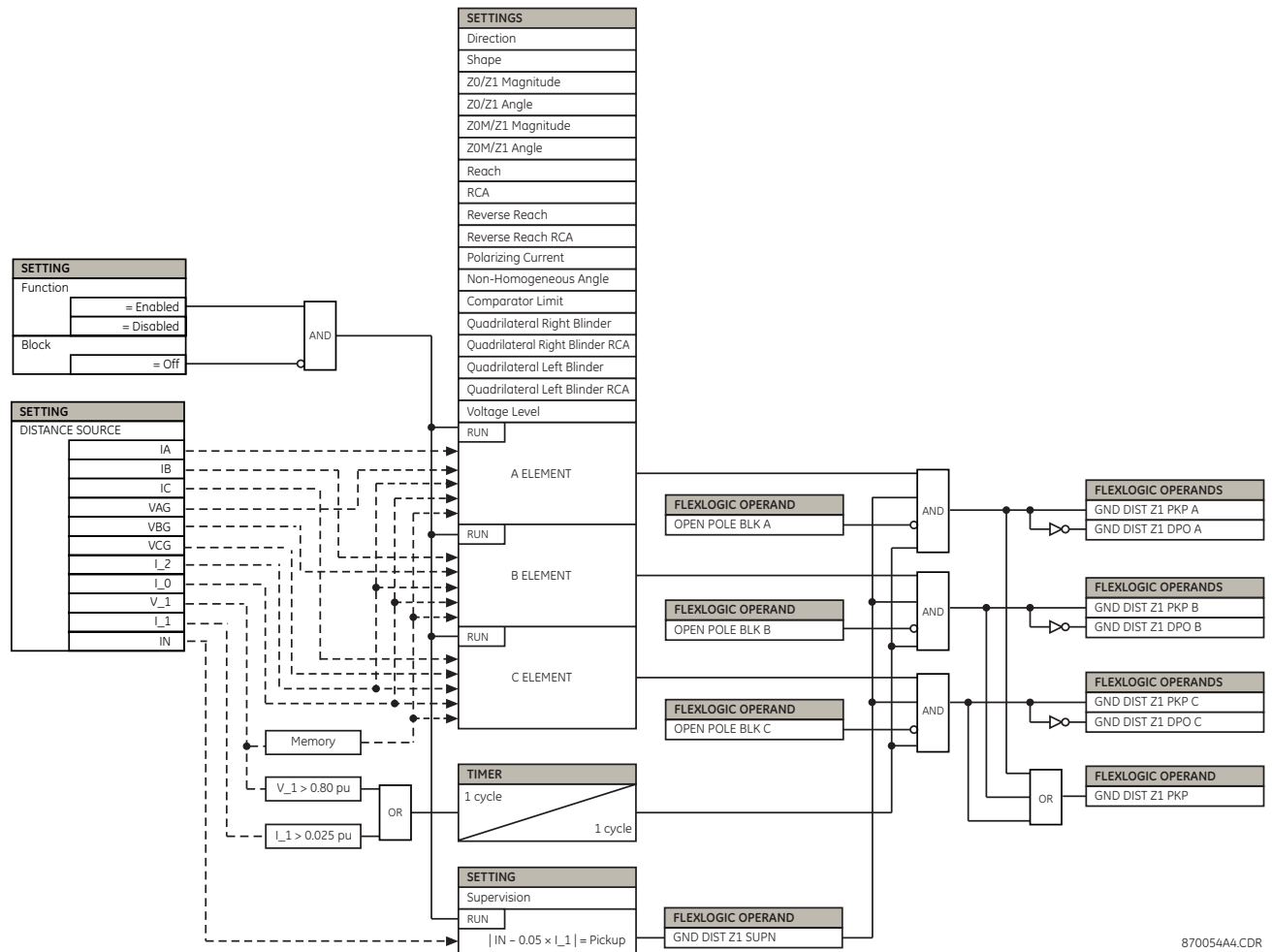
The following figure shows the ground distance operation scheme for zone 2. The logic is analogous for zones 3 through 5.

Figure 184: Ground distance zone 2 operation logic



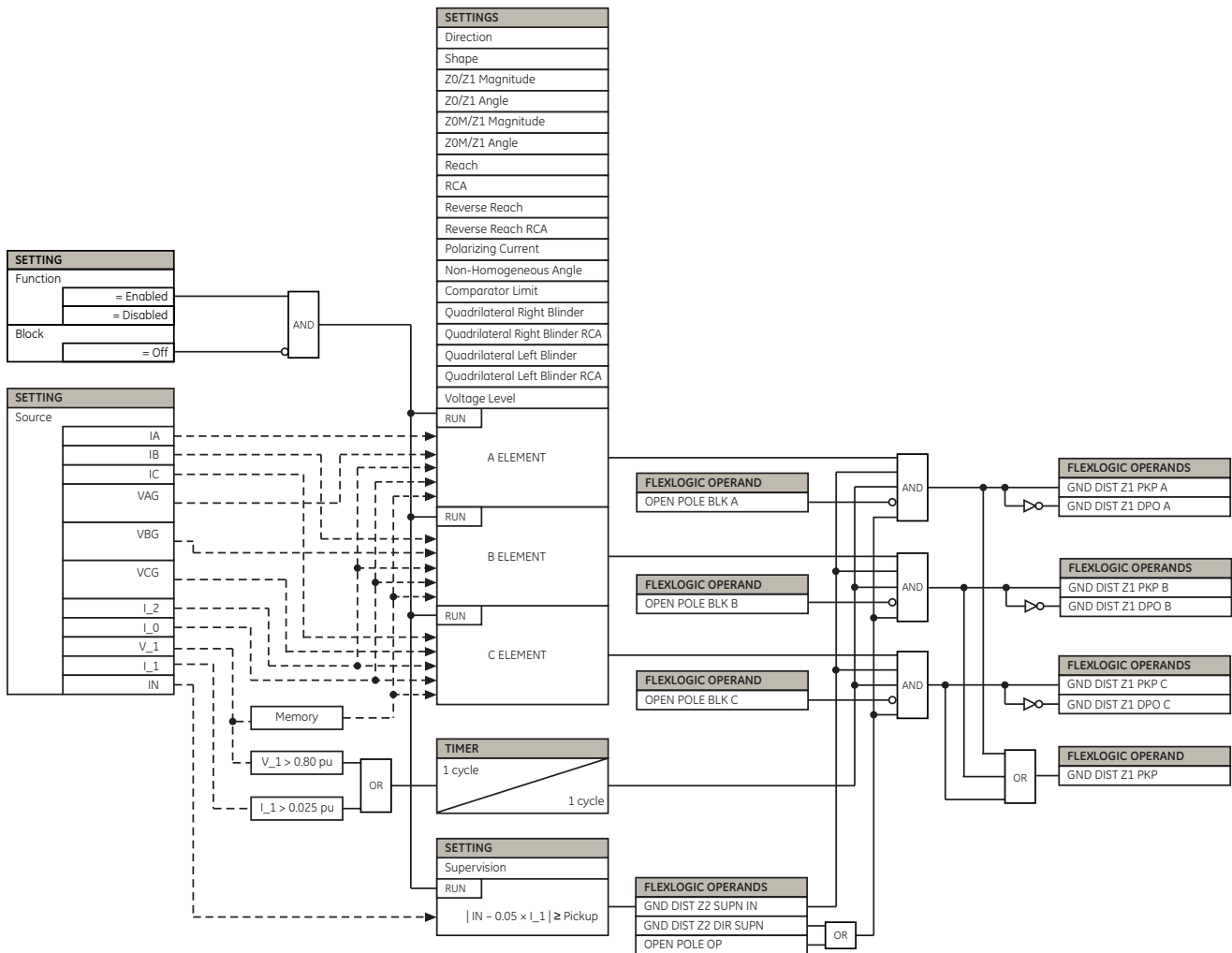
The following figure shows the ground distance scheme logic for zone 1.

Figure 185: Ground distance zone 1 logic



The following figure shows the ground distance scheme logic for zone 2. The logic is analogous for zones 3 through 5.

Figure 186: Ground distance zone 2 logic



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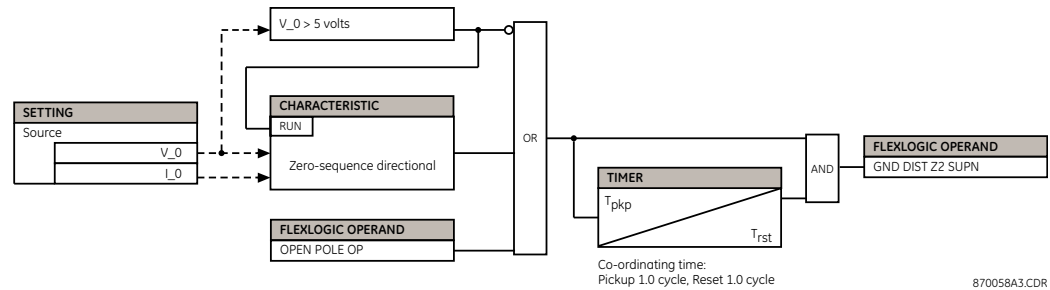
Ground directional supervision

A dual (zero-sequence and negative-sequence) memory-polarized directional supervision applied to the ground distance protection elements has been shown to give good directional integrity. However, a reverse double-line-to-ground fault can lead to bad operation of the ground element in a sound phase if the zone reach setting is increased to cover high resistance faults.

Ground distance zones 2 through 5 use an additional ground directional supervision to enhance directional integrity. The element’s directional characteristic angle is used as a maximum torque angle together with a 90° limit angle.

The supervision is biased toward operation in order to avoid compromising the sensitivity of ground distance elements at low signal levels. Otherwise, the reverse fault condition that generates concern has high polarizing levels so that a correct reverse fault decision can be reliably made. The supervision for zones 2, 3, and 5 is removed during open pole conditions.

Figure 187: Ground directional supervision logic



Power swing detect

The power swing detect element provides both power swing blocking and out-of-step tripping functions. The element measures the positive-sequence apparent impedance and traces its locus with respect to either two or three user-selectable operating characteristic boundaries. Upon detecting appropriate timing relations, the blocking and/or tripping indications are given through FlexLogic operands. The element incorporates an adaptive disturbance detector. This function does not trigger on power swings, but is capable of detecting faster disturbances—faults in particular—that can occur during power swings. Operation of this dedicated disturbance detector is signaled via the **POWER SWING 50DD** operand.

The power swing detect element asserts two operands intended for blocking selected protection elements on power swings: **POWER SWING BLOCK** is a traditional signal that is safely asserted for the entire duration of the power swing, and **POWER SWING UN/BLOCK** is established in the same way, but resets when an extra disturbance is detected during the power swing. The **POWER SWING UN/BLOCK** operand can be used for blocking selected protection elements if the intent is to respond to faults during power swing conditions.

Different protection elements respond differently to power swings. If tripping is required for faults during power swing conditions, some elements can be blocked permanently (using the **POWER SWING BLOCK** operand), and others can be blocked and dynamically unblocked upon fault detection (using the **POWER SWING UN/BLOCK** operand).

View the operating characteristic and logic figures along with the following discussion to understand the operation of the element.

The power swing detect element operates in three-step or two-step mode, as follows:

- Three-step operation** — The power swing blocking sequence essentially times the passage of the locus of the positive-sequence impedance between the outer and the middle characteristic boundaries. If the locus enters the outer characteristic (indicated by the **POWER SWING OUTER** FlexLogic operand) but stays outside the middle characteristic (indicated by the **POWER SWING MIDDLE** FlexLogic operand) for an interval longer than the **Delay 1 Pickup** setting, the power swing blocking signal (**POWER SWING BLOCK** FlexLogic operand) is established and sealed-in. The blocking signal resets when the locus leaves the outer characteristic, but not sooner than the time specified by the **Delay 1 Reset** setting.
- Two-step operation** — If the two-step mode is selected, the sequence is identical to the three-step operation, but it is the outer and inner characteristics that are used to time the power swing locus.

The out-of-step tripping feature operates as follows for three-step and two-step power swing detection modes:

- Three-step operation** — The out-of-step trip sequence identifies unstable power swings by determining if the impedance locus spends a finite time between the outer and middle characteristics and then a finite time between the middle and inner characteristics. The first step is similar to the power swing blocking sequence. After

the timer specified by the **Delay 1 Pickup** setting times out, latch 1 is set as long as the impedance stays within the outer characteristic.

If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the middle characteristic but stays outside the inner characteristic for a period of time defined by the **Delay 2 Pickup** setting, latch 2 is set as long as the impedance stays inside the outer characteristic. If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the inner characteristic and stays there for a period of time defined the **Delay 3 Pickup** setting, latch 2 is set as long as the impedance stays inside the outer characteristic; the element is now ready to trip.

If the “Early” trip mode is selected, the **POWER SWING TRIP** operand is set immediately and sealed-in for the interval set by the **Seal-In Delay** setting. If the “Delayed” trip mode is selected, the element waits until the impedance locus leaves the inner characteristic, then times out for the **Pickup Delay 2** setting and sets latch 4; the element is now ready to trip. The trip operand is set later, when the impedance locus leaves the outer characteristic.

- **Two-step operation** — Similar to the three-step mode with two exceptions. First, the initial stage monitors the time spent by the impedance locus between the outer and inner characteristics. Second, the stage involving the **Delay 2 Pickup** timer is bypassed. It is up to the user to integrate the blocking (**POWER SWING BLOCK**) and tripping (**POWER SWING TRIP**) FlexLogic operands with other protection functions and output contacts in order to make this element fully operational.

The element can be set to use either lens (mho) or rectangular (quadrilateral) characteristics, as shown in the figure. When set to “Mho,” the element applies the right and left blinders as well. If the blinders are not required, set their settings high enough to effectively disable the blinders.

Figure 188: Power swing detect mho operating characteristic

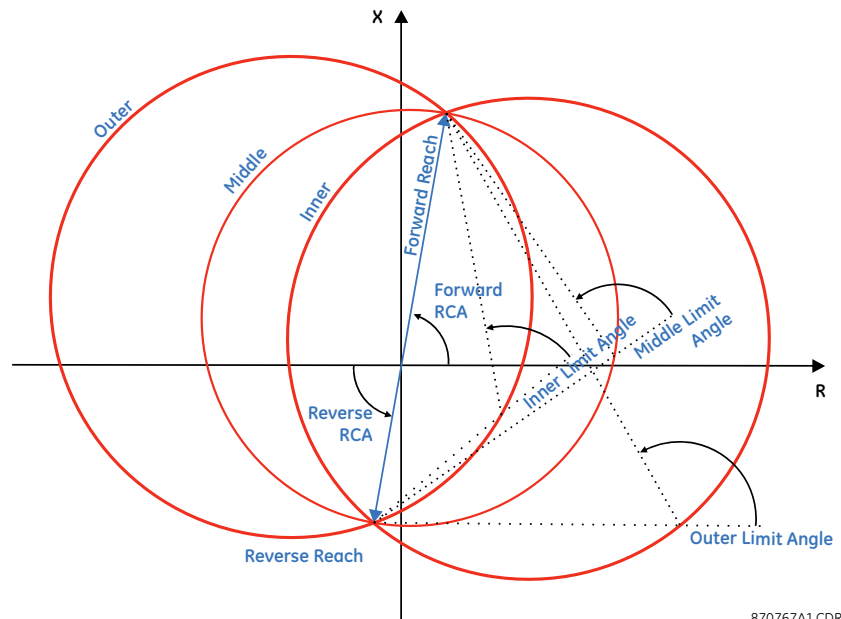
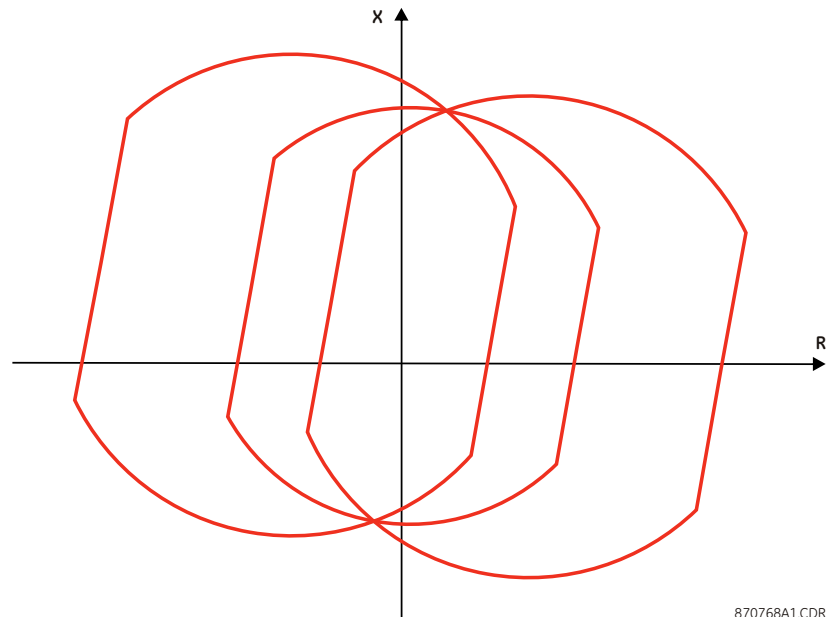
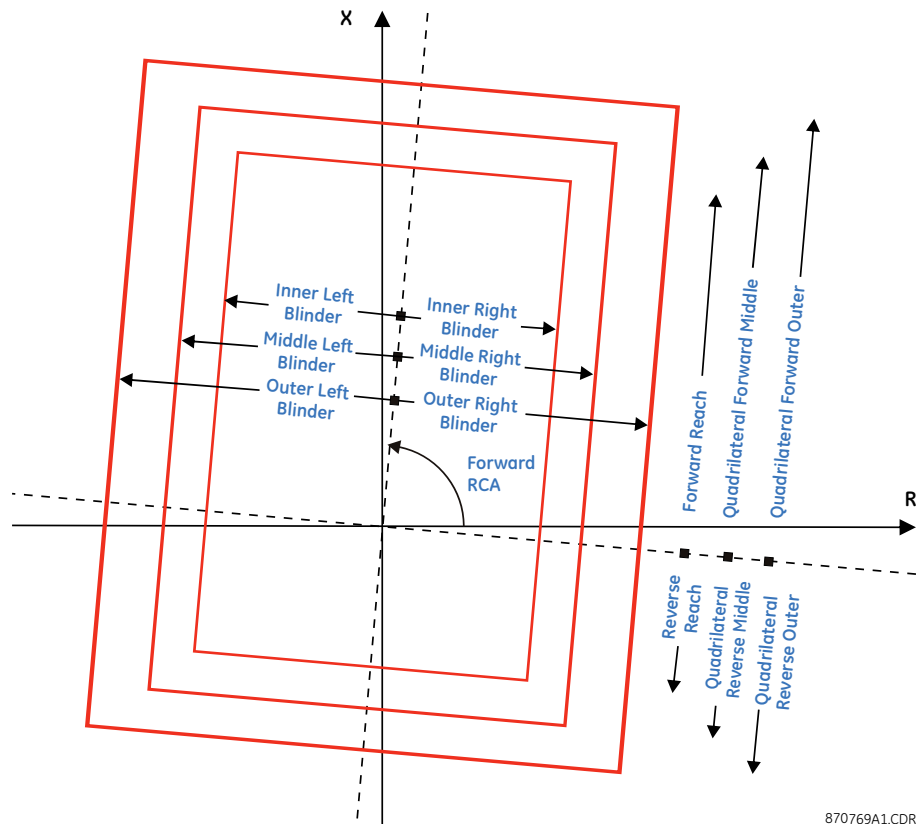


Figure 189: Effect of blinders on the mho operating characteristic



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Figure 190: Power swing detect quadrilateral operating characteristic



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The FlexLogic output operands for the power swing detect element are as follows.

Power swing detection operands

POWER SWING 50DD.....Asserted when the power swing detection element detects a disturbance other than a power swing.

- POWER SWING BLOCK Asserted when the power swing detection blocking element operates.
- POWER SWING INCOMING Asserted when an unstable power swing is detected (incoming locus).
- POWER SWING INNER Asserted when the positive-sequence impedance is in the inner characteristic.
- POWER SWING MIDDLE Asserted when the positive-sequence impedance is in the middle characteristic.
- POWER SWING OUTER Asserted when the positive-sequence impedance is in the outer characteristic.
- POWER SWING OUTGOING Asserted when an unstable power swing is detected (outgoing locus).
- POWER SWING TMR1 PKP Asserted when power swing timer 1 picks up.
- POWER SWING TMR2 PKP Asserted when power swing timer 2 picks up.
- POWER SWING TMR3 PKP Asserted when power swing timer 3 picks up.
- POWER SWING TMR4 PKP Asserted when power swing timer 4 picks up.
- POWER SWING UN/BLOCK Asserted when the out-of-step tripping function operates.

Select the **Settings > Protection > Elements > Group 1 > Power Swing Detect** menu to open the power swing detect configuration window.

Figure 191: Power swing detect configuration window

SETTING	PARAMETER
Function	Disabled
Source	LINE (SRC 1)
Shape	Mho Shape
Mode	Two Step
Slupv	0.600 pu
Fwd Reach	2.50 ohms
Quad Fwd Mid	60.00 ohms
Quad Fwd Out	70.00 ohms
Fwd Rca	85 deg
Reverse Reach	1.00 ohms
Quad Rev Mid	60.00 ohms
Quad Rev Out	70.00 ohms
Rev Rca	85 deg
Outer Limit Angle	120 deg
Middle Limit Angle	90 deg
Inner Limit Angle	60 deg
Outer Rgt Bld	10.00 ohms
Outer Lt Bld	10.00 ohms
Middle Rgt Bld	10.00 ohms
Middle Lt Bld	10.00 ohms
Inner Rgt Bld	10.00 ohms
Inner Lt Bld	10.00 ohms
Delay 1 Pickup	0.030 s
Delay 1 Reset	0.060 s
Delay 2 Pickup	0.017 s
Delay 3 Pickup	0.009 s
Delay 4 Pickup	0.017 s
Sea-In Delay	0.400 s
Trip Mode	Delayed
Block	OFF
Event	Enabled

The following power swing detect settings are available. There is one power swing detect element for each setting group.

Function*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables the power swing detection element. The setting applies to both power swing blocking and out-of-step tripping functions.

Source*Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)**Default: LINE (SRC 1)*

This setting selects the signal source for both blocking and tripping functions.

Shape*Range: Mho, Quad**Default: Mho*

This setting selects the shapes (either mho or quadrilateral) of the outer, middle, and inner characteristics of the power swing detect element. The operating principle is not affected. The mho characteristics use the left and right blinders.

Mode*Range: Two Step, Three Step**Default: Two Step*

This setting selects between the two-step and three-step operating modes and applies it to both power swing blocking and out-of-step tripping functions. The three-step mode applies if there is enough space between the maximum load impedances and distance characteristics of the relay that all three (outer, middle, and inner) characteristics can be placed between the load and the distance characteristics. Whether the spans between the outer and middle as well as the middle and inner characteristics are sufficient is determined by analysis of the fastest power swings expected in correlation with settings of the power swing timers.

The two-step mode uses only the outer and inner characteristics for both blocking and tripping functions. This leaves more space in heavily loaded systems to place two power swing characteristics between the distance characteristics and the maximum load, but allows for only one determination of the impedance trajectory.

Supervision*Range: 0.050 to 30.000 pu in steps of 0.001**Default: 0.600*

A common overcurrent pickup level supervises all three power swing characteristics. The supervision responds to the positive-sequence current.

Forward Reach*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 2.50 ohms*

This setting specifies the forward reach of all three mho characteristics and the inner quadrilateral characteristic. For a simple system consisting of a line and two equivalent sources, this reach needs to be higher than the sum of the line and remote source positive-sequence impedances. Detailed transient stability studies can be needed for complex systems in order to determine this setting. The angle of this reach impedance is specified by the [Forward RCA](#) setting.

Quadrilateral Forward Middle*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 60.00 ohms*

This setting specifies the forward reach of the middle quadrilateral characteristic. The angle of this reach impedance is specified by the [Forward RCA](#) setting. The setting is not used if the shape setting is "Mho."

Quadrilateral Forward Outer*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 70.00 ohms*

This setting specifies the forward reach of the outer quadrilateral characteristic. The angle of this reach impedance is specified by the **Forward RCA** setting. The setting is not used if the shape setting is "Mho."

Forward RCA*Range: 40 to 90° in steps of 1**Default: 85°*

This setting specifies the angle of the forward reach impedance for the mho characteristics, angles of all blinders, and both forward and reverse reach impedances of the quadrilateral characteristics.

Reverse Reach*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 1.00 ohms*

This setting specifies the reverse reach of all three mho characteristics and the inner quadrilateral characteristic. For a simple system of a line and two equivalent sources, this reach needs to be higher than the positive-sequence impedance of the local source. Detailed transient stability studies can be needed for complex systems to determine this setting. The angle of this reach impedance is specified by the **Reverse RCA** setting for "Mho," and the **Forward RCA** setting for inner "Quad."

Quadrilateral Reverse Middle*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 60.00 ohms*

This setting specifies the reverse reach of the middle quadrilateral characteristic. The angle of this reach impedance is specified by the **Forward RCA** setting. The setting is not used if the shape setting is "Mho."

Quadrilateral Reverse Outer*Range: 0.10 to 500.00 ohms in steps of 0.01**Default: 70.00 ohms*

This setting specifies the reverse reach of the outer quadrilateral characteristic. The angle of this reach impedance is specified by the **Forward RCA** setting. The setting is not used if the shape setting is "Mho."

Reverse RCA*Range: 40 to 90° in steps of 1**Default: 85°*

This setting specifies the angle of the reverse reach impedance for the mho characteristics. This setting applies to mho shapes only.

Outer Limit Angle*Range: 40 to 140° in steps of 1**Default: 120°*

This setting specifies the outer power swing characteristic. The convention depicted in the power swing detect mho operating characteristic diagram are to be observed: values greater than 90° result in an apple-shaped characteristic; values less than 90° result in a lens shaped characteristic. This angle must be selected in consideration of the maximum expected load. If the maximum load angle is known, coordinate the outer limit angle with a 20° security margin. Detailed studies can be needed for complex systems to determine this setting. This setting applies to mho shapes only.

Middle Limit Angle

Range: 40 to 140° in steps of 1

Default: 90°

This setting specifies the middle power swing detect characteristic. It is relevant only for the three-step mode. A typical is close to the average of the outer and inner limit angles. This setting applies to mho shapes only.

Inner Limit Angle

Range: 40 to 140° in steps of 1

Default: 60°

This setting specifies the inner power swing detect characteristic. The inner characteristic is used by the out-of-step tripping function: beyond the inner characteristic out-of-step trip action is definite (the actual trip can be delayed as per the **Trip Mode** setting). Therefore, this angle must be selected in consideration to the power swing angle beyond which the system becomes unstable and cannot recover.

Outer Right Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the right blinder. The blinder applies to both the outer "Mho" and "Quad" characteristics. Set this value suitably high if no blinder is required for the "Mho" characteristic.

Outer Left Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the left blinder. The blinder applies to both the outer "Mho" and "Quad" characteristics. Set this value high if no blinder is required for the "Mho" characteristic.

Middle Right Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the right blinder. The blinder applies to both the middle "Mho" and "Quad" characteristics. Set this value high if no blinder is required for the "Mho" characteristic.

Middle Left Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the left blinder. The blinder applies to both the middle "Mho" and "Quad" characteristics. Set this value high if no blinder is required for the "Mho" characteristic.

Inner Right Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the right blinder. The blinder applies to both the inner "Mho" and "Quad" characteristics. Set this value high if no blinder is required for the "Mho" characteristic.

Inner Left Blinder

Range: 0.10 to 500.00 ohms in steps of 0.01

Default: 10.00 ohms

This setting specifies the resistive reach of the left blinder. The blinder applies to both the inner "Mho" and "Quad" characteristics. Set this value high if no blinder is required for the "Mho" characteristic.

Delay 1 Pickup

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.030 seconds

All the coordinating timers are related to each other and need to be set to detect the fastest expected power swing and produce out-of-step tripping in a secure manner. Set the timers in relation to the power swing detect characteristics, mode of power swing detect operation, and mode of out-of-step tripping. This timer defines the interval that the impedance locus must spend between the outer and inner characteristics (two-step operating mode), or between the outer and middle characteristics (three-step operating mode) before the power swing blocking signal is established. This time delay must be set shorter than the time required for the impedance locus to travel between the two selected characteristics during the fastest expected power swing. This setting is relevant for both power swing blocking and out-of-step tripping.

Delay 1 Reset

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.050 seconds

This setting specifies the dropout delay for the power swing blocking signal. Detection of a condition requiring a block output sets latch 1 after the time specified in the **Delay 1 Pickup** setting. When the impedance locus leaves the outer characteristic, **Delay 1 Reset** is started. When the timer times-out, the latch is reset. Select this setting to give extra security for the power swing blocking action.

Delay 2 Pickup

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.017 seconds

This setting controls the out-of-step tripping function in the three-step mode. This timer specifies the interval the impedance locus must spend between the middle and inner characteristics before the second step of the out-of-step tripping sequence is completed. This time delay must be set shorter than the time required for the impedance locus to travel between the two characteristics during the fastest expected power swing.

Delay 3 Pickup

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.009 seconds

This setting controls the out-of-step tripping function only. It defines the interval the impedance locus must spend within the inner characteristic before the last step of the out-of-step tripping sequence is completed and the element is armed to trip. The actual moment of tripping is controlled by the **Trip Mode** setting. This time delay is provided for extra security before the out-of-step trip action is executed.

Delay 4 Pickup

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.017 seconds

This setting controls the out-of-step tripping function in the "Delayed" trip mode. This timer specifies the interval the impedance locus must spend outside the inner characteristic but within the outer characteristic before the element is armed for the delayed trip. The delayed trip occurs when the impedance leaves the outer characteristic. This time delay is provided for extra security. Set it considering the fastest expected power swing.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001
 Default: 0.400 seconds

The out-of-step trip FlexLogic operand (POWER SWING TRIP) is sealed-in for the specified period of time. The sealing-in is crucial in the delayed trip mode, as the original trip signal is a very short pulse occurring when the impedance locus leaves the outer characteristic after the out-of-step sequence is completed.

Trip Mode

Range: Early, Delayed
 Default: Delayed

Selection of the “Early” trip mode results in an instantaneous trip after the last step in the out-of-step tripping sequence is completed. The early trip mode stresses the circuit breakers as the currents at that moment are high (the electromotive forces of the two equivalent systems are approximately 180° apart). Selection of the “Delayed” trip mode results in a trip at the moment when the impedance locus leaves the outer characteristic. Delayed trip mode relaxes the operating conditions for the breakers as the currents at that moment are low. Make the selection considering the capability of the breakers in the system.

Block

Range: any FlexLogic operand
 Default: Off

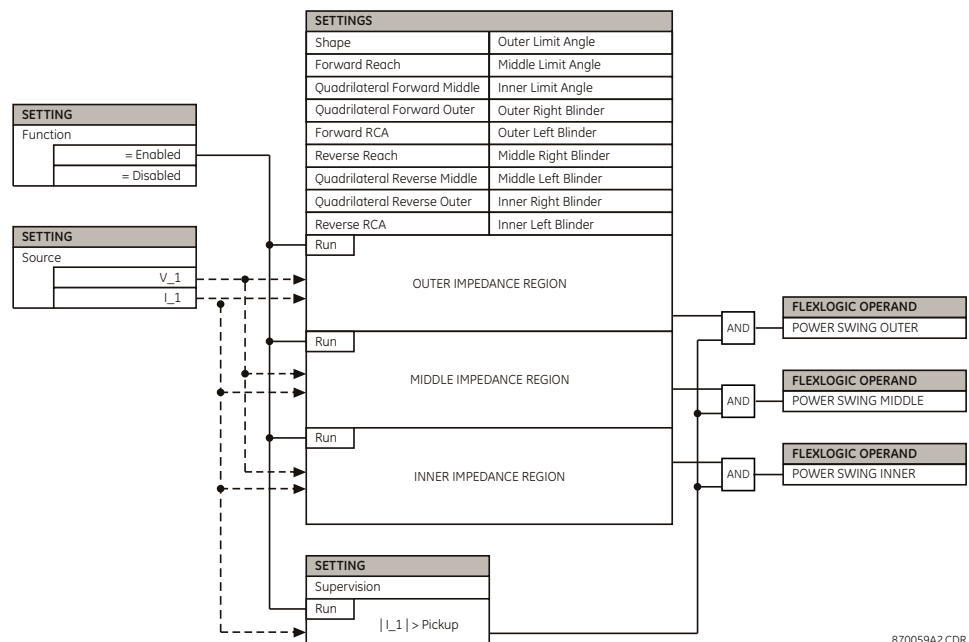
This setting selects the FlexLogic operand used for blocking the out-of-step function only. The power swing blocking function is operational all the time as long as the element is enabled. The blocking signal resets the output POWER SWING TRIP operand but does not stop the out-of-step tripping sequence.

Events

Range: Enabled, Disabled
 Default: Enabled

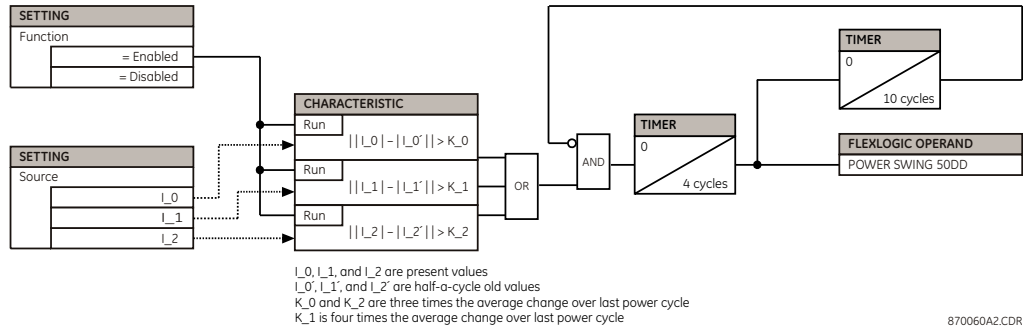
This setting enables and disables the logging of power swing detect events in the sequence of events recorder.

Figure 192: Power swing detect scheme logic, sheet 1 of 3



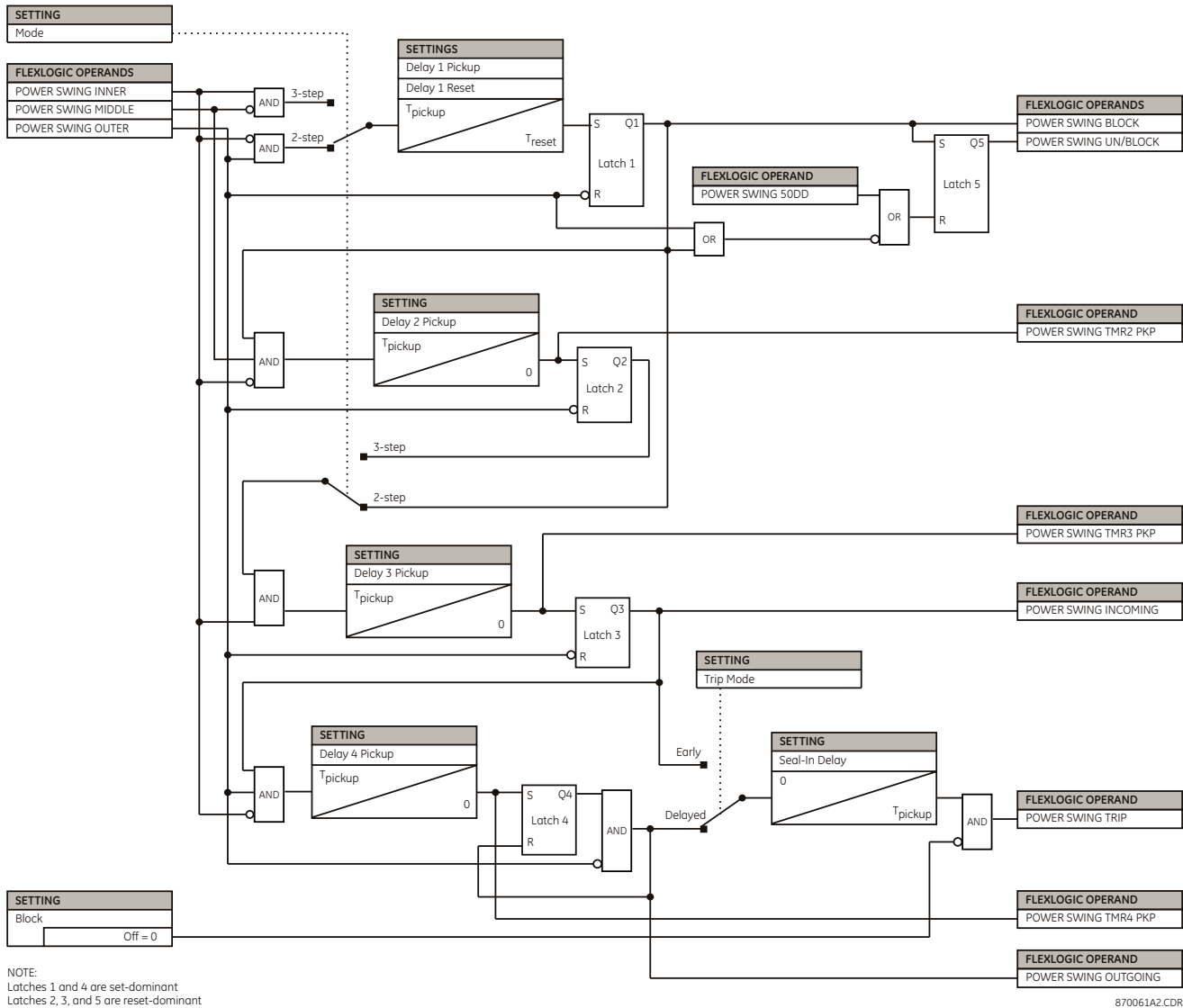
870059A2.CDR

Figure 193: Power swing detect scheme logic, sheet 2 of 3



870060A2.CDR

Figure 194: Power swing detect scheme logic, sheet 3 of 3

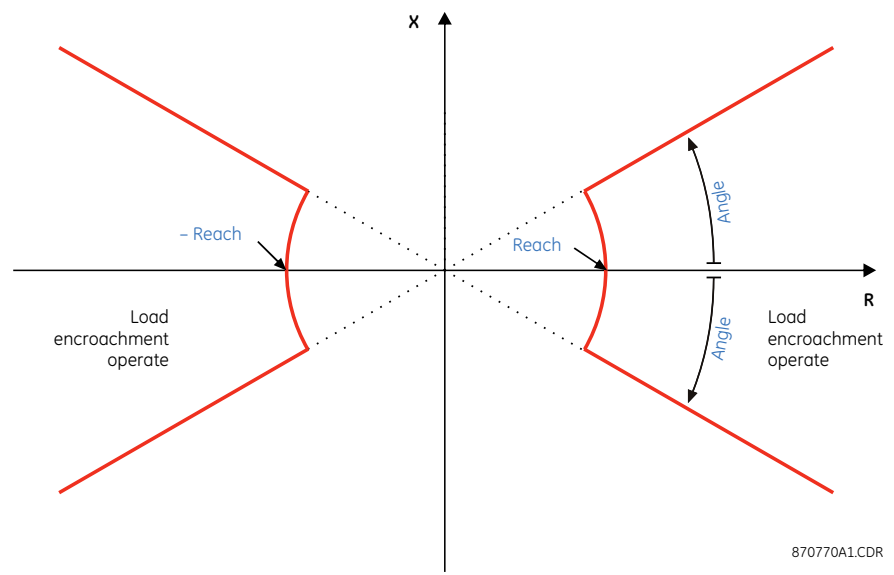


870061A2.CDR

Load encroachment

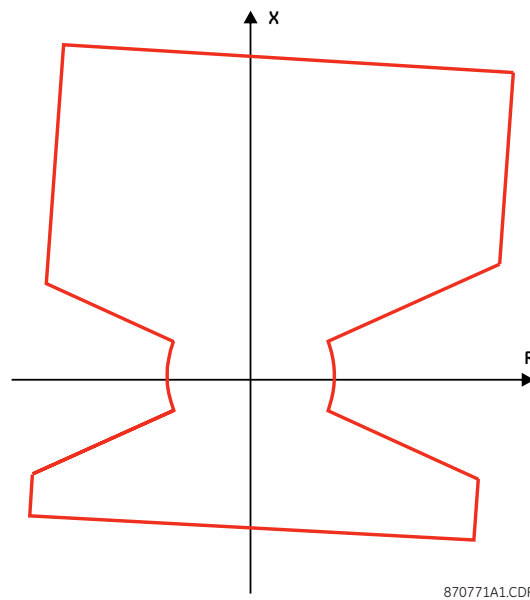
The load encroachment element responds to the positive-sequence voltage and current and applies the characteristic shown.

Figure 195: Load encroachment characteristic



The element operates if the positive-sequence voltage is above a user-specified level and asserts its output signal that can be used to block selected protection elements, such as distance or phase overcurrent. The following figure shows an effect of the load encroachment characteristics used to block the quadrilateral distance element.

Figure 196: Load encroachment applied to distance element



Select the **Settings > Protection > Elements > Group 1 > Load Encroachment** menu to open the load encroachment configuration window.

Figure 197: Load encroachment configuration settings

SETTING	PARAMETER
Function	Disabled
Source	LINE (SRC 1)
Min Volt	0.250 pu
Reach	0.70 ohms
Angle	30 deg
Pickup Delay	0.000 s
Reset Delay	0.000 s
Block	OFF
Events	Enabled

Distance 1 | Settings: Protection: Elements: Group 1

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the load encroachment element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the load encroachment element.

Minimum Voltage

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.250 pu

This setting specifies the minimum positive-sequence voltage required for operation of the element. When the voltage is below this threshold, a blocking signal is not asserted by the element. When selecting this setting, remember that the D90^{PLUS} measures the phase-to-ground sequence voltages regardless of the VT connection.

The nominal VT secondary voltage as specified in the [Phase VT Secondary](#) setting is the per-unit base for this setting.

Reach

Range: 0.02 to 250.00 ohms in steps of 0.01

Default: 1.00 ohms

This setting specifies the resistive reach of the element as shown in the load encroachment characteristic. Enter this setting in secondary ohms and calculate it as the positive-sequence resistance seen by the relay under maximum load conditions and unity power factor.

Angle

Range: 5 to 50° in steps of 1

Default: 30°

This setting specifies the size of the blocking region as shown on the load encroachment characteristic diagram and applies to the positive-sequence impedance.

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies a delay for the declaration of the load encroachment element between the pickup and operate output states. It is normally set to zero.

Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies a delay for the reset of the load encroachment element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. It is normally set to zero.

Block

Range: any FlexLogic operand

Default: Off

Assertion of the FlexLogic operand assigned to this setting blocks operation of the load encroachment element.

Events

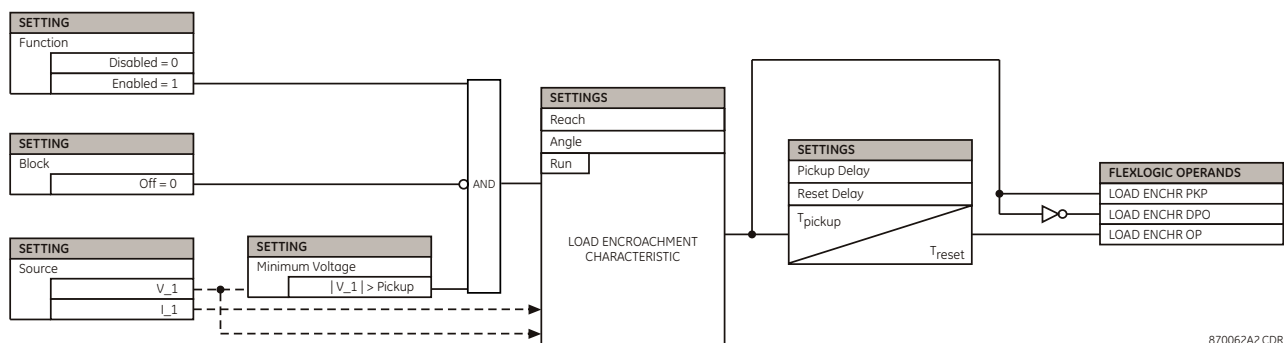
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of load encroachment events in the sequence of events recorder.

The following figure shows the logic for the load encroachment scheme.

Figure 198: Load encroachment logic

**Stepped distance scheme application guidelines**

This section provides general application guidelines for implementing stepped distance schemes with the D90^{PLUS}.

Phase current supervision and fuse failure for stepped distance

The phase-to-phase (delta) current is used to supervise the phase distance elements, primarily to ensure that in a de-energized state the distance elements are not picked up due to noise or induced voltages on the line.

However, this supervision feature can also be employed to prevent operation under fuse failure conditions. This obviously requires that the setting must be above maximum load current and less than the minimum fault conditions for which operation is expected. This potential problem can be avoided by the use of a separate fuse fail function, which means that the phase current supervision can be set much lower, typically two times the capacitance charging current of the line.

The usage of the fuse fail function is also important during double-contingency events, such as an external fault during fuse fail conditions. The current supervision alone does not prevent misoperation in such circumstances.

Keep in mind that the fuse failure element provided on the D90^{PLUS} needs time to detect fuse fail conditions. This can create a race between the instantaneous zone 1 and the fuse failure element. Therefore, for maximum security, it is recommended to set the current

supervision above the maximum load current and use the fuse failure function as well. The current supervision prevents misoperation immediately after the fuse fail condition, giving some time for the fuse failure element to take over and block the distance elements permanently. This is of secondary importance for time-delayed zones 2 and up as the fuse failure element has some extra time for guaranteed operation. The current supervision can be set less than the maximum load current for the time delayed zones.

Blocking distance elements during fuse fail conditions is not acceptable in some applications or under some protection philosophies. Applied solutions vary as follows:

- Not using the fuse failure element for blocking at all
- Using the fuse failure element and modifying (through FlexLogic and multiple setting groups mechanisms) other protection functions or other devices to provide some protection after detecting fuse fail conditions and blocking the distance elements
- Using the fuse failure element and accepting the fact that the distance protection does not respond to subsequent internal faults until the problem is addressed



To be fully operational, the fuse failure element must be enabled and its output FlexLogic operand must be indicated as the blocking signal for the selected protection elements.

For convenience, the current supervision threshold incorporates the $\sqrt{3}$ factor.

Phase distance zone 1 guidelines for stepped distance

As typically used for direct tripping, the zone 1 reach must be chosen so that it does not extend beyond the far end(s) of the protected line. Zone 1 provides nominally instantaneous protection for any phase fault within a pre-determined distance from the relay location. To ensure that no overreach occurs typically requires a setting of 80% to 90% of the line length, which covers CT and VT errors, relay inaccuracy, and transient overreach, as well as uncertainty in the line impedance for each phase, although transposition can minimize this latter concern.

The total device inaccuracy is less than 5%. This includes both steady state and transient overreach, even when supplied from CVTs under the source impedance ratios (SIRs) of up to 30.

Phase distance zone 2 guidelines for stepped distance

Zone 2 is an overreaching element, which essentially covers the final 10% to 20% of the line length with a time delay. The additional function for the zone 2 is as a timed backup for faults on the remote bus. The reach is set typically to 125% of the positive-sequence impedance of the line to ensure operation, with an adequate margin, for a fault at 100% of the line length. The necessary time delay must ensure that coordination is achieved with the clearance of a close-in fault on the next line section, including the breaker operating time.

The zone 2 time delay is typically set from 0.2 to 0.6 seconds, although this can be reviewed more carefully if a short line terminates on the remote bus, since the two zone 2 elements can overlap and therefore not coordinate satisfactorily.

Phase distance zone 3 guidelines for stepped distance

If a remote backup philosophy is followed, then the reach of this element must be set to account for any infeed at the remote bus, plus the impedance of the longest line that terminates on this remote bus. The time delay must coordinate with other time-delayed protections on any remote line. Circuit loading limitations created by a long zone reach can be overcome by using lens or quadrilateral characteristics, a load encroachment supervising characteristic, or both. Also consider a situation where the load impedance

can enter into the relay characteristic for a time longer than the chosen time delay, which can occur transiently during a system power swing. For this reason, use the power swing blocking function.

Phase distance zone 4 guidelines for stepped distance

As a further contribution to remote backup, the reach of this element must be set to account for any infeed at the remote bus. The time delay must coordinate with other time-delayed protection schemes on the next line. The use of a lens characteristic or the load encroachment element can be advantageous if load limits are a problem.

To avoid extremely large reach settings, the D90^{PLUS} has the ability to implement any element so that it is reverse looking. This can provide a back up for the longest line terminated on the local bus. This strategy is beneficial if the reduced reach helps discrimination between the load and fault conditions, but it must be implemented at both ends of the protected line.

Phase distance zone 5 guidelines for stepped distance

An additional fifth phase distance zone can be used in special applications. This zone can be the start zone for arming tripping from all other zones, in both forward and reverse directions of the protected line. This zone can also be used as an additional reverse-looking zone for implementation of two reverse-looking zones, thus providing two-zone backup reverse-looking protection. The fifth distance zone can be used as an alarm zone, indicating that load impedance is approaching the zone characteristic.

Ground distance neutral current supervision guidelines for stepped distance

The current supervision for the ground distance elements responds to an internally calculated neutral current ($3 \times I_0$). Base the setting for this element on twice the zero-sequence line capacitance current or the maximum zero-sequence unbalance under maximum load conditions. Do not use this element to prevent an output when the load impedance is inside the distance characteristic on a steady-state basis.

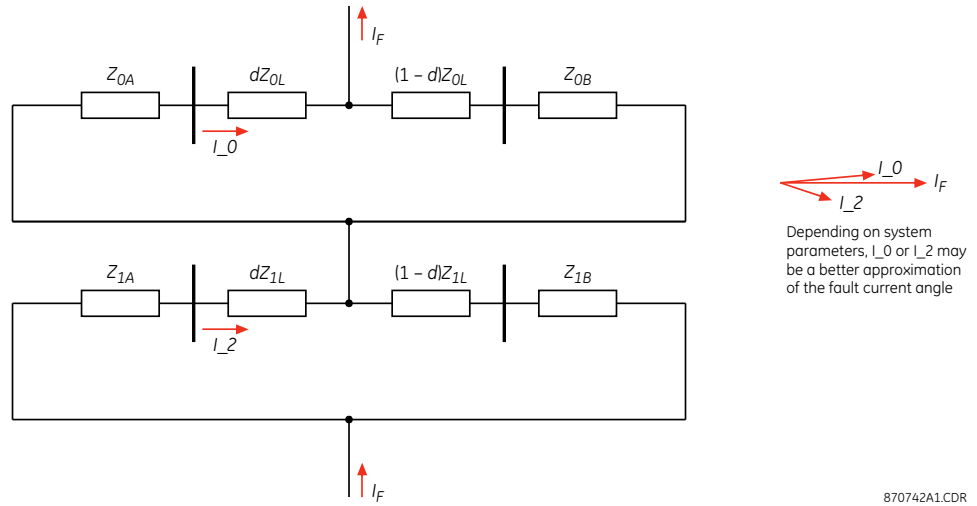
Polarizing current and non-homogeneity correction angle of quadrilateral characteristic for stepped distance

An ideal reactance line for single-line-to-ground faults is polarized from the fault current flowing through the fault resistance. Such a line defines constant reach and can be implemented by the following angle comparator.

$$I \times Z - V \text{ vs. } j \times I_F \quad \text{Eq. 8}$$

The relay can only approximate the unknown fault current by the zero-sequence or the negative-sequence currents measured at the relaying point. Depending on system parameters, either the zero-sequence or the negative-sequence current presents better approximation of the fault current angle.

Figure 199: Understanding system homogeneity



Given the equivalent systems shown in the figure, the angular difference between the zero-sequence or negative-sequence current at the D90^{PLUS} and the fault current can be calculated as follows:

$$\begin{aligned} \Theta_{_0} &= \text{angle} \left(\frac{I_F}{I_{_0}(\text{at relay})} \right) = \text{angle} \left(\frac{Z_{0A} + Z_{0L} + Z_{0B}}{Z_{0B} + (1-d)Z_{0L}} \right) \\ \Theta_{_2} &= \text{angle} \left(\frac{I_F}{I_{_2}(\text{at relay})} \right) = \text{angle} \left(\frac{Z_{1A} + Z_{1L} + Z_{1B}}{Z_{1B} + (1-d)Z_{1L}} \right) \end{aligned} \tag{Eq. 9}$$

If $|\Theta_{_0}| < |\Theta_{_2}|$, then the zero-sequence network is more homogenous (that is, the zero-sequence current better approximates the fault current), and zero-sequence polarizing is selected. Otherwise, negative-sequence is a better polarizing signal.

The calculated Θ angles reflect errors between the ideal and applied polarizing angles. Therefore, after selecting the polarizing current, choose the corresponding angle as the non-homogeneity correction angle. For example, calculations yielding $\Theta_{_0} = 5^\circ$ and $\Theta_{_2} = -1^\circ$ result in selecting the negative-sequence for polarization, and the value of -1° for non-homogeneity correction.

Quite often the non-homogeneity correction angle is used to apply extra security rather than correct the angle between the relay and the fault currents. For extra security, set the angle to negative values.

Approach with care the ability to select an optimum polarizing signal and to correct for non-homogeneity. The best polarizing signal and the correcting angle both depend on system parameters and intended reach of the zone. If the system configuration is static, the selection is straightforward.

When the system configuration changes significantly, consider all relevant system topologies for calculations. Either make a compromise choice, or apply different settings via switchable setting groups depending on system conditions. In highly non-homogenous and dynamic systems where the correction for non-homogeneity is not feasible, consider conservative reach (reduced) or correction angle (negative) settings, or both.

Ground distance zone 1 guidelines for stepped distance

The zone 1 reach must be set so that nominally instantaneous operation does not extend beyond the end of the protected line. However this can be somewhat more complicated than for the phase elements, because of zero sequence mutual induction with an adjacent parallel line, possibly carried on the same tower, which can be of service and grounded at multiple points. A fault beyond 100% of the protected line can cause overreach unless the

reach is reduced significantly, sometimes as low as 65% of the line length. If the line being protected does not have a significant interaction with an adjacent circuit, then the typical 80% setting can be used. If there is significant mutual coupling between the parallel lines, then the mutual compensation feature of the ground distance elements can be used instead of a drastic reduction in the reach.

However, even in this case, there is more uncertainty as compared with the phase distance elements because the zero-sequence impedance of the line and thus the zero-sequence compensating factors can vary significantly due to weather and other conditions.

Ground distance zone 2 guidelines for stepped distance

To ensure that the zone 2 can see 100% of the line, inter-circuit mutual effects must be considered, as they can contribute to a significant under-reach. Typically this occurs on double circuit lines, when both lines carry the same current. Conduct an analytical study to determine the appropriate reach setting.

The main purpose of this element is to operate for faults beyond the reach of the local zone 1 element, and therefore a time delay must be used similar to the phase fault case.

Ground distance zone 3 guidelines for stepped distance

This remote back up function must have a reach that is set to account for any infeed at the remote bus, plus the impedance of the longest line that terminates on this remote bus. Similar to the phase fault case, a zone 3 element must be time coordinated with timed clearances on the next section.

Ground distance zone 4 guidelines for stepped distance

As a further contribution to a remote backup philosophy, the reach of this element must be set to account for any infeed at the remote bus. The time delay must coordinate with other time-delayed protections on the next line. The use of a lens characteristic or load encroachment element is advantageous when load limits are a problem. To avoid extremely large reach settings, the D90^{PLUS} has the ability to implement any element so that it is reverse-looking. This strategy can be beneficial if the reduced reach enhances the discrimination between the load and fault conditions. If adopted, this approach must be implemented at both ends of the protected line.

Ground distance zone 5 guidelines for stepped distance

An additional fifth ground distance zone can be used in special applications. This zone can be the start zone for arming tripping from all other zones, in both forward and reverse directions of the protected line. This zone can also be used as an additional reverse-looking zone for implementation of two reverse-looking zones, thus providing two-zone backup reverse-looking protection. The fifth distance zone can be used as an alarm zone, indicating that load impedance is approaching the zone characteristic.

Series compensated line protection application guidelines

This section provides general application guidelines for implementing protection for series compensated lines with the D90^{PLUS}.

It is recommended to apply a combination of distance, ground directional overcurrent, and high-set overcurrent functions for protection of series compensated lines. The setting rules described here must take into account a variety of system configurations, particularly a status of series capacitors (in-service, by-passed). Either consider the worst-case topology or, if possible, apply adaptive settings through the multiple settings groups mechanism.

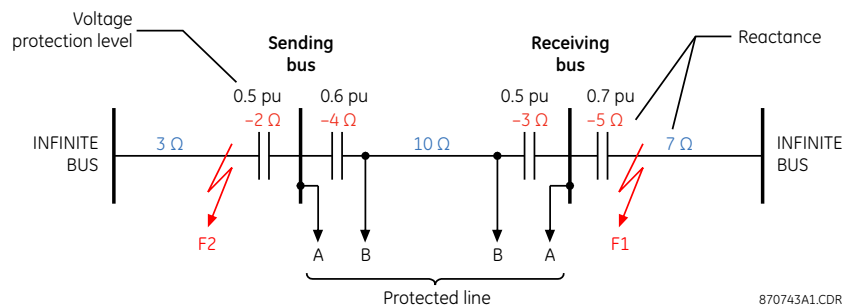
A line compensating capacitor is a bank of three physical capacitors and their overvoltage protecting devices (air gaps, MOVs, or both). If none of the MOV or gaps conducts any significant current, the positive-sequence, negative-sequence, and zero-sequence

reactance of the three-phase bank equal the reactance of the actual (phase) capacitors. However, under asymmetrical conditions such as a single-line-to-ground fault, when only one MOV or gap may operate, the series capacitor bank creates extra (series) asymmetry in addition to the fault (shunt) asymmetry. The positive-sequence, negative-sequence, and zero-sequence impedances differ from each other and do not equal the impedance of the phase capacitors. Moreover, there can be mutual coupling between the sequence networks representing the series capacitor bank. This makes analytical analysis of fault conditions very burdensome. For setting calculations, however, it is justified to assume that the zero-sequence, positive-sequence, and negative-sequence reactance of the capacitor bank equal the reactance of the actual (phase) capacitors. This represents a worst-case low-current fault scenario, when the steady-state effects of series compensation are most weighty.

Distance setting guidelines for protecting series compensated lines

Traditionally, the reach setting of an underreaching distance function is specified based on the net inductive impedance between the potential source of the relay and the far-end busbar, or location for which the zone must not overreach. Faults behind series capacitors on the protected and adjacent lines need to be considered for this purpose. For further illustration, a sample system shown in the figure is considered.

Figure 200: Example of series compensated system



Assuming 20% security margin, the underreaching zone is set as follows. At the sending bus, one must consider an external fault at F1, as the 5 Ω capacitor contributes to the overreaching effect. Any fault behind F1 is less severe as extra inductive line impedance increases the apparent impedance.

- Reach setting: $0.8 \times (10 - 3 - 5) = 1.6 \Omega$ if the line-side (B) VTs are used
- Reach setting: $0.8 \times (10 - 4 - 3 - 5) = -1.6 \Omega$ if the bus-side (A) VTs are used

The negative value means that an underreaching zone cannot be used as the circuit between the potential source of the relay and an external fault for which the relay must not pickup, since it is overcompensated (that is, capacitive).

At the receiving bus, one must consider a fault at F2.

- Reach setting: $0.8 \times (10 - 4 - 2) = 3.2 \Omega$ if the line-side (B) VTs are used
- Reach setting: $0.8 \times (10 - 4 - 3 - 2) = 0.8 \Omega$ if the bus-side (A) VTs are used

However, to practically cope with the effect of sub-synchronous oscillations, it can be necessary to reduce the reach even more. Since the characteristics of sub-synchronous oscillations are in complex relations with fault and system parameters, no specific setting recommendations are given with respect to extra security margin for sub-synchronous oscillations. It is strongly recommended to use a power system simulator to verify the reach settings or to use an adaptive D90^{PLUS} feature for dynamic reach control.

Ground directional overcurrent guidelines for protecting series compensated lines

The ground directional overcurrent function (negative-sequence overcurrent or neutral overcurrent) uses an offset impedance to guarantee correct fault direction discrimination. The following setting rules apply:

- If the net impedance between the potential source and the local equivalent system is inductive, then there is no need for an offset. Otherwise, the offset impedance shall be at least the net capacitive reactance.
- The offset cannot be higher than the net inductive reactance between the potential source and the remote equivalent system. For simplicity and extra security, the far-end busbar can be used rather than the remote equivalent system.

As the ground directional functions are meant to provide maximum fault resistance coverage, it is justified to assume that the fault current is very low and none of the series capacitors is guaranteed to get by-passed. Consider settings of the negative-sequence directional overcurrent protection element for the sample series compensated system.

For the sending bus relay, bus-side VTs:

1. The net inductive reactance from the relay into the local system is $-2 \Omega + 3 \Omega = 1 \Omega > 0$. There is no need for offset.
2. The net inductive reactance from relay through far-end busbar is $-4 \Omega + 10 \Omega - 3 \Omega = 3 \Omega$. The offset cannot be greater than 3Ω .
3. Therefore, it is recommended to use a 1.5Ω offset impedance.

For the sending bus relay, line-side VTs:

1. The net inductive reactance from relay into local system is $-2 \Omega + 3 \Omega - 4 \Omega = -3 \Omega < 0$. An offset impedance $\geq 3 \Omega$ must be used.
2. The net inductive reactance from relay through far-end busbar = $10 \Omega - 3 \Omega = 7 \Omega$. The offset cannot be greater than 7Ω .
3. Therefore, it is recommended to use a 5Ω offset impedance.

For the receiving bus relay, bus-side VTs:

1. The net inductive reactance from relay into local system is $-5 \Omega + 7 \Omega = 2 \Omega > 0$. There is no need for offset.
2. The net inductive reactance from relay through far-end busbar is $-3 \Omega + 10 \Omega - 4 \Omega = 3 \Omega$; the offset cannot be greater than 3Ω .
3. Therefore, it is recommended to use a 1.5Ω offset impedance.

For the receiving bus relay, line-side VTs:

1. The net inductive reactance from relay into local system is $-3 \Omega - 5 \Omega + 7 \Omega = -1 \Omega < 0$. An offset impedance $\geq 1 \Omega$ must be used.
2. The net inductive reactance from relay through far-end busbar is $10 \Omega - 4 \Omega = 6 \Omega$. The offset cannot be higher than 6Ω .
3. Therefore, it is recommended to use 3.5Ω offset impedance.

High-set overcurrent guidelines for protecting series compensated lines

Especially at low SIR values, fast fault clearance times are extremely important, from both system stability and equipment damage viewpoints. The high-set overcurrent element, when set appropriately, can be useful in achieving these goals. It helps the setting calculations if the system impedances are reasonably well known.

Set the overcurrent pickup to the greater of the following values:

- The maximum infeed seen by the $D90^{\text{plus}}$, for a close in reverse fault
- The maximum fault level seen by the $D90^{\text{plus}}$ for a fault at 100% of the protected line

The maximum error of the phase overcurrent elements is less than 2%. Use a safety factor of 1.25 to account for relay errors and system impedance uncertainty.

If CT saturation is an issue, such as close to a generation where long lasting DC components are likely to saturate the CTs, note that the instantaneous overcurrent elements require 1.33 cycles of data to operate for a multiple of pickup of 1.01. For higher multiples of pickup, the relation between the multiple of pickup and the amount of data required for operation before complete CT saturation is approximately linear. For example, for a multiple of pickup of 4, approximately $1.33 / 4 = 0.332$ of a power cycle is required by the phase instantaneous overcurrent element to operate. Do not confuse this information with the operating time, which includes some inherent delays, such as a trip rated output contact.

Current elements

This section outlines the current element settings.

Time overcurrent curves

The inverse time overcurrent curves used by the time overcurrent elements are the IEEE, IEC, GE Type IAC, and I^2t standard curve shapes. This allows for simplified coordination with downstream devices. If however, none of these curve shapes is adequate, FlexCurves can be used to customize the inverse time curve characteristics. The definite time curve is also an option that can be appropriate if only simple protection is required.

The following overcurrent curve types are available:

- IEEE Extremely Inverse
- IEEE Very Inverse
- IEEE Moderately Inverse
- IEC Curve A (BS142)
- IEC Curve B (BS142)
- IEC Curve C (BS142)
- IAC Extremely Inverse
- IAC Very Inverse
- IAC Inverse
- IAC Short Inverse
- I^2t
- FlexCurves A, B, C, and D
- Recloser curves
- Definite Time

A multiplier (time dial) setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier setting value. For example, all times for a multiplier of 10 are 10 times the multiplier 1 or base curve values. Setting the multiplier to zero results in an instantaneous response to all current levels above pickup.

Time overcurrent time calculations are made with an internal energy capacity memory variable. When this variable indicates that the energy capacity has reached 100%, a time overcurrent element operates. If less than 100% energy capacity is accumulated in this variable and the current falls below the dropout threshold of 97 to 98% of the pickup value, the variable must be reduced. Two methods of this reset operation are available: instantaneous and timed. The instantaneous method is for applications with other relays,

such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The timed method can be used where the relay must coordinate with electromechanical relays.

IEEE curves

The IEEE time overcurrent curve shapes conform to industry standards and the IEEE C37.112-1996 curve classifications for extremely, very, and moderately inverse curves. The IEEE curves are derived by the operate and reset time equations.

$$T = TDM \times \left[\frac{A}{\left(\frac{I}{I_{pickup}}\right)^p - 1} + B \right] \tag{Eq. 10}$$

$$T_{reset} = TDM \times \left[\frac{t_r}{1 - \left(\frac{I}{I_{pickup}}\right)^2} \right] \tag{Eq. 11}$$

where

- T = operate time (in seconds)
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- A, B, p = constants defined in the table
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")
- t_r = characteristic constant defined in the table

Table 13: IEEE inverse time curve constants

IEEE curve shape	A	B	p	t_r
IEEE Extremely Inverse	28.2	0.1217	2.0000	29.1
IEEE Very Inverse	19.61	0.491	2.0000	21.6
IEEE Moderately Inverse	0.0515	0.1140	0.02000	4.85

Table 7-1: IEEE curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IEEE Extremely Inverse										
0.5	11.341	4.761	1.823	1.001	0.648	0.464	0.355	0.285	0.237	0.203
1.0	22.682	9.522	3.647	2.002	1.297	0.927	0.709	0.569	0.474	0.407
2.0	45.363	19.043	7.293	4.003	2.593	1.855	1.418	1.139	0.948	0.813
4.0	90.727	38.087	14.587	8.007	5.187	3.710	2.837	2.277	1.897	1.626
6.0	136.090	57.130	21.880	12.010	7.780	5.564	4.255	3.416	2.845	2.439
8.0	181.454	76.174	29.174	16.014	10.374	7.419	5.674	4.555	3.794	3.252
10.0	226.817	95.217	36.467	20.017	12.967	9.274	7.092	5.693	4.742	4.065
IEEE Very Inverse										
0.5	8.090	3.514	1.471	0.899	0.654	0.526	0.450	0.401	0.368	0.345
1.0	16.179	7.028	2.942	1.798	1.308	1.051	0.900	0.802	0.736	0.689
2.0	32.358	14.055	5.885	3.597	2.616	2.103	1.799	1.605	1.472	1.378
4.0	64.716	28.111	11.769	7.193	5.232	4.205	3.598	3.209	2.945	2.756
6.0	97.074	42.166	17.654	10.790	7.849	6.308	5.397	4.814	4.417	4.134
8.0	129.432	56.221	23.538	14.387	10.465	8.410	7.196	6.418	5.889	5.513

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
10.0	161.790	70.277	29.423	17.983	13.081	10.513	8.995	8.023	7.361	6.891
IEEE Moderately Inverse										
0.5	3.220	1.902	1.216	0.973	0.844	0.763	0.706	0.663	0.630	0.603
1.0	6.439	3.803	2.432	1.946	1.688	1.526	1.412	1.327	1.260	1.207
2.0	12.878	7.606	4.864	3.892	3.377	3.051	2.823	2.653	2.521	2.414
4.0	25.756	15.213	9.729	7.783	6.753	6.102	5.647	5.307	5.041	4.827
6.0	38.634	22.819	14.593	11.675	10.130	9.153	8.470	7.960	7.562	7.241
8.0	51.512	30.426	19.458	15.567	13.507	12.204	11.294	10.614	10.083	9.654
10.0	64.390	38.032	24.322	19.458	16.883	15.255	14.117	13.267	12.604	12.068

IEC curves

For European applications, the D90^{Plus} offers three standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, and IEC Curve C. The IEC curves are derived by the operate and reset time equations.

$$T_{operate} = TDM \times \frac{K}{\left(\frac{I}{I_{pickup}}\right)^E - 1} \tag{Eq. 12}$$

$$T_{reset} = TDM \times \frac{t_r}{1 - \left(\frac{I}{I_{pickup}}\right)^2} \tag{Eq. 13}$$

where

- $T_{operate}$ = operate time (in seconds)
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- K, E = constants defined in the table
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")
- t_r = characteristic constant defined in the table

Table 8: IEC (BS) inverse time curve constants

IEC curve shape	K	E	t_r
IEC Curve A (BS142)	0.140	0.020	9.7
IEC Curve B (BS142)	13.500	1.000	43.2
IEC Curve C (BS142)	80.000	2.000	58.2
IEC Short Inverse	0.050	0.040	0.500

Table 9: IEC (BS) curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IEC Curve A										
0.05	0.860	0.501	0.315	0.249	0.214	0.192	0.176	0.165	0.156	0.149
0.10	1.719	1.003	0.630	0.498	0.428	0.384	0.353	0.330	0.312	0.297
0.20	3.439	2.006	1.260	0.996	0.856	0.767	0.706	0.659	0.623	0.594
0.40	6.878	4.012	2.521	1.992	1.712	1.535	1.411	1.319	1.247	1.188
0.60	10.317	6.017	3.781	2.988	2.568	2.302	2.117	1.978	1.870	1.782

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.80	13.755	8.023	5.042	3.984	3.424	3.070	2.822	2.637	2.493	2.376
1.00	17.194	10.029	6.302	4.980	4.280	3.837	3.528	3.297	3.116	2.971
IEC Curve B										
0.05	1.350	0.675	0.338	0.225	0.169	0.135	0.113	0.096	0.084	0.075
0.10	2.700	1.350	0.675	0.450	0.338	0.270	0.225	0.193	0.169	0.150
0.20	5.400	2.700	1.350	0.900	0.675	0.540	0.450	0.386	0.338	0.300
0.40	10.800	5.400	2.700	1.800	1.350	1.080	0.900	0.771	0.675	0.600
0.60	16.200	8.100	4.050	2.700	2.025	1.620	1.350	1.157	1.013	0.900
0.80	21.600	10.800	5.400	3.600	2.700	2.160	1.800	1.543	1.350	1.200
1.00	27.000	13.500	6.750	4.500	3.375	2.700	2.250	1.929	1.688	1.500
IEC Curve C										
0.05	3.200	1.333	0.500	0.267	0.167	0.114	0.083	0.063	0.050	0.040
0.10	6.400	2.667	1.000	0.533	0.333	0.229	0.167	0.127	0.100	0.081
0.20	12.800	5.333	2.000	1.067	0.667	0.457	0.333	0.254	0.200	0.162
0.40	25.600	10.667	4.000	2.133	1.333	0.914	0.667	0.508	0.400	0.323
0.60	38.400	16.000	6.000	3.200	2.000	1.371	1.000	0.762	0.600	0.485
0.80	51.200	21.333	8.000	4.267	2.667	1.829	1.333	1.016	0.800	0.646
1.00	64.000	26.667	10.000	5.333	3.333	2.286	1.667	1.270	1.000	0.808
IEC Short Inverse										
0.05	0.153	0.089	0.056	0.044	0.038	0.034	0.031	0.029	0.027	0.026
0.10	0.306	0.178	0.111	0.088	0.075	0.067	0.062	0.058	0.054	0.052
0.20	0.612	0.356	0.223	0.175	0.150	0.135	0.124	0.115	0.109	0.104
0.40	1.223	0.711	0.445	0.351	0.301	0.269	0.247	0.231	0.218	0.207
0.60	1.835	1.067	0.668	0.526	0.451	0.404	0.371	0.346	0.327	0.311
0.80	2.446	1.423	0.890	0.702	0.602	0.538	0.494	0.461	0.435	0.415
1.00	3.058	1.778	1.113	0.877	0.752	0.673	0.618	0.576	0.544	0.518

IAC curves

The curves for the General Electric type IAC relay family are derived from the formulae:

$$T_{operate} = \text{TDM} \times \left(A + \frac{B}{\left(\frac{I}{I_{pickup}} - C\right)} + \frac{D}{\left(\frac{I}{I_{pickup}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{pickup}} - C\right)^3} \right) \quad \text{Eq. 14}$$

$$T_{reset} = \text{TDM} \times \frac{t_r}{1 - \left(\frac{I}{I_{pickup}}\right)^2} \quad \text{Eq. 15}$$

where

- $T_{operate}$ = operate time (in seconds)
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- A to E = constants defined in the table
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")
- t_r = characteristic constant defined in the table

Table 10: GE type IAC inverse time curve constants

IAC curve shape	A	B	C	D	E	t_r
IAC Extreme Inverse	0.0040	0.6379	0.6200	1.7872	0.2461	6.008
IAC Very Inverse	0.0900	0.7955	0.1000	-1.2885	7.9586	4.678
IAC Inverse	0.2078	0.8630	0.8000	-0.4180	0.1947	0.990
IAC Short Inverse	0.0428	0.0609	0.6200	-0.0010	0.0221	0.222

Table 11: GE type IAC curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IAC Extremely Inverse										
0.5	1.699	0.749	0.303	0.178	0.123	0.093	0.074	0.062	0.053	0.046
1.0	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093
2.0	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185
4.0	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370
6.0	20.387	8.990	3.635	2.133	1.474	1.115	0.893	0.743	0.636	0.556
8.0	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741
10.0	33.979	14.983	6.058	3.555	2.457	1.859	1.488	1.239	1.060	0.926
IAC Very Inverse										
0.5	1.451	0.656	0.269	0.172	0.133	0.113	0.101	0.093	0.087	0.083
1.0	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165
2.0	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331
4.0	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662
6.0	17.407	7.872	3.225	2.061	1.598	1.359	1.215	1.117	1.046	0.992
8.0	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323
10.0	29.012	13.121	5.374	3.434	2.663	2.266	2.025	1.862	1.744	1.654
IAC Inverse										
0.5	0.578	0.375	0.266	0.221	0.196	0.180	0.168	0.160	0.154	0.148
1.0	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297
2.0	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594
4.0	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188
6.0	6.931	4.496	3.192	2.656	2.353	2.158	2.022	1.921	1.843	1.781
8.0	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375
10.0	11.552	7.494	5.320	4.426	3.922	3.597	3.369	3.201	3.072	2.969
IAC Short Inverse										
0.5	0.072	0.047	0.035	0.031	0.028	0.027	0.026	0.026	0.025	0.025
1.0	0.143	0.095	0.070	0.061	0.057	0.054	0.052	0.051	0.050	0.049
2.0	0.286	0.190	0.140	0.123	0.114	0.108	0.105	0.102	0.100	0.099
4.0	0.573	0.379	0.279	0.245	0.228	0.217	0.210	0.204	0.200	0.197
6.0	0.859	0.569	0.419	0.368	0.341	0.325	0.314	0.307	0.301	0.296
8.0	1.145	0.759	0.559	0.490	0.455	0.434	0.419	0.409	0.401	0.394
10.0	1.431	0.948	0.699	0.613	0.569	0.542	0.524	0.511	0.501	0.493

I²t curves

The I²t curves are derived as follows:

$$T_{operate} = TDM \times \frac{100}{\left(\frac{I}{I_{pickup}}\right)^2} \quad \text{Eq. 16}$$

$$T_{reset} = TDM \times \frac{100}{\left(\frac{I}{I_{pickup}}\right)^{-2}} \quad \text{Eq. 17}$$

where

- $T_{operate}$ = operate time in seconds
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")

Table 12: I²t curve trip times (in seconds)

Multiplier (TDM)	Current (I / I_{pickup})									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.01	0.44	0.25	0.11	0.06	0.04	0.03	0.02	0.02	0.01	0.01
0.10	4.44	2.50	1.11	0.63	0.40	0.28	0.20	0.16	0.12	0.10
1.00	44.44	25.00	11.11	6.25	4.00	2.78	2.04	1.56	1.23	1.00
10.00	444.44	250.00	111.11	62.50	40.00	27.78	20.41	15.63	12.35	10.00
100.00	4444.4	2500.0	1111.1	625.00	400.00	277.78	204.08	156.25	123.46	100.00
600.00	26666.7	15000.0	6666.7	3750.0	2400.0	1666.7	1224.5	937.50	740.74	600.00

FlexCurves

FlexCurves are described in the FlexCurves section later in this chapter. The curve shapes for FlexCurve are derived from the formulae:

$$T_{operate} = TDM \times \text{FlexCurve time at } \frac{I}{I_{pickup}} \text{ when } \frac{I}{I_{pickup}} \geq 1.00 \quad \text{Eq. 18}$$

$$T_{reset} = TDM \times \text{FlexCurve time at } \frac{I}{I_{pickup}} \text{ when } \frac{I}{I_{pickup}} \leq 0.98 \quad \text{Eq. 19}$$

where

- $T_{operate}$ = operate time (in seconds)
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")

Definite time curve

The Definite Time curve shape operates as soon as the pickup level is exceeded for a specified period of time. The base definite time curve delay is in seconds. The curve multiplier of 0.00 to 600.00 makes this delay adjustable from instantaneous to 600.00 seconds in steps of 10 ms. The definite time curve shapes are defined as follows:

$$T_{operate} = TDM \text{ in seconds, where } I > I_{pickup} \tag{Eq. 20}$$

$$T_{reset} = TDM \text{ in seconds} \tag{Eq. 21}$$

where

- $T_{operate}$ = operate time (in seconds)
- TDM = multiplier setting
- I = input current
- I_{pickup} = pickup current setting
- T_{reset} = reset time in seconds (assuming the energy capacity is 100% and the reset mode is "Timed")

Recloser curves

The D90^{Plus} uses the FlexCurve feature to facilitate programming of 41 recloser curves. See the *FlexCurves* settings section earlier in this chapter for details.

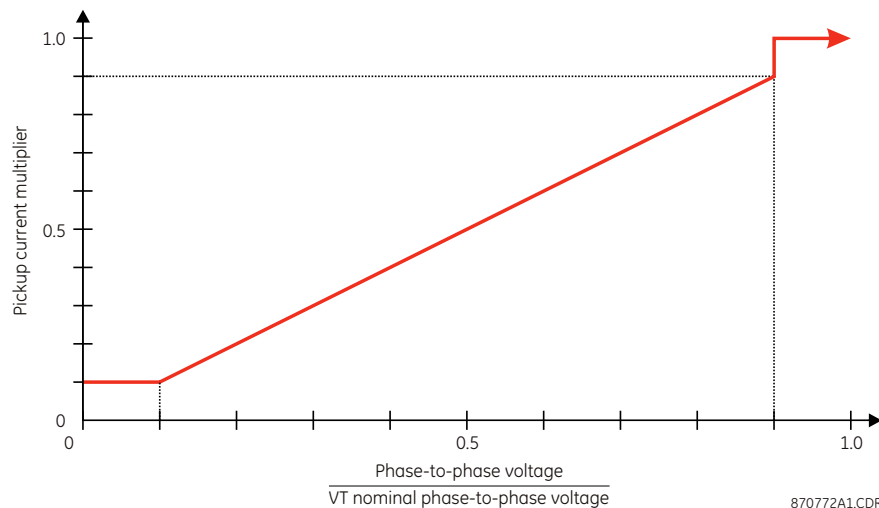
Phase time overcurrent

The phase time overcurrent element can provide a specified time-delay operating characteristic versus the applied current or be used as a simple definite time element. The phase current input quantities can be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: "Timed" and "Instantaneous." When the element is blocked, the time accumulator resets according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator clears immediately.

The **Phase TOC1 Pickup** setting can be dynamically reduced by a voltage restraint feature (when enabled). This is accomplished via the multipliers (Mvr) corresponding to the phase-to-phase voltages of the voltage restraint characteristic curve (see figure); the pickup level is calculated as Mvr times the **Phase TOC1 Pickup** setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

Figure 201: Phase time overcurrent voltage restraint characteristic



Select the **Settings > Protection > Elements > Group 1 > Current > Phase TOC** menu item to open the phase time overcurrent configuration window.

Figure 202: Phase time overcurrent configuration settings

PARAMETER	PHASE TOC1	PHASE TOC2
Function	Disabled	Disabled
Signal Source	LINE (SRC 1)	LINE (SRC 1)
Input	Phasor	Phasor
Pickup	1.000 pu	1.000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Voltage Restraint	Disabled	Disabled
Block A	OFF	OFF
Block B	OFF	OFF
Block C	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each phase time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase time overcurrent protection element.

Signal Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how phase current input quantities are interpreted by the D90^{PLUS}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the time inverse overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed

Default: Instantaneous

The “Instantaneous” reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The “Timed” reset method can be used where the relay must coordinate with electromechanical relays.

Voltage Restraint

Range: Enabled, Disabled

Default:

This setting enables and disables the phase time overcurrent voltage restraint feature.

Block A

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting block’s phase A of the phase time overcurrent element.

Block B

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting block’s phase B of the phase time overcurrent element.

Block C

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting block’s phase C of the phase time overcurrent element.

Events

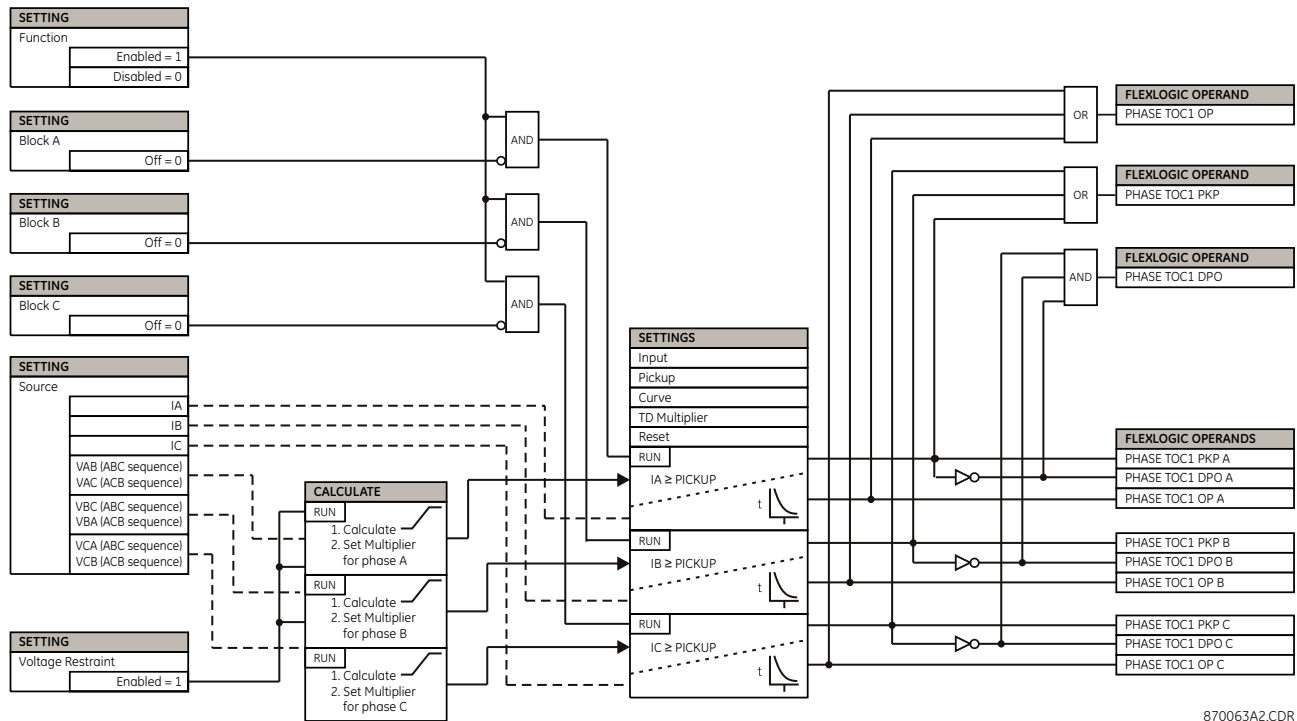
Range: Enabled, Disabled

Default: varies with UR^{Plus}-series model; refer to the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of phase time overcurrent events in the sequence of events recorder.

The logic for the phase time overcurrent 1 element is shown as follows. The logic is identical for all phase instantaneous overcurrent elements.

Figure 203: Phase time overcurrent 1 scheme logic



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Phase instantaneous overcurrent

The phase instantaneous overcurrent element can be used as an instantaneous element with no intentional delay or as a definite time element. The input current is the fundamental phasor magnitude.

Select the **Settings > Protection > Elements > Group 1 > Current > Phase IOC** menu to open the phase instantaneous overcurrent configuration window.

Figure 204: Phase instantaneous overcurrent configuration settings

PARAMETER	PHASE IOC1	PHASE IOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Delay	0.00 s	0.00 s
Reset Delay	0.00 s	0.00 s
Block A	OFF	OFF
Block B	OFF	OFF
Block C	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each phase instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the [PHASE IOC OP](#) operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the phase instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block A, Block B, Block C

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to these settings blocks' phases A, B, and C, respectively, of the phase instantaneous overcurrent element.

Events

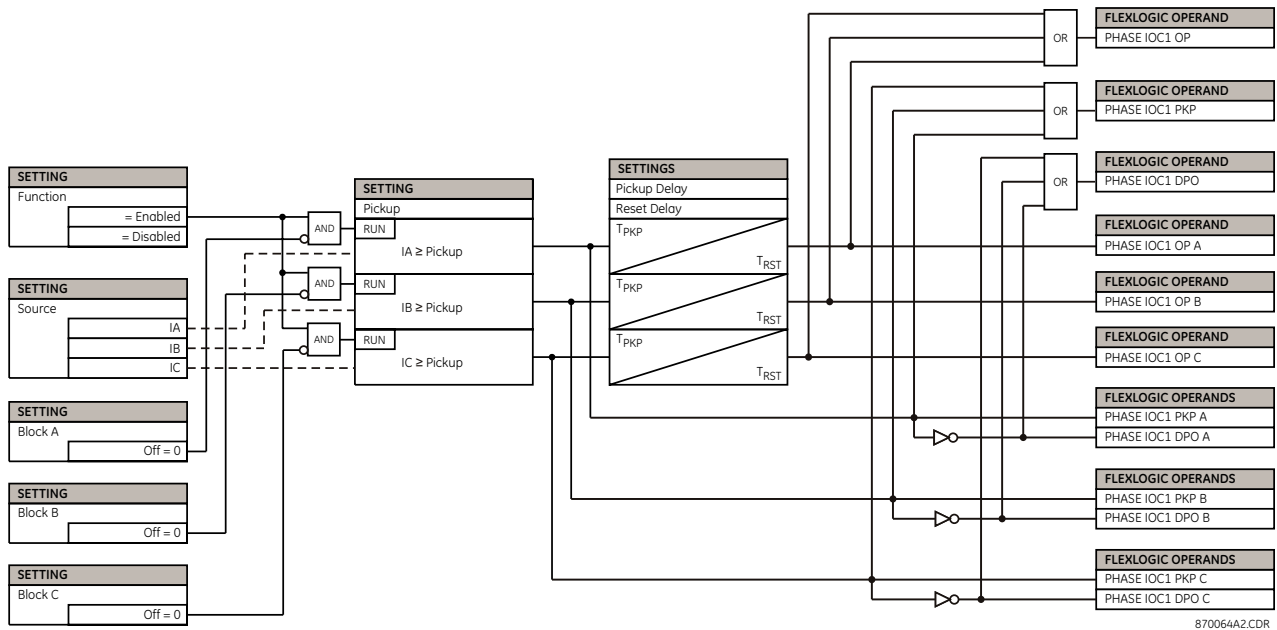
Range: Enabled, Disabled

Default: varies with UR^{PLUS}-series model; see the EnerVista UR^{PLUS} Setup software

This setting enables and disables the logging of phase instantaneous overcurrent events in the sequence of events recorder.

The figure shows the logic for the phase instantaneous overcurrent 1 element. The logic is identical for all phase instantaneous overcurrent elements.

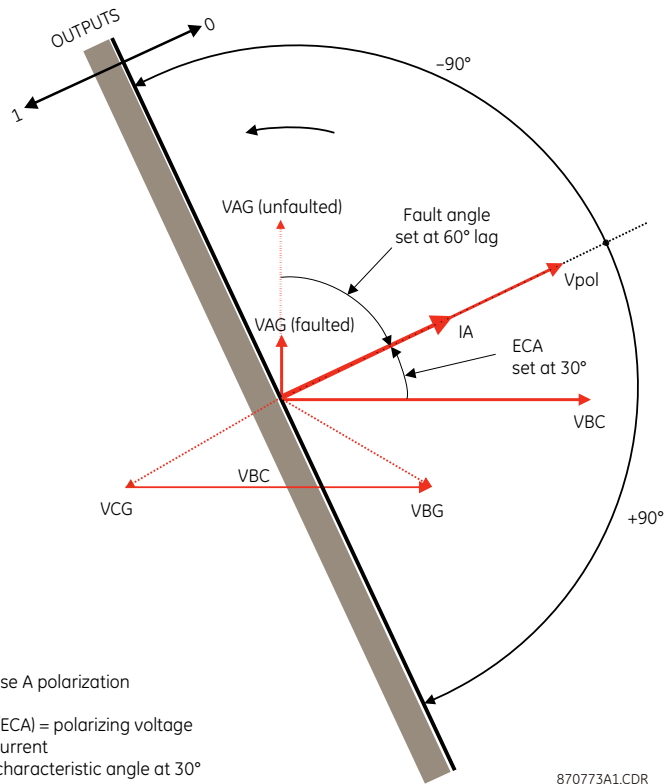
Figure 205: Phase instantaneous overcurrent 1 scheme logic



Phase directional overcurrent

The phase directional elements (one for each of phases A, B, and C) determine the phase current flow direction for steady state and fault conditions and can be used to control the operation of the phase overcurrent elements via the **Block** inputs of these elements.

Figure 206: Phase A directional polarization



This element is intended to apply a block signal to an overcurrent element to prevent an operation when current is flowing in a particular direction. The direction of current flow is determined by measuring the phase angle between the current from the phase CTs and the line-line voltage from the VTs, based on the 90° or quadrature connection. If there is a requirement to supervise overcurrent elements for flows in opposite directions, such as can happen through a bus-tie breaker, two phase directional elements should be programmed with opposite element characteristic angle (ECA) settings.

To increase security for three phase faults very close to the VTs used to measure the polarizing voltage, a voltage memory feature is incorporated. This feature stores the polarizing voltage the moment before the voltage collapses, and uses it to determine direction. The voltage memory remains valid for one second after the voltage has collapsed.

The main component of the phase directional element is the phase angle comparator with two inputs: the operating signal (phase current) and the polarizing signal (the line voltage, shifted in the leading direction by the characteristic angle, ECA).

The table shows the operating and polarizing signals used for phase directional control.

Table 13: Operating and polarizing signals

Phase	Operating signal	Polarizing signal V_{pol}	
		ABC phase sequence	ACB phase sequence
A	angle of IA	angle of VBC × (1∠ECA)	angle of VCB × (1∠ECA)
B	angle of IB	angle of VCA × (1∠ECA)	angle of VAC × (1∠ECA)
C	angle of IC	angle of VAB × (1∠ECA)	angle of VBA × (1∠ECA)

When the phase directional overcurrent element is disabled or the operating current is below 5% × CT nominal, the element output is logic 0.

When the phase directional overcurrent element is enabled, the operating current is above 5% × CT nominal, and the polarizing voltage is above the **Voltage Cut Off Level** setting value, the element output is dependent on the phase angle between the operating and polarizing signals. The element output is logic 0 when the operating current is within polarizing voltage ±90°; for all other angles, the element output is logic 1.

Once the voltage memory has expired, the phase overcurrent elements under directional control can be set to block or trip on overcurrent as follows. When the **Block When Voltage Memory Expires** value is “Yes,” the directional element blocks the operation of any phase overcurrent element under directional control when voltage memory expires. When the **Block When Voltage Memory Expires** value is “No,” the directional element allows tripping of phase overcurrent elements under directional control when voltage memory expires.

In all cases, directional blocking is permitted to resume when the polarizing voltage becomes greater than the polarizing voltage threshold.



The phase directional element responds to the forward load current. In the case of a following reverse fault, the element needs some time—in the order of 8 ms—to establish a blocking signal. Some protection elements, such as instantaneous overcurrent, respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 ms must be added to all the instantaneous protection elements under the supervision of the phase directional element. If current reversal is of concern, a longer delay—in the order of 20 ms—is needed.

Select the **Settings > Protection > Elements > Group 1 > Current > Phase Directional OC** menu to open the phase directional overcurrent configuration window.

Figure 207: Phase directional overcurrent configuration settings

PARAMETER	PHASE DIR1	PHASE DIR2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Block	OFF	OFF
ECA	30 deg	30 deg
Pol V Threshold	0.700 pu	0.700 pu
Block when V Mem Exp	No	No
Events	Disabled	Disabled

URPlus_03.urs Protection: Elements: Group 1: Current

The following settings are available for each phase directional overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting is used to select the source for the operating and polarizing signals. The operating current for the phase directional element is the phase current for the selected current source. The polarizing voltage is the line voltage from the phase VTs, based on the 90° or quadrature connection and shifted in the leading direction by the element characteristic angle (ECA).

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the phase directional overcurrent element.

ECA

Range: 0 to 359° in steps of 1

Default: 30°

This setting specifies the element characteristic angle, that is, the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of the D90^{PLUS} protection elements, a block is applied to an element by asserting logic 1 at the blocking input. Program the phase directional overcurrent element using this setting so that the output is logic 1 for current in the non-tripping direction.

Polarizing Voltage Threshold

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.700 pu

This setting is used to establish the minimum level of voltage for which the phase angle measurement is reliable. The setting is based on VT accuracy.

Block When Voltage Memory Expires

Range: Yes, No
 Default: No

This setting is used to select the required operation upon expiration of voltage memory. When set to “Yes,” the directional element blocks the operation of any phase overcurrent element under directional control, when voltage memory expires. When set to “No,” the directional element allows tripping of phase overcurrent elements under directional control.

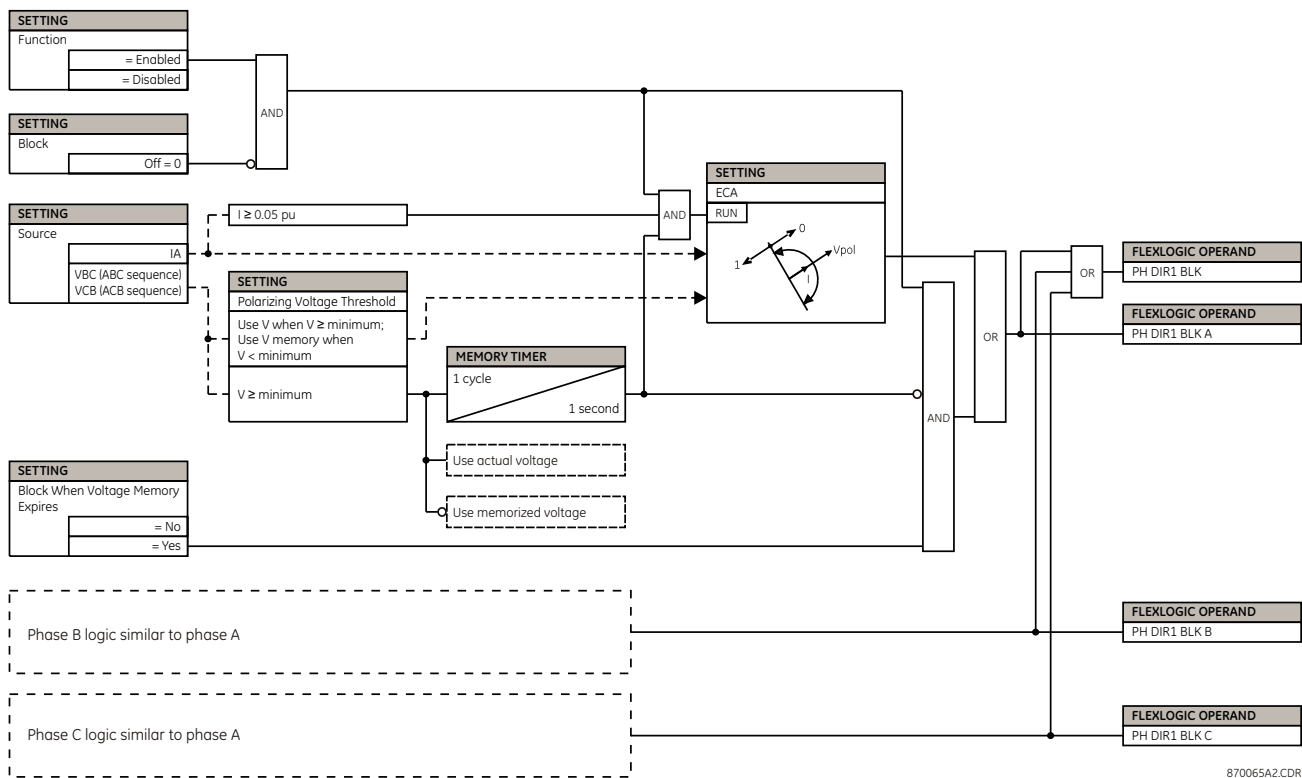
Events

Range: Enabled, Disabled
 Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of phase directional overcurrent events in the sequence of events recorder.

The figure shows the logic for the phase directional overcurrent 1 element. The logic is identical for all phase directional overcurrent elements.

Figure 208: Phase directional overcurrent 1 scheme logic



Neutral time overcurrent

The neutral time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple definite time element. The neutral current input value is a quantity calculated as 3I₀ from the phase currents and can be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: “Timed” and “Instantaneous.” When the element is blocked, the time accumulator resets according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator clears immediately.

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral TOC** menu to open the neutral time overcurrent configuration window.

Figure 209: Neutral time overcurrent configuration settings

PARAMETER	NEUTRAL TOC1	NEUTRAL TOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Input	Phasor	Phasor
Pickup	1.000 pu	1.000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each neutral time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how neutral current input quantities are interpreted by the D90^{Plus}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: *Instantaneous, Timed*
 Default: *Instantaneous*

The “Instantaneous” reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The “Timed” reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: *any FlexLogic operand or shared operand*
 Default: *Off*

Assertion of the operand assigned to this setting blocks operation of the neutral time overcurrent element.

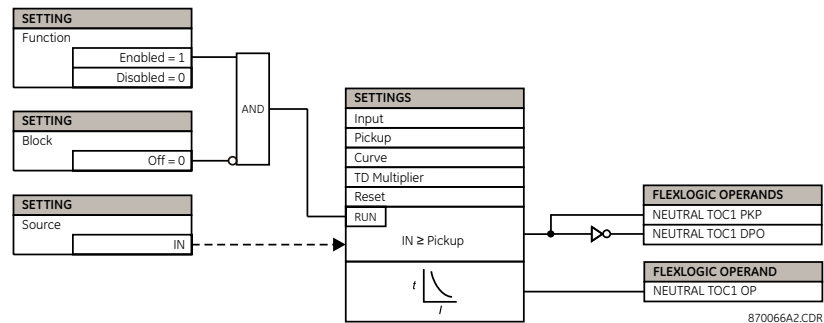
Events

Range: *Enabled, Disabled*
 Default: *varies with UR^{Plus}-series model; refer to the EnerVista UR^{Plus} Setup software*

This setting enables and disables the logging of neutral time overcurrent events in the sequence of events recorder.

The figure shows the logic for the neutral time overcurrent 1 element. The logic is identical for all neutral time overcurrent elements.

Figure 210: Neutral time overcurrent 1 logic



Neutral instantaneous overcurrent

The neutral instantaneous overcurrent element can be used as an instantaneous function with no intentional delay or as a definite time function. The element essentially responds to the magnitude of a neutral current fundamental frequency phasor calculated from the phase currents. A positive-sequence restraint is applied for better performance. A small portion (6.25%) of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity of the element, as follows:

$$I_{op} = 3 \times (I_{0} - K \times I_{1}), \text{ where } k = \frac{1}{16} \tag{Eq. 22}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs) during double-line and three-phase faults
- Switch-off transients during double-line and three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how test currents are injected into the relay. For single-phase injection, the operating quantity is

$$I_{op} = 0.9375 \times I_{injected} \quad \text{Eq. 23}$$

For three-phase pure zero-sequence injection, the operating quantity is

$$I_{op} = 3 \times I_{injected} \quad \text{Eq. 24}$$

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral IOC** menu to open the neutral instantaneous overcurrent configuration window.

Figure 211: Neutral instantaneous overcurrent configuration settings

PARAMETER	NEUTRAL IOC1	NEUTRAL IOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Delay	0.00 s	0.00 s
Reset Delay	0.00 s	0.00 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each neutral instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the **NEUTRAL IOC OP** operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the neutral instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting blocks operation of the neutral instantaneous overcurrent element.

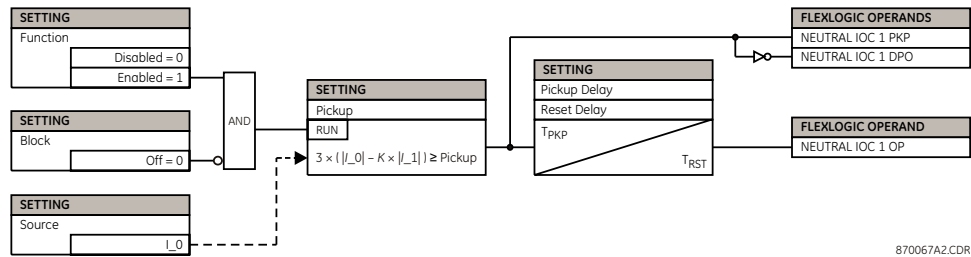
Events

Range: Enabled, Disabled
 Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of neutral instantaneous overcurrent events in the sequence of events recorder.

The figure shows the logic for the neutral instantaneous overcurrent 1 element. The logic is identical for all neutral instantaneous overcurrent elements.

Figure 212: Neutral instantaneous overcurrent 1 scheme logic



Neutral directional overcurrent

There are two neutral directional overcurrent protection elements available. The element provides both forward and reverse fault direction indications the **NEUTRAL DIR OC1 FWD** and **NEUTRAL DIR OC1 REV** operands, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as forward or reverse, respectively (directional unit).

The **overcurrent unit** responds to the magnitude of a fundamental frequency phasor of either the neutral current calculated from the phase currents or the ground current. There are separate pickup settings for the forward-looking and reverse-looking functions. If set to use the calculated 3I₀, the element applies a positive-sequence restraint for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times (|I_0| - K \times |I_1|) \tag{Eq. 25}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs) during double-line and three-phase faults
- Switch-off transients during double-line and three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay. For single-phase injection, the operating quantity is

$$I_{op} = (1 - K) \times I_{injected} \tag{Eq. 26}$$

For three-phase pure zero-sequence injection, the operating quantity is

$$I_{op} = 3 \times I_{injected} \tag{Eq. 27}$$

The positive-sequence restraint is removed for low currents. If the positive-sequence current is below 0.8 pu, the restraint is removed by changing the constant K to zero. This facilitates better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors as the current is low.

The **directional** unit uses the zero-sequence current (I_{0}) or ground current (IG) for fault direction discrimination and can be programmed to use either zero-sequence voltage ("Calculated V_0 " or "Measured VX "), ground current (IG), or both for polarizing. The phasors for the neutral directional overcurrent element directional unit are described below, where V_0 is the zero-sequence voltage, I_0 is the zero-sequence current, ECA is the element characteristic angle, IG is the ground current, and

$$V_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}) \quad \text{Eq. 28}$$

$$I_0 = \frac{1}{3}I_N = \frac{1}{3}(I_A + I_B + I_C) \quad \text{Eq. 29}$$

Table 14: Phasors for "Calculated $3I_0$ " configuration

Polarizing mode	Direction	Compared phasors
Voltage	Forward	$-V_0 + Z_{\text{offset}} \times I_0$ and $I_0 \times 1 \angle ECA$
	Reverse	$-V_0 + Z_{\text{offset}} \times -I_0$ and $I_0 \times 1 \angle ECA$
Current	Forward	IG and I_0
	Reverse	IG and $-I_0$
Dual	Forward	$-V_0 + Z_{\text{offset}} \times I_0$ and $I_0 \times 1 \angle ECA$ or IG and I_0
	Reverse	$-V_0 + Z_{\text{offset}} \times I_0$ and $I_0 \times 1 \angle ECA$ or IG and $-I_0$

The operating current for overcurrent unit for the "Calculated $3I_0$ " configuration is

$$I_{op} = 3 \times (|I_0| - K \times |I_{-1}|) \quad \text{if } |I_{-1}| > 0.8 \text{ pu}$$

$$I_{op} = 3 \times |I_0| \quad \text{if } |I_{-1}| \leq 0.8 \text{ pu} \quad \text{Eq. 30}$$

Table 15: Phasors for "Measured IG " configuration

Polarizing mode	Direction	Compared phasors
Voltage	Forward	$-V_0 + Z_{\text{offset}} \times IG/3$ and $IG \times 1 \angle ECA$
	Reverse	$-V_0 + Z_{\text{offset}} \times -IG/3$ and $-IG \times 1 \angle ECA$

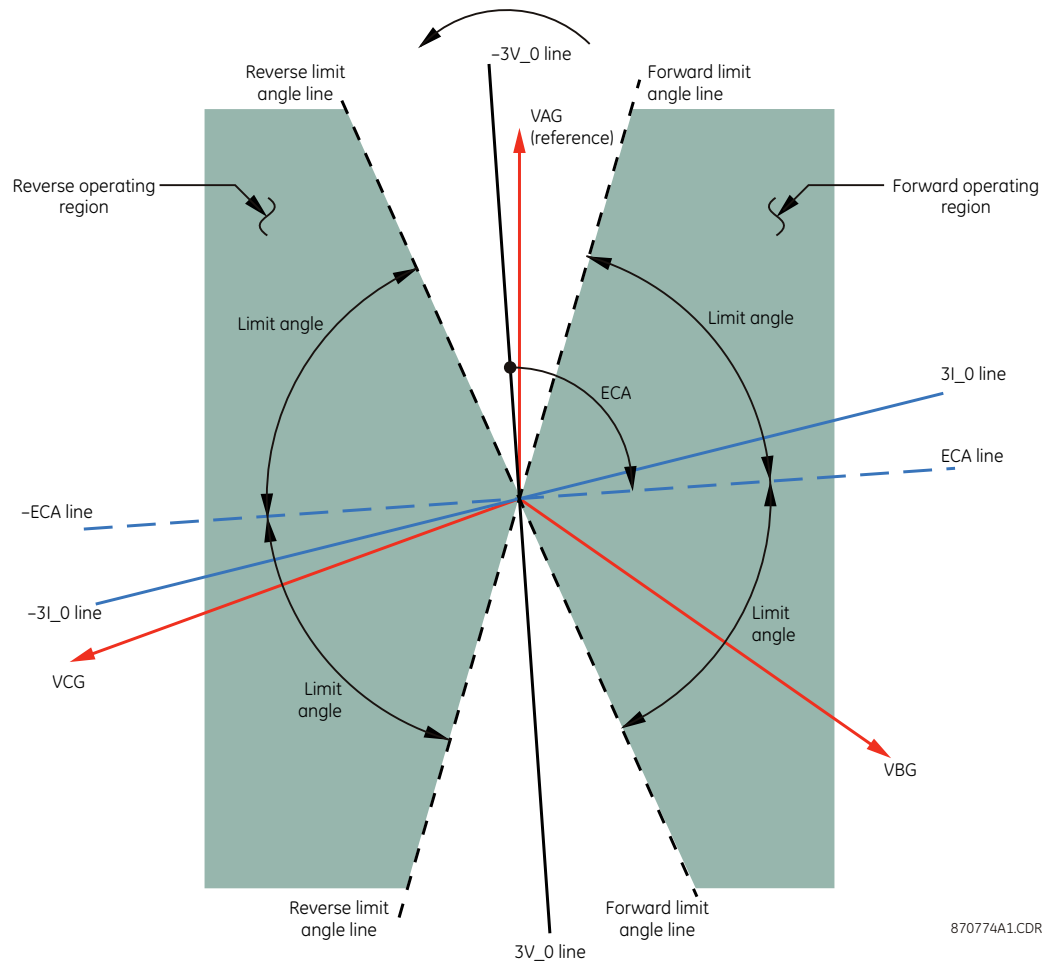
The operating current for overcurrent unit for the "Measured IG " configuration is

$$I_{op} = |IG| \quad \text{Eq. 31}$$

When the **Polarizing Voltage** setting is programmed as "Measured VX ," one-third of this voltage is used in place of V_0 . The following figure explains the usage of the voltage polarized directional unit of the element.

The figure shows the voltage-polarized phase angle comparator characteristics for a phase A to ground fault, with the element characteristic angle equal to 90° (center line of operating characteristic), forward limit angle equal to 80° (the \pm angular limit with the ECA for operation), and reverse limit angle equal to 80° (the \pm angular limit with the ECA for operation).

Figure 213: Neutral directional voltage polarized characteristics



The neutral directional overcurrent element incorporates a current reversal logic. If the reverse direction is indicated for at least 1.25 of a power system cycle, the prospective forward indication is delayed by 1.5 of a power system cycle. The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals results in faster directional discrimination bringing more security to the element operation.

The forward-looking function is designed to be more secure as compared to the reverse-looking function, and therefore is to be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and is to be used for the blocking direction. This allows for better protection coordination.

Take this bias into account when using the neutral directional overcurrent element to directionalize other protection elements.



Proper application of this element requires that the operating current and the polarizing voltage (or current) be measured from the same side of the transformer.

Select the **Settings > Protection > Elements > Group 1 > Current > Neutral Directional OC** menu to open the neutral directional overcurrent configuration window.

Figure 214: Neutral directional overcurrent configuration settings

PARAMETER	NEUTRAL DIR OC1	NEUTRAL DIR OC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Polarizing	Voltage	Voltage
Polarizing Voltage	Calculated V0	Calculated V0
Operating Current	Calculated 3I0	Calculated 3I0
Positive-Sequence Restraint	0.063	0.063
Offset	0.00 ohms	0.00 ohms
Forward ECA	75 ° Lag	75 ° Lag
Forward Limit Angle	90 deg	90 deg
Forward Pickup	0.050 pu	0.050 pu
Reverse Limit Angle	90 deg	90 deg
Reverse Pickup	0.050 pu	0.050 pu
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each neutral directional overcurrent element.

Function

Default: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the neutral directional overcurrent protection element.

Polarizing

Range: Voltage, Current, Dual

Default: Voltage

This setting selects the polarizing mode for the directional unit.

If "Voltage" polarizing is selected, the element uses the zero-sequence voltage angle for polarization. The user can use either the zero-sequence voltage V_0 calculated from the phase voltages, or the zero-sequence voltage supplied externally as the auxiliary voltage V_x , both from the neutral directional [Source](#) setting.

The calculated V_0 can be used as polarizing voltage only if the voltage transformers are connected in Wye. The auxiliary voltage can be used as the polarizing voltage provided the [Auxiliary VT Connection](#) setting is "Vn" and the auxiliary voltage is connected to a zero-sequence voltage source (such as open delta connected secondary of VTs).

The zero-sequence (V_0) or auxiliary voltage (V_x), accordingly, must be greater than the Voltage Cutoff Level of the general voltage inputs (found under the **Protection > Power System > AC Inputs - Voltage** settings) to be validated for use as a polarizing signal. If the polarizing signal is invalid, neither forward nor reverse indication is given. In addition, the zero-sequence current (I_0) must be greater than the [Current Cutoff Level](#) setting value specified in the **Protection > Power System > AC Inputs - Current** menu.

If "Current" polarizing is selected, the element uses the ground current angle connected externally and configured under the neutral directional [Source](#) setting for polarization. The ground CT must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be greater than 0.05 pu to be validated as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given.

For a choice of current polarizing, it is recommended that the polarizing signal be analyzed to ensure that a known direction is maintained irrespective of the fault location. For example, if using an autotransformer neutral current as a polarizing source, ensure that a reversal of the ground current does not occur for a high-side fault. Assume that the low-side system impedance is minimal when checking for this condition. A similar situation arises for a wye/delta/wye transformer, where current in one transformer winding neutral can reverse when faults on both sides of the transformer are considered.

If “Dual” polarizing is selected, the element performs both directional comparisons as described. A given direction is confirmed if either voltage or current comparators indicate so. If a conflicting (simultaneous forward and reverse) indication occurs, the forward direction overrides the reverse direction.

Polarizing Voltage

Range: Calculated V0, Measured VX

Default: Calculated V0

This setting selects the polarizing voltage used by the directional unit when the “Voltage” or “Dual” polarizing mode is set. The polarizing voltage can be programmed to be either the zero-sequence voltage calculated from the phase voltages (“Calculated V0”) or supplied externally as an auxiliary voltage (“Measured VX”).

Operating Current

Range: Calculated 3I0, Measured IG

Default: Calculated 3I0

This setting indicates whether the 3I₀ current calculated from the phase currents, or the ground current is used by this protection. This setting acts as a switch between the neutral and ground modes of operation (ANSI devices 67N and 67G). If set to “Calculated 3I0,” the element uses the phase currents and applies the positive-sequence restraint. If set to “Measured IG,” the element uses ground current supplied to the ground CT of the CT bank configured as the neutral directional “Source.” If this setting is “Measured IG,” then the **Polarizing** setting must be “Voltage,” as it is not possible to use the ground current as an operating and polarizing signal simultaneously.

Positive-Sequence Restraint

Range: 0.000 to 0.500 in steps of 0.001

Default: 0.063

This setting controls the amount of the positive-sequence restraint. Set it to 0.063 for backward compatibility with firmware revisions 3.40 and older. Set it to zero to remove the restraint. Set it higher if large system unbalances or poor CT performance are expected.

Offset

Range: 0.00 to 250.00 ohms in steps of 0.01

Default: 0.00 ohms

This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. In regular applications, the offset impedance ensures proper operation even if the zero-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance is not to be larger than the zero-sequence impedance of the protected circuit. Practically, it is several times smaller. Enter the offset impedance in secondary ohms.

Forward ECA

Range: -90 to 90° in steps of 1

Default: -70°

This setting defines the characteristic angle (ECA) for the forward direction in the “Voltage” polarizing mode. The “Current” polarizing mode uses a fixed ECA of 0°. The ECA in the reverse direction is the angle set for the forward direction shifted by 180°.

Forward Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

Forward Pickup

Range: 0.006 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting defines the pickup level for the overcurrent unit of the element in the forward direction. When selecting this setting, keep in mind that the design uses a positive-sequence restraint technique for the “Calculated 3I0” mode of operation.

Reverse Limit Angle

Range: 40 to 90° in steps of 1

Default: 90°

This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

Reverse Pickup

Range: 0.006 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. When selecting this setting, keep in mind that the design uses a positive-sequence restraint technique for the “Calculated 3I0” mode of operation.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the neutral directional overcurrent element.

Events

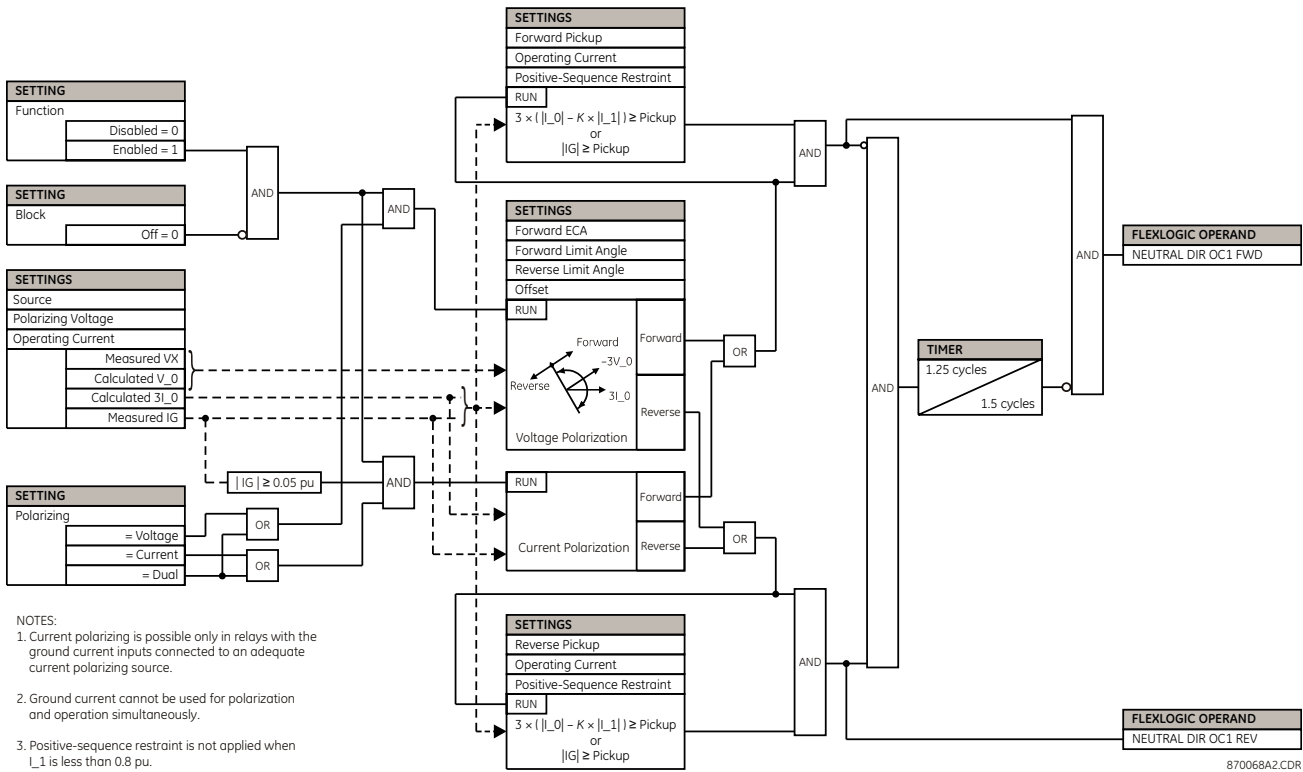
Range: Enabled, Disabled

Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of neutral directional overcurrent events in the sequence of events recorder.

The figure shows the logic for the neutral directional overcurrent 1 element. The logic is identical for both neutral directional overcurrent elements.

Figure 215: Neutral directional overcurrent 1 scheme logic



Ground time overcurrent

This element can provide a required time-delay operating characteristic versus the applied current or be used as a simple definite time element. The ground current input value is the quantity measured by the ground input CT and is the fundamental phasor or RMS magnitude. Two methods of resetting operation are available: "Timed" and "Instantaneous." When the element is blocked, the time accumulator resets according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator clears immediately.



These elements measure the current that is connected to the ground channel of an AC module. This channel can be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

Select the **Settings > Protection > Elements > Group 1 > Current > Ground TOC** menu to open the ground time overcurrent configuration window.

Figure 216: Ground time overcurrent configuration settings

PARAMETER	GROUND TOC1	GROUND TOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Input	Phasor	Phasor
Pickup	1.000 pu	1.000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Block	OFF	OFF
Events	Disabled	Disabled

URPlus_03.urs Protection: Elements: Group 1: Current

The following settings are available for each ground time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the ground time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the ground time overcurrent protection element.

Input

Range: Phasor, RMS

Default: Phasor

This setting selects how ground current input quantities are interpreted by the D90^{Plus}. Inputs can be selected as fundamental phasor magnitudes or total waveform RMS magnitudes as required by the application.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the ground time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the [Curve](#) setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: *Instantaneous, Timed*
 Default: *Instantaneous*

The “Instantaneous” reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The “Timed” reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: *any FlexLogic operand or shared operand*
 Default: *Off*

Assertion of the operand assigned to this setting blocks operation of the ground time overcurrent element.

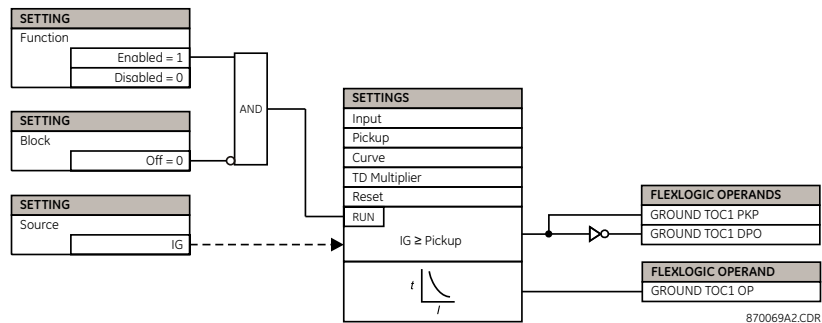
Events

Range: *Enabled, Disabled*
 Default: *varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software*

This setting enables and disables the logging of ground time overcurrent events in the sequence of events recorder.

The figure shows the logic for the ground time overcurrent 1 element. The logic is identical for all ground time overcurrent elements.

Figure 217: Ground time overcurrent scheme logic



Ground instantaneous overcurrent

The ground instantaneous overcurrent element can be used as an instantaneous element with no intentional delay or as a definite time element. The ground current input is the quantity measured by the ground input CT and is the fundamental phasor magnitude.



These elements measure the current that is connected to the ground channel of an AC module. This channel can be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

Select the **Settings > Protection > Elements > Group 1 > Current > Ground IOC** menu to open the ground instantaneous overcurrent configuration window.

Figure 218: Ground instantaneous overcurrent configuration settings

PARAMETER	GROUND IOC1	GROUND IOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Delay	0.00 s	0.00 s
Reset Delay	0.00 s	0.00 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each ground instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the ground instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the ground instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the ground instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the **GROUND IOC OP** operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the ground instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the ground instantaneous overcurrent element.

Events

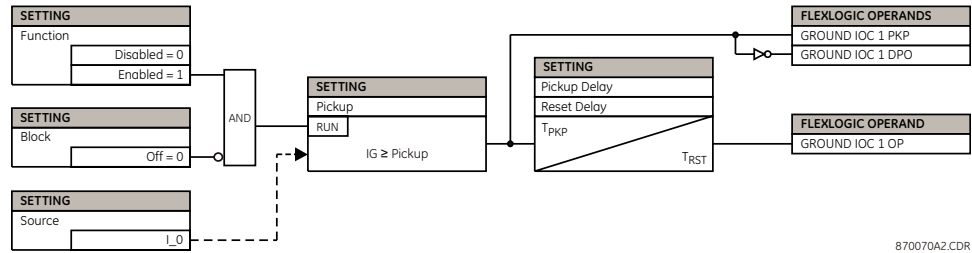
Range: Enabled, Disabled

Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of ground instantaneous overcurrent events in the sequence of events recorder.

The figure shows the logic for the ground instantaneous overcurrent 1 element. The logic is identical for all ground instantaneous overcurrent elements.

Figure 219: Ground instantaneous overcurrent scheme logic



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Negative-sequence time overcurrent

The negative-sequence time overcurrent element can be used to determine and clear unbalance in the system. The input for calculating negative-sequence current is the fundamental phasor value.

Two methods of resetting operation are available: “Timed” and “Instantaneous.” When the element is blocked, the time accumulator resets according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator clears immediately.

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence TOC** menu to open the negative-sequence time overcurrent configuration window.

Figure 220: Negative-sequence time overcurrent configuration settings

PARAMETER	NEGATIVE SEQ TOC1	NEGATIVE SEQ TOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Curve	IEEE Mod Inv	IEEE Mod Inv
TD Multiplier	1.00	1.00
Reset	Instantaneous	Instantaneous
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each negative-sequence time overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence time overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence time overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the neutral time overcurrent pickup level in per-unit values.

Curve

Range: IEEE Mod Inv, IEEE Very Inv, IEEE Ext Inv, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inv, IAC Ext Inv, IAC Very Inv, IAC Inverse, IAC Short Inv, I2t, Definite Time, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Mod Inv

This setting selects the inverse time overcurrent curve style.

TD Multiplier

Range: 0.00 to 600.00 in steps of 0.01

Default: 1.00

This setting specifies a multiple of the base curve shape specified by the **Curve** setting. Programming this value to zero results in an instantaneous response to all current levels above pickup.

Reset

Range: Instantaneous, Timed

Default: Instantaneous

The “Instantaneous” reset method is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The “Timed” reset method can be used where the relay must coordinate with electromechanical relays.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the negative-sequence time overcurrent element.

Events

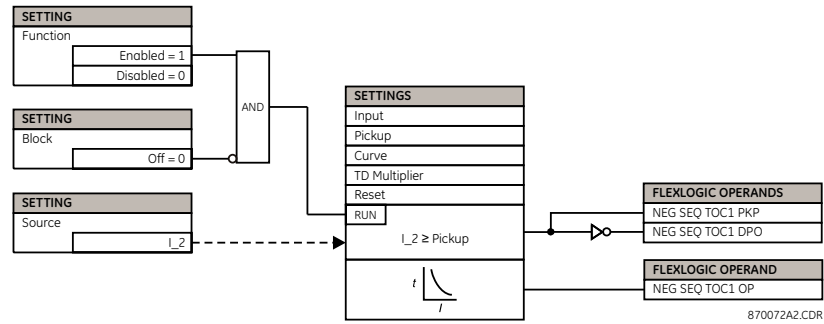
Range: Enabled, Disabled

Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of negative-sequence time overcurrent events in the sequence of events recorder.

The figure shows the logic for the negative-sequence time overcurrent 1 element. The logic is identical for all negative-sequence time overcurrent elements.

Figure 221: Negative-sequence time overcurrent scheme logic



Negative-sequence instantaneous overcurrent

The negative-sequence instantaneous overcurrent element can be used as an instantaneous function with no intentional delay or as a definite time function. The element responds to the negative-sequence current fundamental frequency phasor magnitude (calculated from the phase currents) and applies a positive-sequence restraint for better performance: a small portion (12.5%) of the positive-sequence current magnitude is subtracted from the negative-sequence current magnitude when forming the operating quantity.

$$I_{op} = |I_{-2}| - K \times |I_{-1}| \quad \text{where } K = \frac{1}{8} \tag{Eq. 32}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence currents resulting from

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs) during three-phase faults
- Fault inception and switch-off transients during three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how the test currents are injected into the relay. The operating quantity for single-phase injection is

$$I_{op} = 0.2917 \times I_{injected} \tag{Eq. 33}$$

The operating quantity for three-phase injection, opposite rotation, is

$$I_{op} = I_{injected} \tag{Eq. 34}$$

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence IOC** menu to open the negative-sequence instantaneous overcurrent configuration window.

Figure 222: Negative-sequence instantaneous overcurrent configuration settings

PARAMETER	NEGATIVE SEQ IOC1	NEGATIVE SEQ IOC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Delay	0.00 s	0.00 s
Reset Delay	0.00 s	0.00 s
Block	OFF	OFF
Events	Disabled	Disabled

URPlus_03.urs | Protection: Elements: Group 1: Current

The following settings are available for each negative-sequence instantaneous overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence instantaneous overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence instantaneous overcurrent protection element.

Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the negative-sequence instantaneous overcurrent pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting delays the assertion of the **NEG SEQ IOC OP** operands. It is used to achieve timing coordination with other elements and relays.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.00 seconds

This setting specifies a delay for the reset of the phase instantaneous overcurrent element between the operate output state and the return to logic 0 after the input passes outside the defined pickup range. This setting is used to ensure that the relay output contacts are closed long enough to ensure reception by downstream equipment.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks operation of the negative-sequence instantaneous overcurrent element.

Events

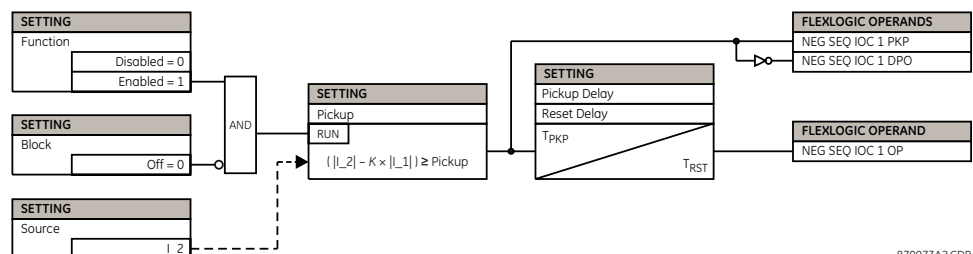
Range: Enabled, Disabled

Default: varies with UR^{Plus}-series model; refer to the EnerVista UR^{Plus} Setup software

This setting enables and disables the logging of negative-sequence instantaneous overcurrent events in the sequence of events recorder.

The figure shows the logic for the negative-sequence instantaneous overcurrent 1 element. The logic is identical for all negative-sequence instantaneous overcurrent elements.

Figure 223: Negative-sequence instantaneous overcurrent scheme logic



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Negative-sequence directional overcurrent

There are two negative-sequence directional overcurrent protection elements available. The element provides both forward and reverse fault direction indications through its output operands **NEG SEQ DIR OC1 FWD** and **NEG SEQ DIR OC1 REV**, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as forward or reverse, respectively (directional unit).

The overcurrent unit of the element essentially responds to the magnitude of a fundamental frequency phasor of either the negative-sequence or neutral current as per user selection. Do not mistake the zero-sequence current with the neutral current, as there is a factor of three difference.

A positive-sequence restraint is applied for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the negative or zero-sequence current magnitude, respectively, when forming the element operating quantity.

$$I_{op} = |I_{-2}| - K \times |I_{-1}| \quad \text{or} \quad I_{op} = 3 \times (|I_{-0}| - K \times |I_{-1}|) \quad \text{Eq. 35}$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence and zero-sequence currents resulting from

- System unbalances under heavy load conditions
- Transformation errors of current transformers (CTs)
- Fault inception and switch-off transients

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The positive-sequence restraint is removed for low currents. If the positive-sequence current is less than 0.8 pu, then the restraint is removed by setting the constant *K* to zero. This results in better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors, as the current is low.

The operating quantity depends on the way the test currents are injected into the D90^{Plus}. For single-phase injection,

$$I_{op} = \frac{1}{3} \times (1 - K) \times I_{injected} \quad \text{for } I_{-2} \text{ mode and}$$

$$I_{op} = (1 - K) \times I_{injected} \quad \text{for } I_{-0} \text{ mode if } |I_{-1}| > 0.8 \text{ pu}$$

The directional unit uses the negative-sequence current (*I*₋₂) and negative-sequence voltage (*V*₋₂).

The following tables define the negative-sequence directional overcurrent element.

Table 16: Negative-sequence directional overcurrent unit

Mode	Operating current
Negative-sequence	$I_{op} = I_{-2} - K \times I_{-1} $
Zero-sequence	$I_{op} = 3 \times (I_{-0} - K \times I_{-1})$ if $ I_{-1} > 0.8 \text{ pu}$ $I_{op} = 3 \times I_{-0} $ if $ I_{-1} \leq 0.8 \text{ pu}$

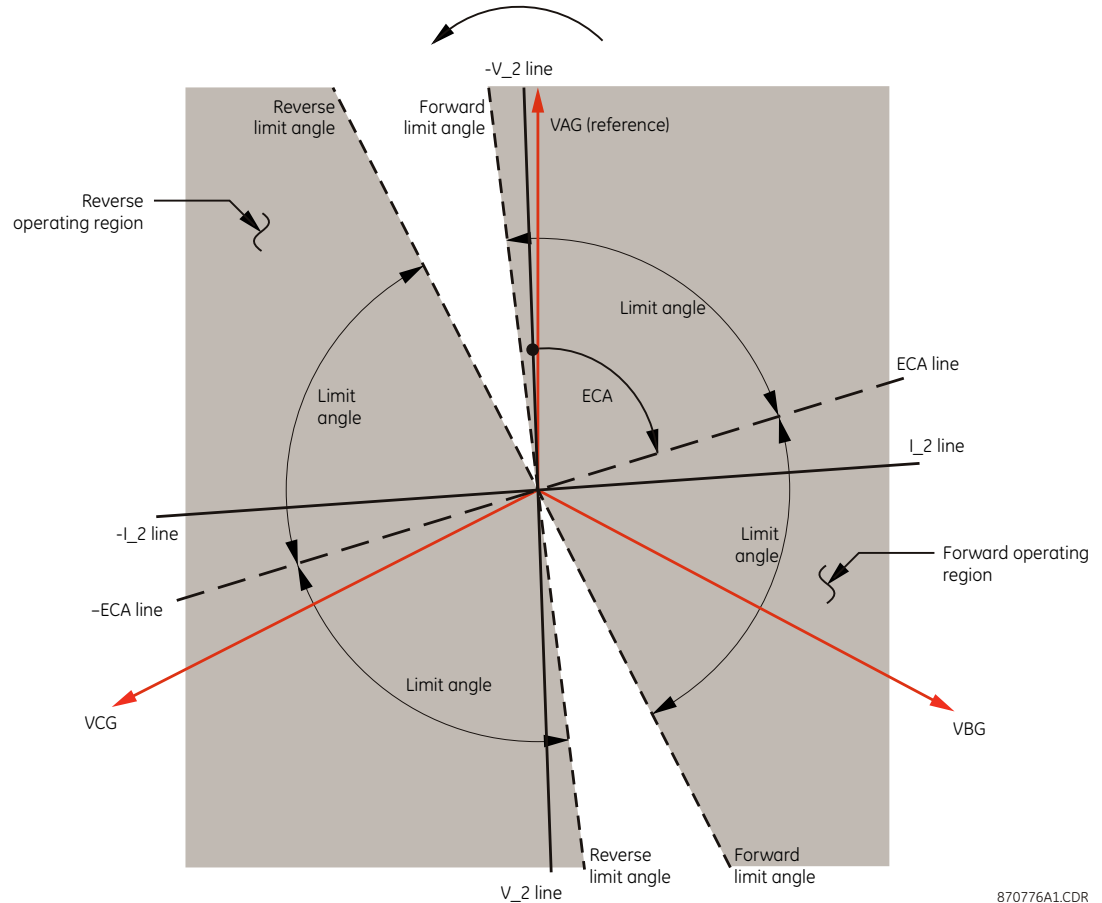
Table 17: Negative-sequence directional unit

Mode	Direction	Compared phasors
Negative-sequence	Forward	$-V_{-2} + Z_{offset} \times I_{-2}$ and $I_{-2} \times 1 \angle ECA$
	Reverse	$-V_{-2} + Z_{offset} \times I_{-2}$ and $-(I_{-2} \times 1 \angle ECA)$
Zero-sequence	Forward	$-V_{-2} + Z_{offset} \times I_{-2}$ and $I_{-2} \times 1 \angle ECA$
	Reverse	$-V_{-2} + Z_{offset} \times I_{-2}$ and $-(I_{-2} \times 1 \angle ECA)$

The negative-sequence voltage must be greater than the Voltage Cutoff Level of the general voltage inputs (found under the **Protection > Power System > AC Inputs - Voltage** settings) to be validated for use as a polarizing signal. If the polarizing signal is not

validated, neither forward nor reverse indication is given. In addition, the negative-sequence current (or zero-sequence current) must be greater than the **Current Cutoff Level** setting value specified in the **Protection > Power System > AC Inputs – Current** menu. The following figure explains the usage of the voltage polarized directional unit of the element.

Figure 224: Negative-sequence directional characteristics



The forward-looking function is designed to be more secure as compared to the reverse-looking function, so use the forward-looking function for the tripping direction. The reverse-looking function is faster compared to the forward-looking function and is to be used for the blocking direction. This allows for better protection coordination. Take this bias into account when using the negative-sequence directional overcurrent element to directionalize other protection elements.

Select the **Settings > Protection > Elements > Group 1 > Current > Negative Sequence Directional OC** menu to open the negative-sequence directional overcurrent configuration window.

Figure 225: Negative-sequence directional overcurrent configuration settings

PARAMETER	NEGATIVE SEQ DIR OC1	NEGATIVE SEQ DIR OC2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Offset	0.00 ohms	0.00 ohms
Type	Neg Sequence	Neg Sequence
Positive-Sequence Restraint	0.063	0.063
Forward ECA	75 ° Lag	75 ° Lag
Forward Limit Angle	90 deg	90 deg
Forward Pickup	0.05 pu	0.05 pu
Reverse Limit Angle	90 deg	90 deg
Reverse Pickup	0.05 pu	0.05 pu
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each negative-sequence directional overcurrent element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence directional overcurrent protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence directional overcurrent protection element.

Offset

Range: 0.00 to 250.00 ohms in steps of 0.01

Default: 0.00 ohms

This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. In regular applications, the offset impedance ensures proper operation even if the negative-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the negative-sequence impedance of the protected circuit. Practically, it is several times smaller. Enter the offset impedance in secondary ohms.

Type

Range: Neg Sequence, Zero Sequence

Default: Neg Sequence

This setting selects the operating mode for the overcurrent unit of the element. The choices are "Neg Sequence" and "Zero Sequence." In some applications it is advantageous to use a directional negative-sequence overcurrent function instead of a directional zero-sequence overcurrent function as inter-circuit mutual effects are minimized.

Pos Seq Restraint*Range: 0.000 to 0.500 in steps of 0.001**Default: 0.063*

This setting controls the amount of the positive-sequence restraint. Set it to zero to remove the restraint. Set it to a higher value if large system unbalances or poor CT performance are expected.

Forward ECA*Range: 0 to 90° Lag in steps of 1**Default: 75° Lag*

This setting specifies the element characteristic angle (ECA) for the forward direction. The element characteristic angle in the reverse direction is the angle set for the forward direction shifted by 180°.

Forward Limit Angle*Range: 40 to 90° in steps of 1**Default: 90°*

This setting specifies a symmetrical limit angle (in both directions from the element characteristic angle) for the forward direction.

Forward Pickup*Range: 0.015 to 30.000 pu in steps of 0.005**Default: 0.050 pu*

This setting specifies the pickup level for the overcurrent unit in the forward direction. This pickup threshold applies to zero-sequence or negative-sequence current based on the **Type** setting. When specifying this setting, keep in mind that the design uses a positive-sequence restraint technique.

Reverse Limit Angle*Range: 40 to 90° in steps of 1**Default: 90°*

This setting specifies a symmetrical limit angle (in both directions from the element characteristic angle) for the reverse direction.

Reverse Pickup*Range: 0.015 to 30.000 pu in steps of 0.005**Default: 0.050 pu*

This setting specifies the pickup level for the overcurrent unit in the reverse direction. This pickup threshold applies to zero-sequence or negative-sequence current based on the **Type** setting. When specifying this setting, keep in mind that the design uses a positive-sequence restraint technique.

Block*Range: any FlexLogic operand or shared operand**Default: Off*

Assertion of the operand assigned to this setting blocks operation of the negative-sequence directional overcurrent element.

Events*Range: Enabled, Disabled**Default: varies with UR^{Plus}-series model; see the EnerVista UR^{Plus} Setup software*

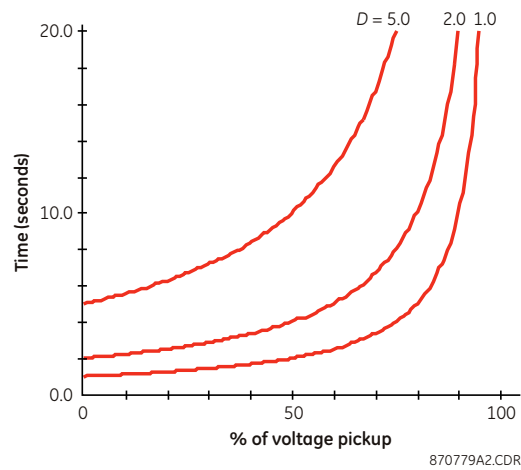
This setting enables and disables the logging of negative-sequence directional overcurrent events in the sequence of events recorder.

The figure shows the logic for the negative-sequence directional overcurrent 1 element. The logic is identical for all negative-sequence directional overcurrent elements.

V is the secondary voltage applied to the relay

V_{pickup} is the pickup level

Figure 227: Inverse time undervoltage curves



At 0% of pickup, the operating time is equivalent to the undervoltage delay setting.

Phase undervoltage

The phase undervoltage element can be used to give a required time delay operating characteristic versus the applied fundamental voltage (phase-to-ground or phase-to-phase for wye VT connections, or phase-to-phase for delta VT connections) or as a definite time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Phase UV** menu to open the phase undervoltage configuration window.

Figure 228: Phase undervoltage configuration settings

PARAMETER	PHASE UV1	PHASE UV2
Function	Disabled	Disabled
Signal Source	LINE (SRC 1)	LINE (SRC 1)
Mode	Phase to Ground	Phase to Ground
Pickup	1.000 pu	1.000 pu
Curve	Definite Time	Definite Time
Delay	1.00 s	1.00 s
Minimum Voltage	0.100 pu	0.100 pu
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each phase undervoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase undervoltage protection element.

Signal Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase undervoltage protection element.

Mode

Range: Phase to Ground, Phase to Phase

Default: Phase to Ground

This setting selects the operating mode. Select phase-to-ground or phase-to-phase for wye VT connections, or phase-to-phase for delta VT connections.

Pickup

Range: 0.000 to 1.100 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase undervoltage pickup level in per-unit values.

Curve

Range: Definite Time, Inverse Time

Default: Definite Time

This setting selects the required time-delay operating characteristic versus the applied fundamental voltage or the definite time element.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the phase undervoltage element.

Minimum Voltage

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.100 pu

This setting specifies the operating voltage in per-unit values below which the element is blocked. A value of "0" allows a dead source to be considered a fault condition.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the phase undervoltage element.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phase undervoltage events in the sequence of events recorder.

The following protection FlexLogic operands are available for the phase undervoltage elements.

Phase undervoltage operands

PHASE UV1 DPO Asserted when at least one phase of the phase undervoltage 1 element drops out.

PHASE UV1 DPO A Asserted when phase A of the phase undervoltage 1 element drops out.

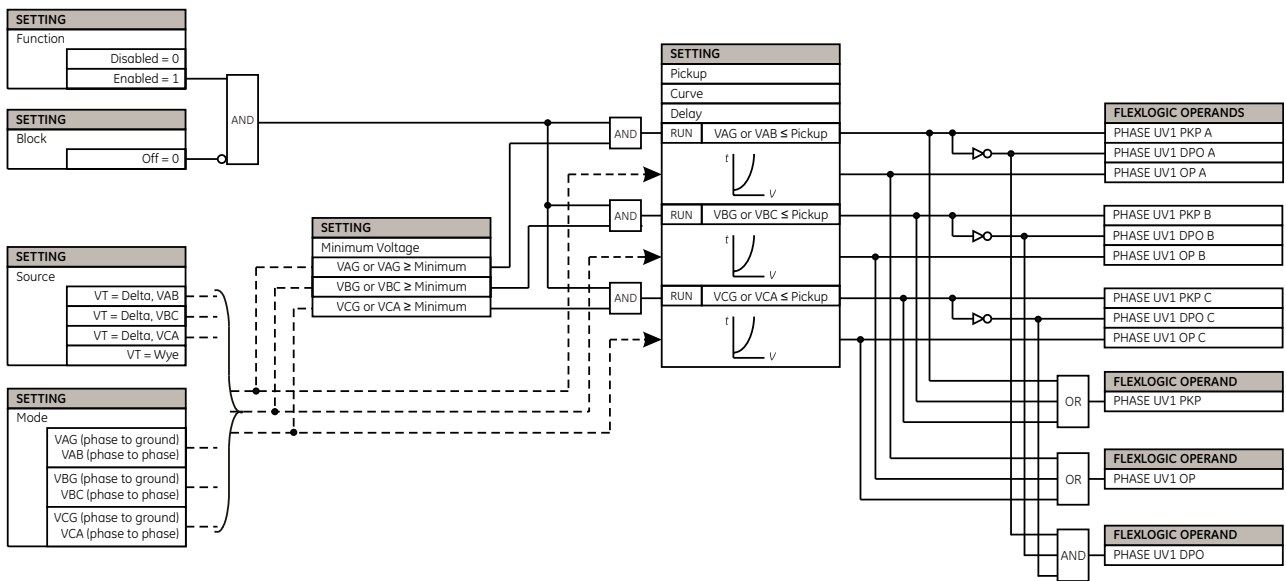
PHASE UV1 DPO B Asserted when phase B of the phase undervoltage 1 element drops out.

PHASE UV1 DPO C Asserted when phase C of the phase undervoltage 1 element drops out.

PHASE UV1 OP.....	Asserted when at least one phase of the phase undervoltage 1 element operates.
PHASE UV1 OP A.....	Asserted when phase A of the phase undervoltage 1 element operates.
PHASE UV1 OP B.....	Asserted when phase B of the phase undervoltage 1 element operates.
PHASE UV1 OP C.....	Asserted when phase C of the phase undervoltage 1 element operates.
PHASE UV1 PKP.....	Asserted when at least one phase of the phase undervoltage 1 element picks up.
PHASE UV1 PKP A.....	Asserted when phase A of the phase undervoltage 1 element picks up.
PHASE UV1 PKP B.....	Asserted when phase B of the phase undervoltage 1 element picks up.
PHASE UV1 PKP C.....	Asserted when phase C of the phase undervoltage 1 element picks up.
PHASE UV2.....	Same set of operands as shown above for the phase undervoltage 2 element.

The figure shows the logic for the phase undervoltage 1 element. The logic is similar for all phase undervoltage elements.

Figure 229: Phase undervoltage 1 logic



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Phase overvoltage

The phase overvoltage element can be used as an instantaneous element with no intentional time delay or as a definite time element. The input voltage is the phase-to-phase voltage, either measured directly from delta-connected VTs or as calculated from phase-to-ground (wye) connected VTs. The specific voltages to be used for each phase are shown in the logic diagram.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Phase OV** menu to open the phase overvoltage configuration window.

Figure 230: Phase overvoltage configuration settings

PARAMETER	PHASE OV1	PHASE OV2
Function	Disabled	Disabled
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	1.000 pu	1.000 pu
Delay	1.00 s	1.00 s
Reset Delay	1.00 s	1.00 s
Block	OFF	OFF
Events	Disabled	Disabled

URPlus_03.urs | Protection: Elements: Group 1: Voltage

The following settings are available for each phase overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the phase overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the phase overvoltage protection element.

Pickup

Range: 0.000 to 1.100 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the phase overvoltage pickup level in per-unit values.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the phase overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum reset time of the phase overvoltage element.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the phase overvoltage element.

Events

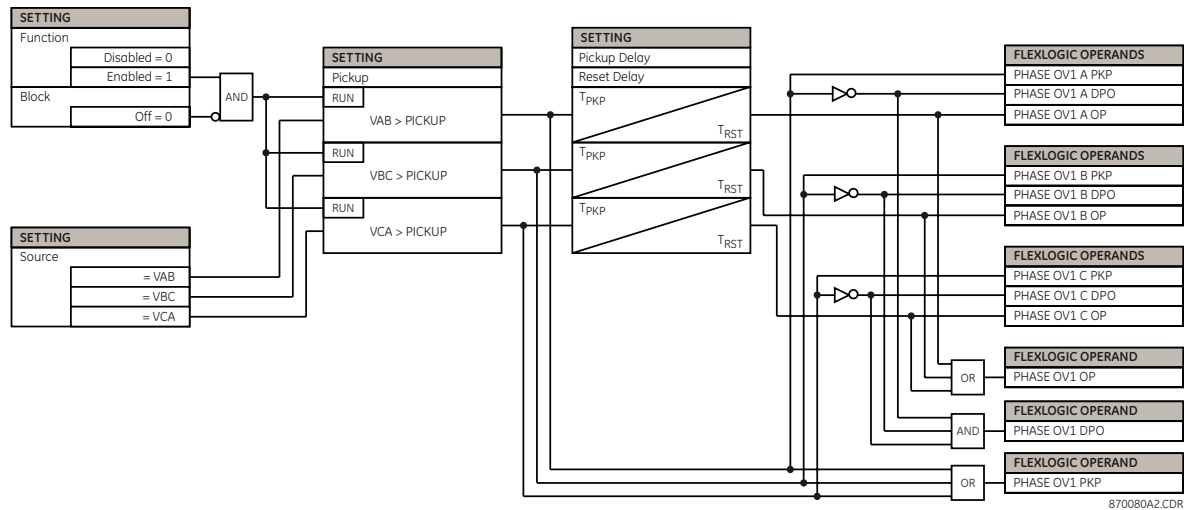
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of phase overvoltage events in the sequence of events recorder.

The figure shows the logic for the phase overvoltage 1 element. The logic is similar for all phase overvoltage elements.

Figure 231: Phase overvoltage logic



Neutral overvoltage

There are three neutral overvoltage elements available. The neutral overvoltage element can be used to detect asymmetrical system voltage condition due to a ground fault or to the loss of one or two phases of the source. The element responds to the system neutral voltage (3V₀), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered in the **Phase VT Secondary** setting is the per-unit base used when setting the pickup level.

The neutral overvoltage element can provide a time-delayed operating characteristic versus the applied voltage (initialized from FlexCurves A, B, or C) or be used as a definite time element. The source assigned to this element must be configured for a phase VT.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be wye-connected.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Neutral OV** menu to open the neutral overvoltage configuration window.

Figure 232: Neutral overvoltage configuration settings

PARAMETER	NEUTRAL OV 1	NEUTRAL OV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.300 pu	0.300 pu
Curve	Definite Time	Definite Time
Pickup Delay	1.00 s	1.00 s
Reset Delay	1.00 s	1.00 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each neutral overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the neutral overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
 Default: LINE (SRC 1)

This setting selects the signal source for the neutral overvoltage protection element.

Pickup

Range: 0.000 to 1.250 pu in steps of 0.001
 Default: 0.300 pu

This setting specifies the neutral overvoltage pickup level in per-unit values.

Curve

Range: Definite Time, FlexCurve A, FlexCurve B, FlexCurve C
 Default: Definite Time

This setting selects whether the neutral overvoltage element provides a time-delayed operating characteristic versus the applied voltage (FlexCurves A, B, or C) or is used as a definite time element.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
 Default: 1.00 seconds

This setting specifies the minimum operating time of the neutral overvoltage element. This setting applies only if the **Curve** setting is "Definite Time."

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01
 Default: 1.00 seconds

This setting specifies the minimum reset time of the neutral overvoltage element.

Block

Range: any FlexLogic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting blocks the neutral overvoltage element.

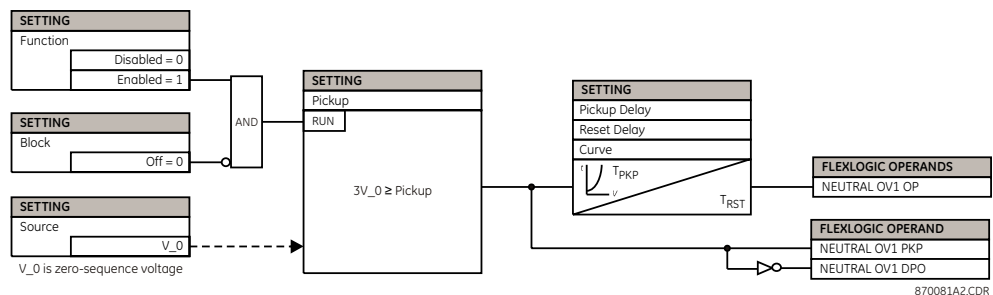
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of neutral overvoltage events in the sequence of events recorder.

The figure shows the logic for the neutral overvoltage 1 element. The logic is similar for all neutral overvoltage elements.

Figure 233: Neutral overvoltage logic

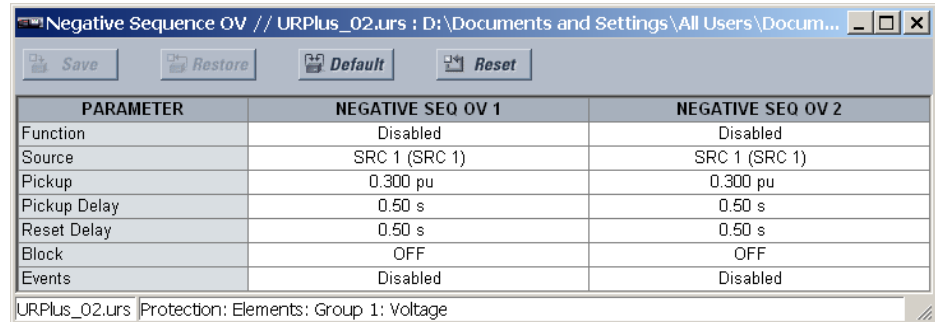


Negative-sequence overvoltage

The negative-sequence overvoltage element can be used to detect loss of one or two phases of the source, a reversed phase sequence of voltage, or a non-symmetrical system voltage condition.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Negative Sequence OV** menu to open the negative-sequence overvoltage configuration window.

Figure 234: Negative-sequence overvoltage configuration settings



PARAMETER	NEGATIVE SEQ OV 1	NEGATIVE SEQ OV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.300 pu	0.300 pu
Pickup Delay	0.50 s	0.50 s
Reset Delay	0.50 s	0.50 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each negative-sequence overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the negative-sequence overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the negative-sequence overvoltage protection element.

Pickup

Range: 0.000 to 1.250 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the negative-sequence overvoltage pickup level in per-unit values.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum operating time of the negative-sequence overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum reset time of the negative-sequence overvoltage element.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the negative-sequence overvoltage element.

Events

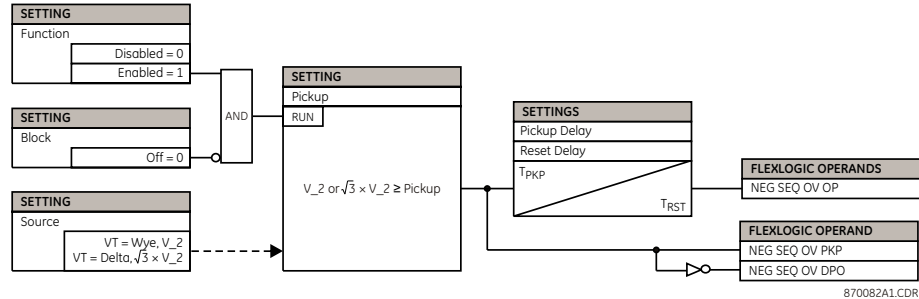
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of negative-sequence overvoltage events in the sequence of events recorder.

The figure shows the logic for the negative-sequence overvoltage 1 element. The logic is similar for all negative-sequence overvoltage elements.

Figure 235: Negative-sequence overvoltage logic



Auxiliary undervoltage

The auxiliary undervoltage element is intended for monitoring undervoltage conditions of the auxiliary voltage. The element pickup selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered for the **Auxiliary VT Secondary** setting is the per-unit base used when setting the pickup level.

Both the **Pickup** and **Delay** settings establish the operating curve of the undervoltage element. The auxiliary undervoltage element can be programmed to use either definite time delay or inverse time delay characteristics.

The auxiliary undervoltage element resets instantaneously.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Auxiliary UV** menu to open the auxiliary undervoltage configuration window.

Figure 236: Auxiliary undervoltage configuration settings

PARAMETER	AUXILIARY UV 1	AUXILIARY UV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.700 pu	0.700 pu
Curve	Definite Time	Definite Time
Delay	1.00 s	1.00 s
Minimum Voltage	0.100 pu	0.100 pu
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each auxiliary undervoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the auxiliary undervoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the auxiliary undervoltage protection element.

Pickup

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.700 pu

This setting specifies the auxiliary undervoltage pickup level in per-unit values.

Curve

Range: Definite Time, Inverse Time

Default: Inverse Time

This setting selects either the required time-delay operating characteristic versus the applied fundamental voltage or the definite time characteristic for the auxiliary undervoltage element.

Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting selects the minimum operating time of the auxiliary undervoltage element.

Minimum Voltage

Range: 0.000 to 3.000 pu in steps of 0.001

Default: 0.100 pu

This setting specifies the operating voltage below which the auxiliary undervoltage element is blocked.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the auxiliary undervoltage element.

Events

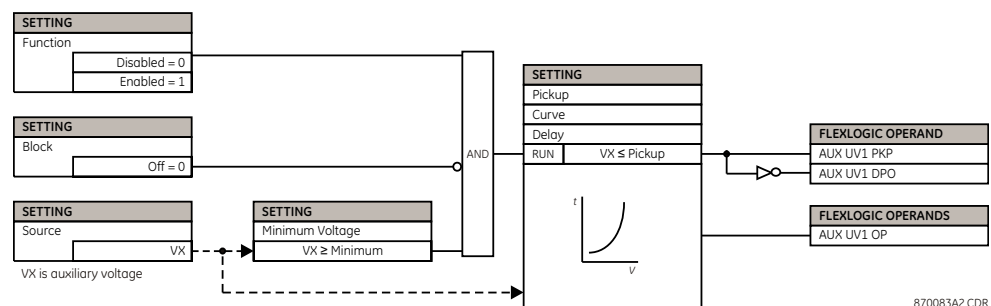
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of auxiliary undervoltage events in the sequence of events recorder.

The figure shows the logic for the auxiliary undervoltage element. The logic is identical for all auxiliary undervoltage elements.

Figure 237: Auxiliary undervoltage logic



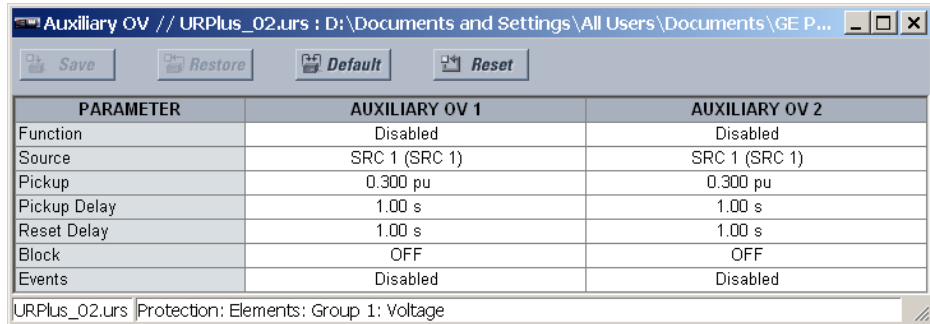
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Auxiliary overvoltage

This element is intended for monitoring overvoltage conditions of the auxiliary voltage. A typical application for this element is monitoring the zero-sequence voltage (3V_0) supplied from an open-corner-delta VT connection. The nominal secondary voltage of the auxiliary voltage channel entered in the **Auxiliary VT Secondary** setting is the per-unit base used when setting the pickup level.

Select the **Settings > Protection > Elements > Group 1 > Voltage > Auxiliary OV** menu to open the auxiliary overvoltage configuration window.

Figure 238: Auxiliary overvoltage configuration settings



PARAMETER	AUXILIARY OV 1	AUXILIARY OV 2
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Pickup	0.300 pu	0.300 pu
Pickup Delay	1.00 s	1.00 s
Reset Delay	1.00 s	1.00 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each auxiliary overvoltage element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the auxiliary overvoltage protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the auxiliary overvoltage protection element.

Pickup

Range: 0.000 to 1.100 pu in steps of 0.001

Default: 0.300 pu

This setting specifies the auxiliary overvoltage pickup level in per-unit values.

Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting selects the minimum operating time of the auxiliary overvoltage element.

Reset Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting specifies the minimum reset time of the auxiliary overvoltage element.

Block

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting blocks the auxiliary overvoltage element.

Events

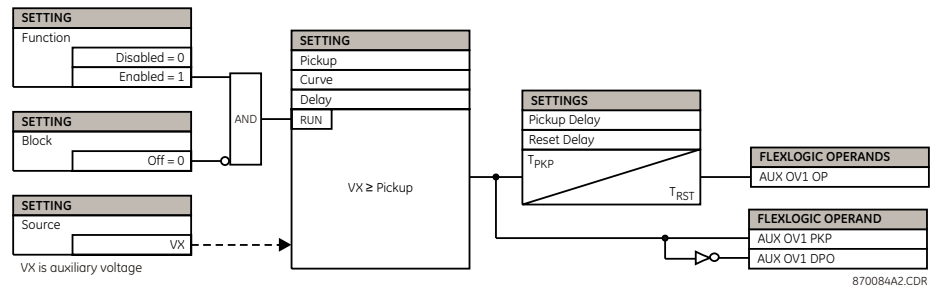
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of auxiliary overvoltage events in the sequence of events recorder.

The figure shows the logic for the auxiliary overvoltage element. The logic is identical for all auxiliary overvoltage elements.

Figure 239: Auxiliary overvoltage logic

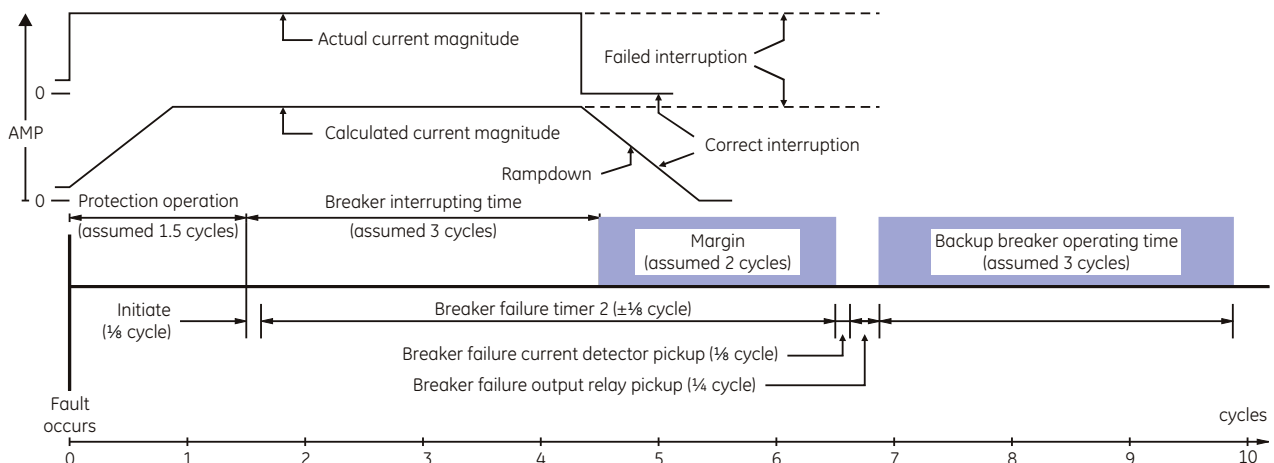


Breaker failure

In general, a breaker failure scheme determines that a breaker signaled to trip has not cleared a fault within a definite time, so further tripping action must be performed. Tripping from the breaker failure scheme needs to trip all breakers, both local and remote, that can supply current to the faulted zone. Usually operation of a breaker failure element causes clearing of a larger section of the power system than the initial trip. Because breaker failure can result in tripping a large number of breakers and this affects system safety and stability, a very high level of security is required.

Two schemes are provided: one for three-pole tripping only and one for three pole plus single-pole operation. The philosophy used in these schemes is identical. The operation of a breaker failure element includes three stages: initiation, determination of a breaker failure condition, and output.

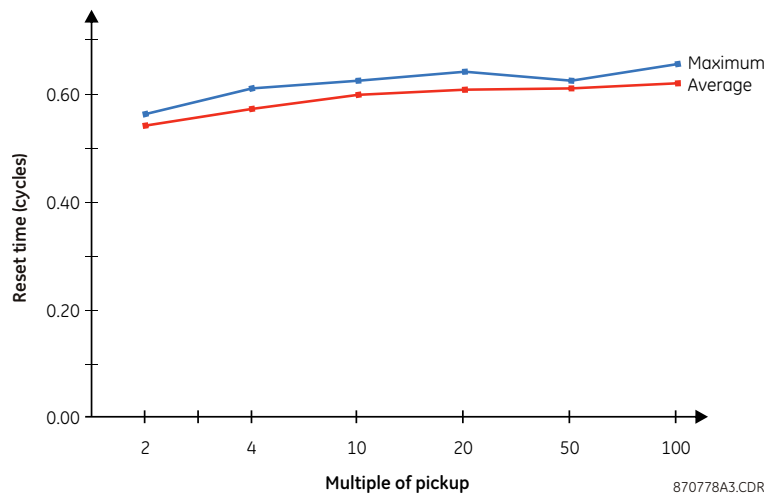
Figure 240: Breaker failure main path sequence



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The current supervision elements reset in less than 0.7 of a power cycle up to a multiple of pickup of 100 (threshold set at 0.01 of the actual fault current), shown as follows.

Figure 241: Breaker failure current supervision reset time



Breaker failure initiation stage

A FlexLogic operand representing the protection trip signal initially sent to the breaker must be selected to initiate the scheme, except if this is already programmed as a trip output (the protection trip signal does not include other breaker commands that are not indicative of a fault in the protected zone). The initiating signal needs to be sealed-in if primary fault detection can reset before the breaker failure timers have finished timing. The seal-in is supervised by current level, so it is reset when the fault is cleared. If required, an incomplete sequence seal-in reset can be implemented by using the initiating operand to also initiate a FlexLogic timer, set longer than any breaker failure timer, whose output operand is selected to block the breaker failure scheme.

Schemes can be initiated either directly or with current level supervision. It is particularly important in any application to decide if a current-supervised initiate is to be used. The use of a current-supervised initiate results in the breaker failure element not being initiated for a breaker that has very little or no current flowing through it, which can be the case for transformer faults. For those situations where it is required to maintain breaker fail coverage for fault levels below the **Phase Current Supv Pickup** or the **Neutral Current Supv Pickup** setting, do not use a current supervised initiate. This feature can be utilized for those situations where coordinating margins can be reduced when high speed reclosing is used. Thus, if this choice is made, fault levels must always be above the supervision pickup levels for dependable operation of the breaker fail scheme. This can also occur in breaker-and-a-half or ring bus configurations where the first breaker closes into a fault; the protection trips and attempts to initiate breaker failure for the second breaker, which is in the process of closing, but does not yet have current flowing through it.

When the scheme is initiated, it immediately sends a trip signal to the breaker initially signaled to trip (this feature is usually described as re-trip). This reduces the possibility of widespread tripping that results from a declaration of a failed breaker.

Determination of a breaker failure condition

The schemes determine a breaker failure condition via three paths. Each of these paths is equipped with a time delay, after which a failed breaker is declared and trip signals are sent to all breakers required to clear the zone. The delayed paths are associated with breaker failure timers 1, 2, and 3, which are intended to have delays increasing with increasing timer numbers. These delayed paths are individually enabled to allow for maximum flexibility.

Timer 1 logic (early path) is supervised by a fast-operating breaker auxiliary contact. If the breaker is still closed (as indicated by the auxiliary contact) and fault current is detected after the delay interval, an output is issued. Operation of the breaker auxiliary switch indicates that the breaker has mechanically operated. The continued presence of current indicates that the breaker has failed to interrupt the circuit.

Timer 2 logic (main path) is not supervised by a breaker auxiliary contact. If fault current is detected after the delay interval, an output is issued. This path is intended to detect a breaker that opens mechanically but fails to interrupt fault current; the logic therefore does not use a breaker auxiliary contact.

The timer 1 and 2 paths provide two levels of current supervision, high-set and low-set, that allow the supervision level to change from a current that flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The high-set detector is enabled after timeout of timer 1 or 2, along with a timer that enables the low-set detector after its delay interval. The delay interval between high-set and low-set is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The overcurrent detectors are required to operate after the breaker failure delay interval to eliminate the need for very fast resetting overcurrent detectors.

Timer 3 logic (slow path) is supervised by a breaker auxiliary contact and a control switch contact used to indicate that the breaker is in/out of service, disabling this path when the breaker is out of service for maintenance. There is no current level check in this logic as it is intended to detect low magnitude faults and it is therefore the slowest to operate.

Breaker failure scheme outputs

The outputs from the breaker failure scheme are

- FlexLogic operands that report on the operation of portions of the scheme
- A FlexLogic operand used to re-trip the protected breaker
- FlexLogic operands that initiate tripping required to clear the faulted zone. The trip output can be sealed-in for an adjustable period.
- Illumination of a front panel annunciator message or messages

Breaker failure settings and logic

Select the **Settings > Protection > Elements > Group 1 > Breaker Failure** menu to open the breaker failure configuration window.

Figure 242: Breaker failure configuration settings

PARAMETER	BF1	BF2
Function	Disabled	Disabled
Mode	3-Pole	3-Pole
Source	BKR 1 (SRC 2)	BKR 2 (SRC 3)
Current Supervision	Yes	Yes
Use Seal-In	Yes	Yes
Three Pole Initiate	OFF	OFF
Block	OFF	OFF
Phase Current Supervision Pickup	1.050 pu	1.050 pu
Neutral Current Supervision Pickup	1.050 pu	1.050 pu
Use Timer 1	Yes	Yes
Timer 1 Pickup Delay	0.000 s	0.000 s
Use Timer 2	Yes	Yes
Timer 2 Pickup Delay	0.000 s	0.000 s
Use Timer 3	Yes	Yes
Timer 3 Pickup Delay	0.000 s	0.000 s
Breaker Position 1 Phase A/3P	OFF	OFF
Breaker Position 2 Phase A/3P	BKR1 CLOSED	BKR2 CLOSED
Breaker Test On	OFF	OFF
Phase Current High-Set Pickup	1.050 pu	1.050 pu
Neutral Current High-Set Pickup	1.050 pu	1.050 pu
Phase Current Low-Set Pickup	1.050 pu	1.050 pu
Neutral Current Low-Set Pickup	1.050 pu	1.050 pu
Low-Set Time Delay	0.000 s	0.000 s
Trip Dropout Delay	0.000 s	0.000 s
Events	Enabled	Enabled
Phase A Initiate	OFF	OFF
Phase B Initiate	OFF	OFF
Phase C Initiate	OFF	OFF
Breaker Position 1 Phase B	OFF	OFF
Breaker Position 1 Phase C	OFF	OFF
Breaker Position 2 Phase B	OFF	OFF
Breaker Position 2 Phase C	OFF	OFF

The following settings are available for each breaker failure element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the breaker failure protection element.

Mode

Range: 1-Pole, 3-Pole

Default: 1-Pole

This setting selects the breaker failure operating mode: single-pole or three-pole.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the breaker failure protection element.

Current Supervision

Range: Yes, No

Default: Yes

If set to “Yes,” the breaker failure element is initiated only if current flowing through the breaker is above the supervision pickup level.

Use Seal-In*Range: Yes, No**Default: Yes*

If set to "Yes," the breaker failure element is sealed-in only if current flowing through the breaker is above the supervision pickup level.

Three Pole Initiate*Range: any FlexLogic operand or shared operand**Default: Off*

This setting selects the operand that initiates three-pole tripping of the breaker when asserted.

Block*Range: any FlexLogic operand or shared operand**Default: Off*

Assertion of the operand assigned to this setting blocks operation of the breaker failure element.

Phase Current Supervision Pickup*Range: 0.001 to 30.000 pu in steps of 0.001**Default: 1.050 pu*

This setting specifies the phase current initiation and seal-in supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker. It can be set as low as necessary (lower than breaker resistor current or lower than load current). High-set and low-set current supervision ensures correct operation.

Neutral Current Supervision Pickup*Range: 0.001 to 30.000 pu in steps of 0.001**Default: 1.050 pu*

This setting specifies the neutral current initiate and seal-in supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker. Neutral current supervision is used only in the three phase scheme to provide increased sensitivity. This setting is valid only for three-pole tripping schemes.

Use Timer 1*Range: Yes, No**Default: Yes*

If this setting value is "Yes," the early path is operational.

Timer 1 Pickup Delay*Range: 0.000 to 65.535 seconds in steps of 0.001**Default: 0 seconds*

Timer 1 is set to the shortest time required for breaker auxiliary contact Status-1 to open, from the time the initial trip signal is applied to the breaker trip circuit, plus a safety margin.

Use Timer 2*Range: Yes, No**Default: Yes*

If this setting value is "Yes," the main path is operational.

Timer 2 Pickup Delay*Range: 0.000 to 65.535 seconds in steps of 0.001**Default: 0 seconds*

Timer 2 is set to the expected opening time of the breaker, plus a safety margin. This safety margin was historically intended to allow for measuring and timing errors in the breaker failure scheme equipment. In microprocessor relays this time is not significant.

In the UR^{Plus}-series devices, which use a Fourier transform, the calculated current magnitude ramps-down to zero one power frequency cycle after the current is interrupted, and this lag needs to be included in the overall margin duration, as it occurs after current interruption. The breaker failure main path sequence diagram shows a margin of two cycles; this interval is considered the minimum appropriate for most applications.

In bulk oil circuit breakers, the interrupting time for currents less than 25% of the interrupting rating can be significantly longer than the normal interrupting time.

Use Timer 3

Range: Yes, No

Default: Yes

If this setting value is "Yes," the slow path is operational.

Timer 3 Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0 seconds

Timer 3 is set to the same interval as timer 2, plus an increased safety margin. Because this path is intended to operate only for low level faults, the delay can be in the order of 300 to 500 ms.

Breaker Position 1 Phase A/3P

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that represents the protected breaker early-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker early-type auxiliary switch contact on pole A. This is normally a non-multiplied form-A contact. The contact can even be adjusted to have the shortest possible operating time.

Breaker Position 2 Phase A/3P

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that represents the breaker normal-type auxiliary switch contact (52/a). When using the single-pole breaker failure scheme, this operand represents the protected breaker auxiliary switch contact on pole A. This can be a multiplied contact.

Breaker Test On

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that represents the breaker in-service/out-of-service switch set to the out-of-service position.

Phase Current High-Set Pickup

Range: 0.001 to 30.000 pu in steps of 0.001

Default: 1.050 pu

This setting specifies the phase current output supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted.

Neutral Current High-Set Pickup*Range: 0.001 to 30.000 pu in steps of 0.001**Default: 1.050 pu*

This setting specifies the neutral current output supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted. Neutral current supervision is used only in the three pole scheme to provide increased sensitivity. This setting is valid only for three-pole breaker failure schemes.

Phase Current Low-Set Pickup*Range: 0.001 to 30.000 pu in steps of 0.001**Default: 1.050 pu*

This setting specifies the phase current output supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current).

Neutral Current Low-Set Pickup*Range: 0.001 to 30.000 pu in steps of 0.001**Default: 1.050 pu*

This setting specifies the neutral current output supervision level. Generally, this setting needs to detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current). This setting is valid only for three-pole breaker failure schemes.

Low-Set Time Delay*Range: 0.000 to 65.535 seconds in steps of 0.001**Default: 0.000 seconds*

This setting specifies the pickup delay for current detection after opening resistor insertion.

Trip Dropout Delay*Range: 0.000 to 65.535 seconds in steps of 0.001**Default: 0.000 seconds*

This setting specifies the time for which the trip output is sealed-in. This timer must be coordinated with the automatic reclosing scheme of the failed breaker, to which the breaker failure element sends a cancel reclosure signal. Reclosure of a remote breaker can also be prevented by holding a transfer trip signal on longer than the reclaim time.

Events*Range: Enabled, Disabled**Default: Enabled*

This setting enables and disables the logging of breaker failure events in the sequence of events recorder.

Phase A Initiate, Phase B Initiate, Phase C Initiate*Range: any FlexLogic operand or shared operand**Default: Off*

These settings select operands to initiate phase A, B, and C single-pole tripping of the breaker and the phase A, B, or C portion of the scheme, accordingly. These settings are only valid for single-pole breaker failure schemes.

Breaker Position 1 Phase B

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand to represent the protected breaker early-type auxiliary switch contact on pole B. This contact is normally a non-multiplied form-A contact. The contact can even be adjusted to have the shortest possible operating time. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 1 Phase C

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand to represent the protected breaker early-type auxiliary switch contact on pole C. This contact is normally a non-multiplied form-A contact. The contact can even be adjusted to have the shortest possible operating time. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 2 Phase B

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that represents the protected breaker normal-type auxiliary switch contact on pole B (52/a). This can be a multiplied contact. This setting is valid only for single-pole breaker failure schemes.

Breaker Position 2 Phase C

Range: any FlexLogic operand or shared operand

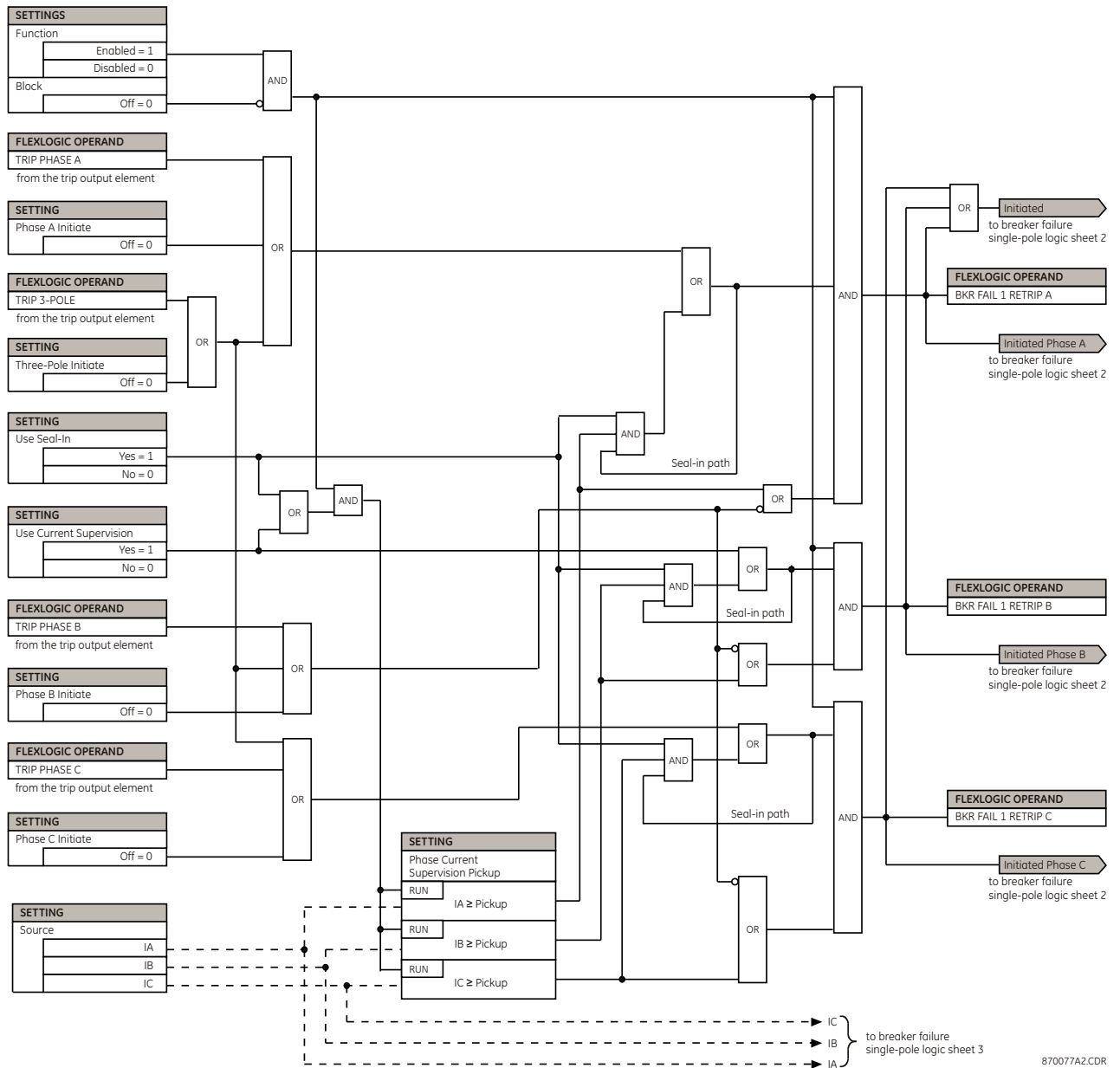
Default: Off

This setting selects the operand that represents the protected breaker normal-type auxiliary switch contact on pole C (52/a). This can be a multiplied contact. For single-pole operation, the scheme has the same overall general concept except that it provides re-tripping of each single pole of the protected breaker. The approach shown in the following single pole tripping diagram uses the initiating information to determine which pole is supposed to trip. The logic is segregated on a per-pole basis. The overcurrent detectors have ganged settings. This setting is valid only for single-pole breaker failure schemes.

Upon operation of the breaker failure element for a single pole trip command, a three-pole trip command needs to be given via the **BKR FAIL 1 TRIP OP** output operand.

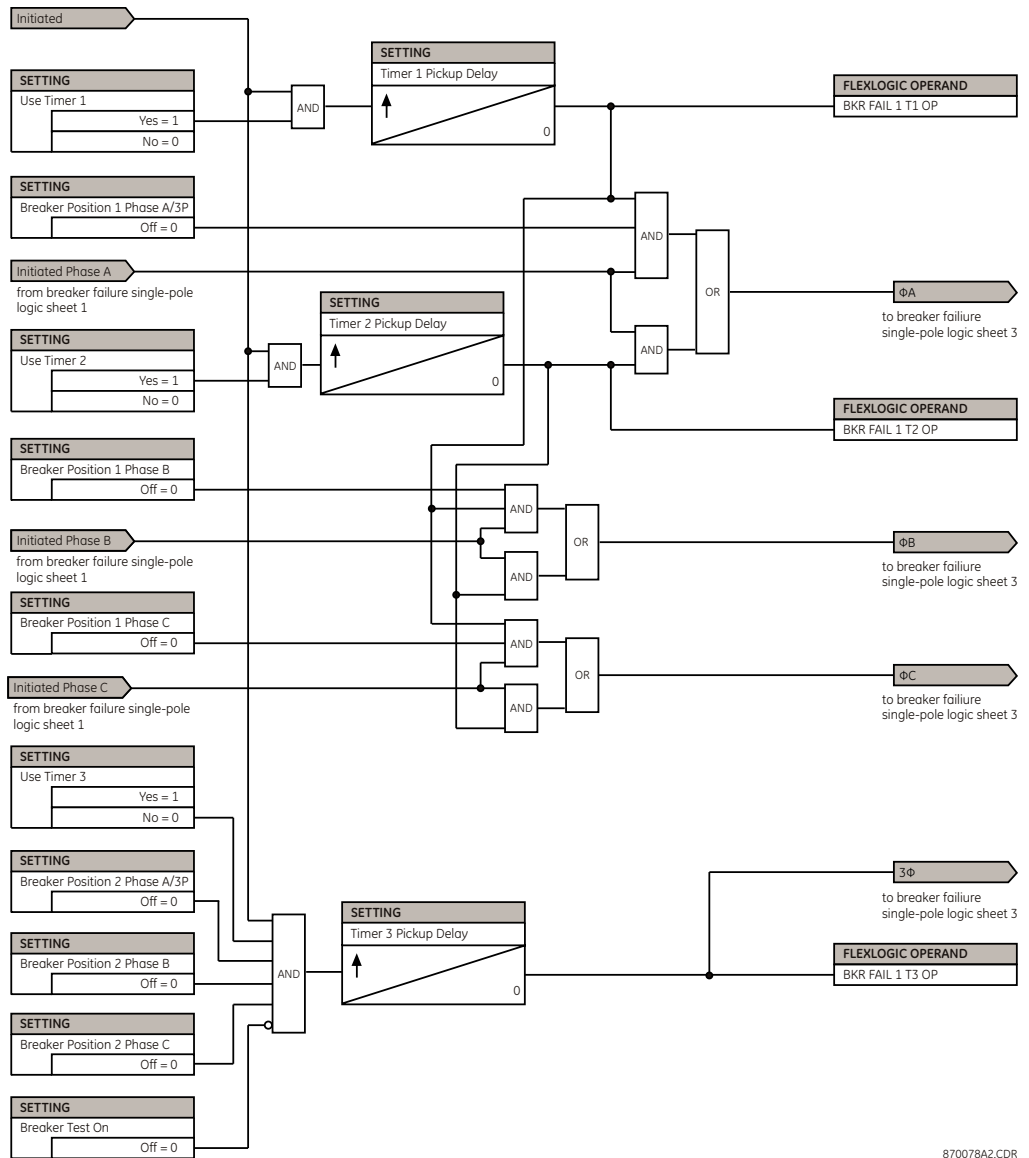
The figures show the logic for the breaker failure element. The logic is identical for both breaker failure elements.

Figure 243: Breaker failure single-pole logic, sheet 1 of 3



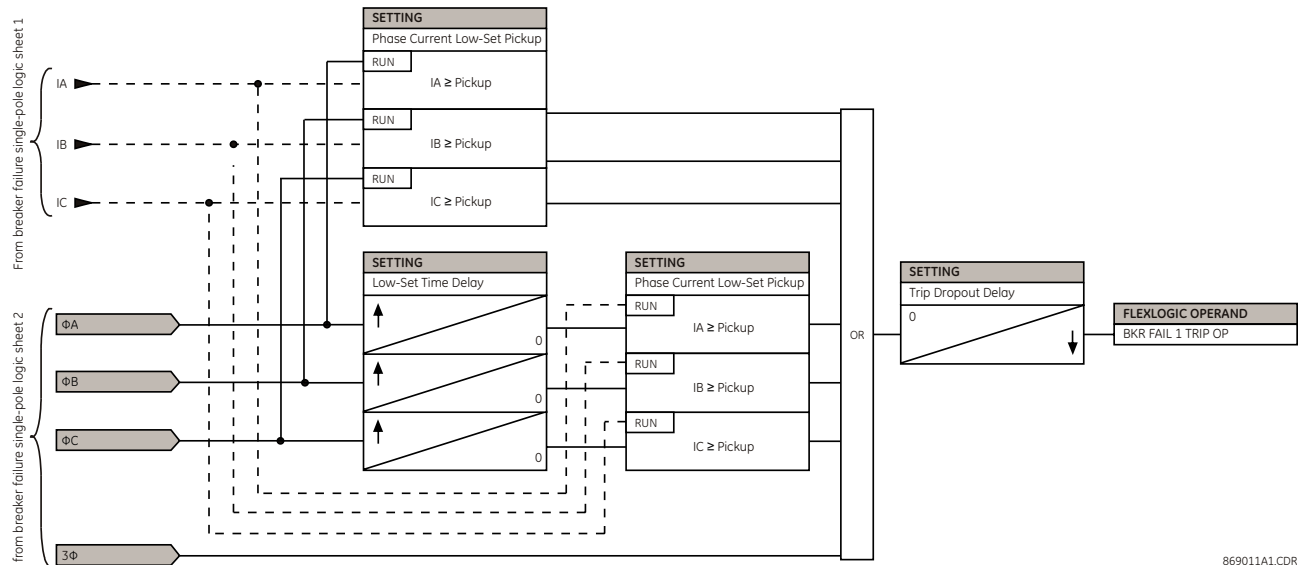
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Figure 244: Breaker failure single-pole logic, sheet 2 of 3



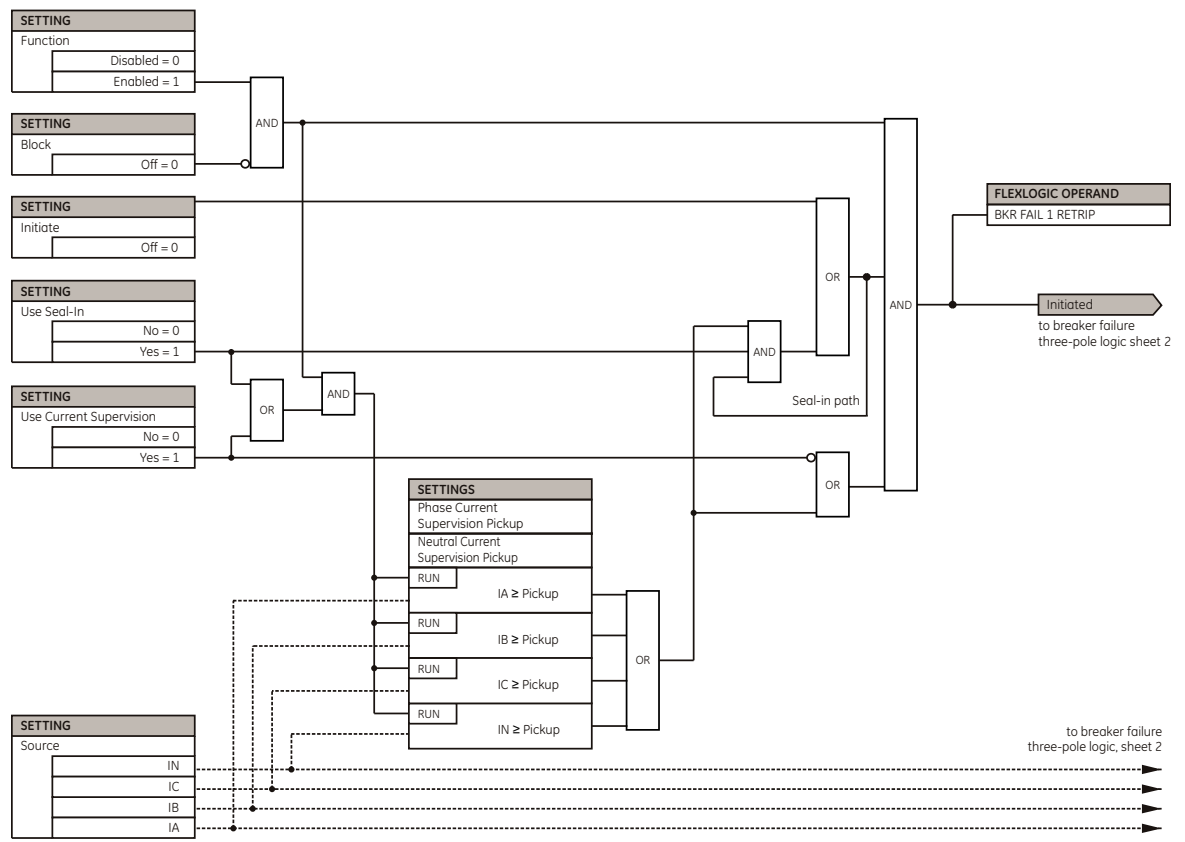
870078A2.CDR

Figure 245: Breaker failure single-pole logic, sheet 3 of 3



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Figure 246: Breaker failure three-pole logic, sheet 1 of 3



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Figure 247: Breaker failure three-pole logic, sheet 2 of 3

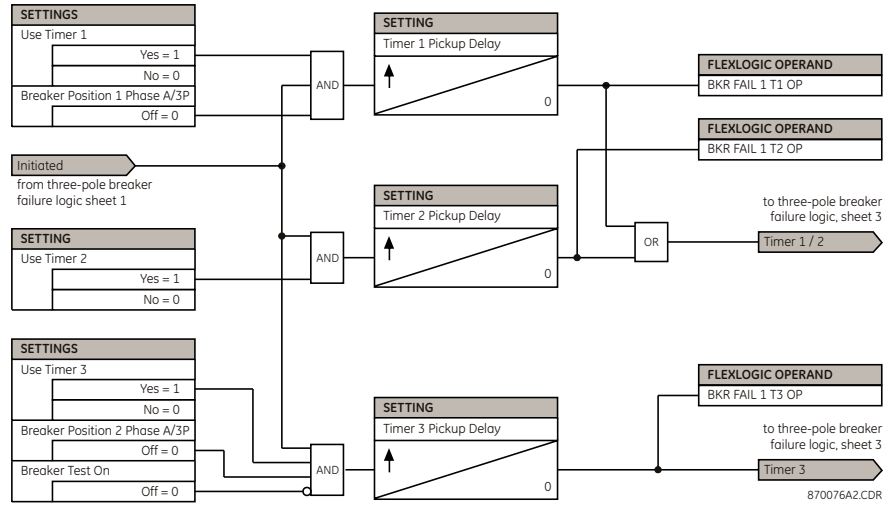
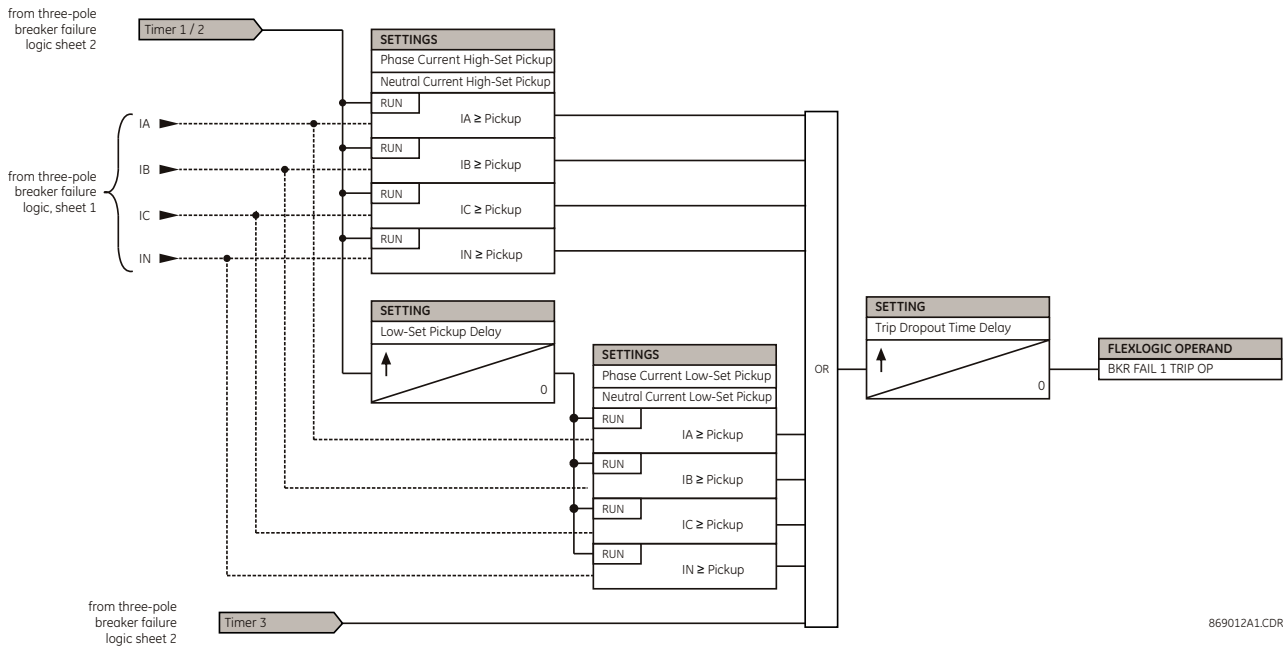


Figure 248: Breaker failure three-pole logic, sheet 3 of 3



Wattmetric zero-sequence directional ground fault

The wattmetric zero-sequence directional element responds to power derived from zero-sequence voltage and current in a direction specified by the element characteristic angle. The angle can be set within all four quadrants and the power can be active or reactive. Therefore, the element can be used to sense either forward or reverse ground faults in inductive, capacitive, or resistive networks. The inverse time characteristic allows time coordination of elements across the network.

Typical applications include ground fault protection in solidly grounded transmission networks, grounded/ungrounded/resistor-grounded/resonant-grounded distribution networks, or for directionalizing other non-directional ground elements.

Select the **Settings > Protection > Elements > Group 1 > Wattmetric** menu to open the wattmetric zero-sequence directional ground fault configuration window.

Figure 249: Wattmetric ground fault configuration window

PARAMETER	WATTMETRIC GND FLT 1	WATTMETRIC GND FLT 2
Function	Disabled	Disabled
Signal Source	LINE (SRC 1)	LINE (SRC 1)
Voltage	Calculated VN	Calculated VN
OV PKP	0.20 pu	0.20 pu
Current	Calculated IN	Calculated IN
OC PKP	0.060 pu	0.060 pu
OC PKP DEL	0.20 s	0.20 s
PWR PKP	0.100 pu	0.100 pu
REF PWR	0.500 pu	0.500 pu
ECA	0 ° Lag	0 ° Lag
PWR PKP DEL	0.20 s	0.20 s
Curve	Definite Time	Definite Time
Multiplier	1.00 s	1.00 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each wattmetric zero-sequence directional ground fault element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the wattmetric zero-sequence directional ground fault protection element.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the wattmetric zero-sequence directional ground fault protection element.

Voltage

Range: Calculated VN, Measured VX

Default: Calculated VN

The wattmetric zero-sequence directional ground fault element uses neutral voltage (that is, three times the zero-sequence voltage). This setting allows selecting between the internally calculated neutral voltage or the externally supplied voltage (broken delta VT connected to the auxiliary channel bank of the relay). When the latter selection is made, the auxiliary channel must be identified by the user as a neutral voltage under the VT bank settings. This element operates only if the auxiliary voltage is configured as neutral.

OV Pickup

Range: 0.02 to 1.10 pu in steps of 0.01

Default: 0.20 pu

This setting specifies the minimum zero sequence voltage supervising the directional power measurement. This threshold needs to be higher than possible unbalance during normal operation of the system. Typically, this setting is selected at 0.1 to 0.2 pu for the ungrounded or resonant grounded systems, and at 0.05 to 0.1 pu for solidly or resistor-grounded systems. When using externally supplied voltage via the auxiliary voltage channel, 1 pu is the nominal voltage of this channel as per VT bank settings. When using internally calculated neutral voltage, 1 pu is the nominal phase to ground voltage as per the VT bank settings.

Current

Range: Calculated IN, Measured IG

Default: Calculated IN

The wattmetric zero-sequence directional ground fault element responds to the neutral current (that is, three times zero-sequence current), either calculated internally from the phase currents or supplied externally via the ground CT input from more accurate sources, such as the core balanced CT. This setting allows selecting the source of the operating current.

OC Pickup

Range: 0.002 to 30.000 pu in steps of 0.001

Default: 0.060 pu

This setting specifies the current supervision level for the measurement of the zero-sequence power.

OC Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.20 seconds

This setting specifies delay for the overcurrent portion of this element. The delay applies to the **WATTMETRIC 1 PKP** operand driven from the overcurrent condition.

Power Pickup

Range: 0.001 to 1.200 pu in steps of 0.001

Default: 0.100 pu

This setting specifies the operating point of the element. A value of 1 pu is a product of the 1 pu voltage as specified for the overvoltage condition of this element, and 1 pu current as specified for the overcurrent condition of this element.

Reference Power

Range: 0.001 to 1.200 pu in steps of 0.001

Default: 0.500 pu

This setting is used to calculate the inverse time characteristic delay (defined by S_{ref} in the following equations). A value of 1 pu represents the product of a 1 pu voltage (as specified in the overvoltage condition for this element) and a 1 pu current (as specified in the overcurrent condition for this element).

ECA

Range: 0 to 360° Lag in steps of 1

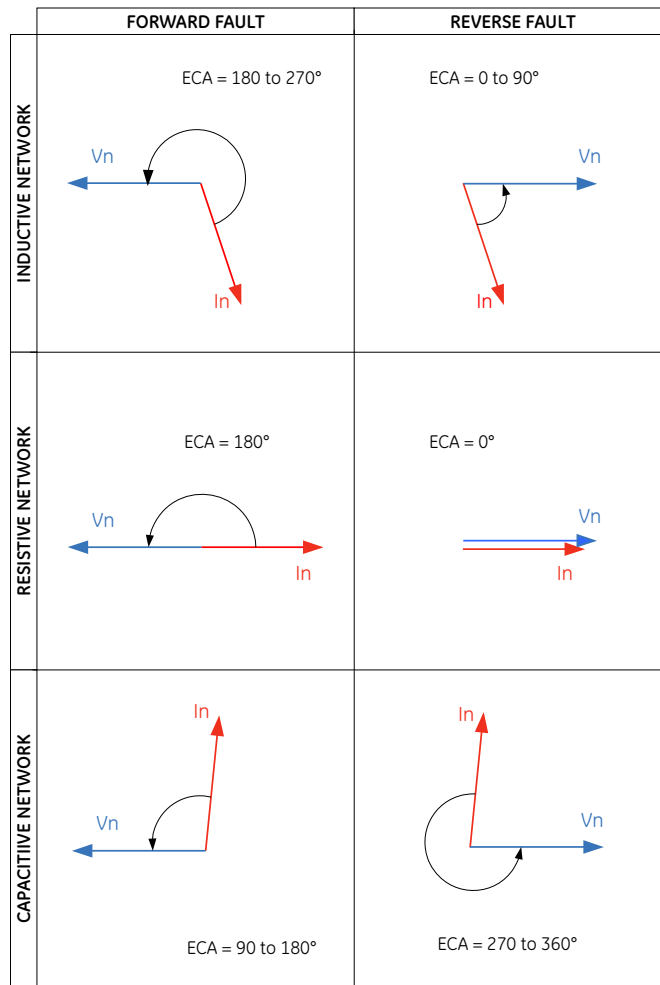
Default: 0° Lag

This setting adjusts the maximum torque angle of the element. The operating power is calculated as:

$$S_{op} = \text{Re} (V_n (I_n \times 1 \angle \text{ECA})^*) \quad \text{Eq. 37}$$

where * indicates the complex conjugate. By varying the element characteristic angle, the element can be made to respond to forward or reverse direction in inductive, resistive, or capacitive networks, as shown in the following figure.

Figure 250: Wattmetric characteristic angle response



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Power Pickup Delay

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.20 seconds

This setting specifies a definite time delay before the inverse time characteristic is activated. If the curve selection is set as “Definite Time,” the element operates after this security time delay. If the curve selection is “Inverse” or one of the FlexCurves, the element uses both the definite and inverse time timers simultaneously. The definite time timer, specified by this setting, is used and when expires it releases the inverse time timer for operation (torque control).

Curve

Range: Definite Time, Inverse, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: Definite Time

This setting selects one of three methods to delay operate signal once all conditions are met to discriminate fault direction. The “Definite Time” selection allows for a fixed time delay defined by the **Power Pickup Delay** setting.

The “Inverse” selection allows for inverse time characteristics delay defined by the following formula:

$$t = m \times \frac{S_{ref}}{S_{op}} \tag{Eq. 38}$$

where

m is a multiplier defined by the multiplier setting

S_{ref} is the pickup setting

S_{op} is the operating power at the time. This timer starts after the definite time timer expires.

The four FlexCurves allow for custom user-programmable time characteristics. When working with FlexCurves, the element uses the operate to pickup ratio, and the multiplier setting is not applied:

$$t = \text{FlexCurve}\left(\frac{S_{op}}{S_{ref}}\right) \tag{Eq. 39}$$

Again, the FlexCurve timer starts after the definite time timer expires.

Multiplier

Range: 0.01 to 2.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting is applicable if the wattmetric Curve setting is "Inverse" and defines the multiplier factor for the inverse time delay.

Block

Range: any FlexLogic operand

Default: Off

Assertion of the FlexLogic operand assigned to this setting blocks operation of the wattmetric zero-sequence directional ground fault element.

Events

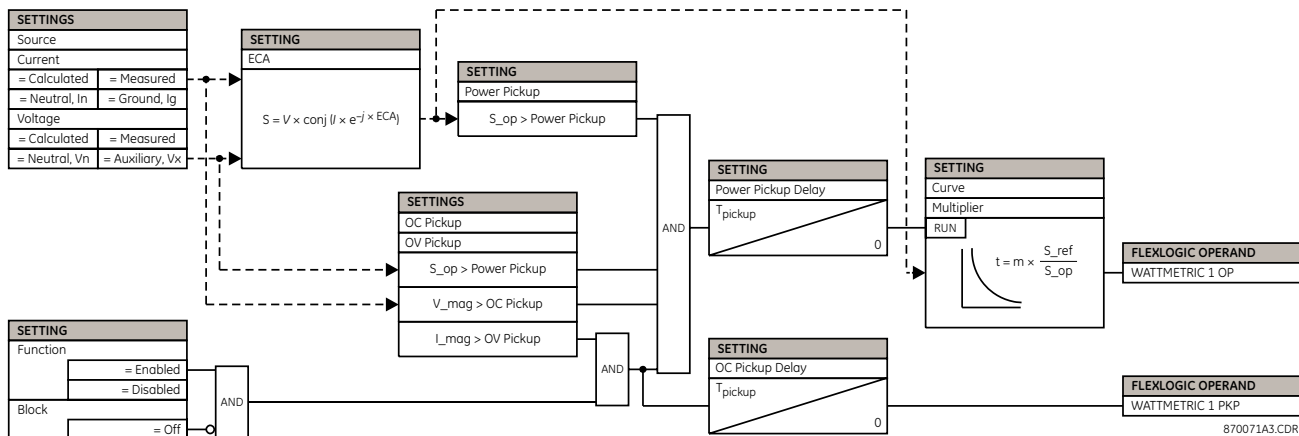
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of wattmetric zero-sequence directional ground fault events in the sequence of events recorder.

The figure shows the logic for the wattmetric zero-sequence directional ground fault 1 element. The logic is identical for both wattmetric elements.

Figure 251: Wattmetric zero-sequence directional ground fault logic



Control elements

Control elements generally are used for control rather than protection.

Pilot-aided schemes

This section contains settings for selecting and configuring protection signaling schemes. All schemes are available for single-pole tripping applications and can be used with single-bit, two-bit, or four-bit communications channels. Choices of communications channels include remote inputs, remote outputs, and telecommunications interfaces.

The D90^{Plus} includes six common pilot-aided schemes, as follows:

- Direct under-reaching transfer trip (DUTT)
- Permissive under-reaching transfer trip (PUTT)
- Permissive over-reaching transfer trip (POTT)
- Hybrid permissive over-reaching transfer trip (hybrid POTT)
- Directional comparison blocking
- Directional comparison unblocking (DCUB)

Direct under-reaching transfer trip

The direct under-reaching transfer trip (DUTT) scheme uses an under-reaching zone 1 distance element to key transfer trip signals to the remote ends, where on receipt, the DUTT pilot scheme operates without additional protection supervision. For proper operation of the scheme, the zone 1 phase and ground distance elements must be enabled, configured, and set according to the principles of distance relaying.

In single-pole tripping applications, the DUTT scheme uses local fault type identification provided by the phase selector together with information received from the remote terminals. The latter can be coded into one, two, or four bits over the communications channel.

The scheme generates output operands ([DUTT TX1](#) through [DUTT TX4](#)) that are used to transmit the direct under-reaching signals to the remote ends. Choices of communications channel include remote inputs, remote outputs, and telecommunications interfaces. When used with telecommunications facilities, the output operands need to be assigned to operate output contacts connected to assert the individual bits at the interface.

To make the scheme a fully operational stand-alone feature, the output operands must be configured to interface with other relay functions, in particular output contacts. Typically, the output operands are programmed to initiate a trip, breaker fail, and autoreclose, and drive an annunciator indication. When used in conjunction with the trip output element, the scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > DUTT Scheme** menu to access the direct under-reaching transfer trip settings.

Figure 252: DUTT scheme configuration settings

SETTING	PARAMETER
Function	Disabled
Seal-In Delay	0.000 s
Communication Bits	1
RX1	OFF
RX2	OFF
RX3	OFF
RX4	OFF
Event	Disabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the direct under-reaching transfer trip (DUTT) scheme.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

The DUTT OP FlexLogic operand is produced according to the scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels, such as a power line carrier. This setting specifies a minimum guaranteed duration for the **DUTT OP** pulse. As this operand activates the trip table of the DUTT scheme, the trip operands (**DUTT TRIP A**, **DUTT TRIP B**, **DUTT TRIP C**, and **DUTT TRIP 3P**) are sealed-in for the same period of time.

Communication Bits

Range: 1, 2, 4

Default: 2

This setting specifies the number of bits available on the communications channel. With only one bit available, the scheme sends the direct under-reaching transfer trip command on bit 1 (the **DUTT TX1** operand) and responds to the direct trip command received on bit 1 (the **RX1** setting). The scheme uses only local fault type identification provided by the phase selector to assert the trip operands (**DUTT TRIP A**, **DUTT TRIP B**, **DUTT TRIP C**, and **DUTT TRIP 3P**).

RX1, RX2, RX3, RX4

Range: any FlexLogic operand

Default: OFF

These settings allow the user to select the FlexLogic operands that represent the receive signals for the scheme. Typically input contacts interfacing with a signaling system are used.

The DUTT scheme requires a secure and dependable signaling system. For this reason, a series-parallel combination of receive signal contacts is often used. This is accomplished by using a multi-bit communications system to transmit redundant copies of the transmit signal (often via different paths) and building appropriate security logic (such as series (AND gate) or two-out-of-three voting logic) with FlexLogic. The **RX1** to **RX4** settings should be associated with the final (secure) transmit signals.

These settings are used in the following manner:

- Single bit applications — Only **RX1** is used
- Two-bit applications — **RX1** and **RX2** must be used
- Four-bit applications — **RX1** through **RX4** must be used

In multi-terminal applications, the receive signals from two or more remote terminals need to be connected through OR gates in protection FlexLogic and the resulting signals configured as the **RX1** through **RX4** settings.

Events

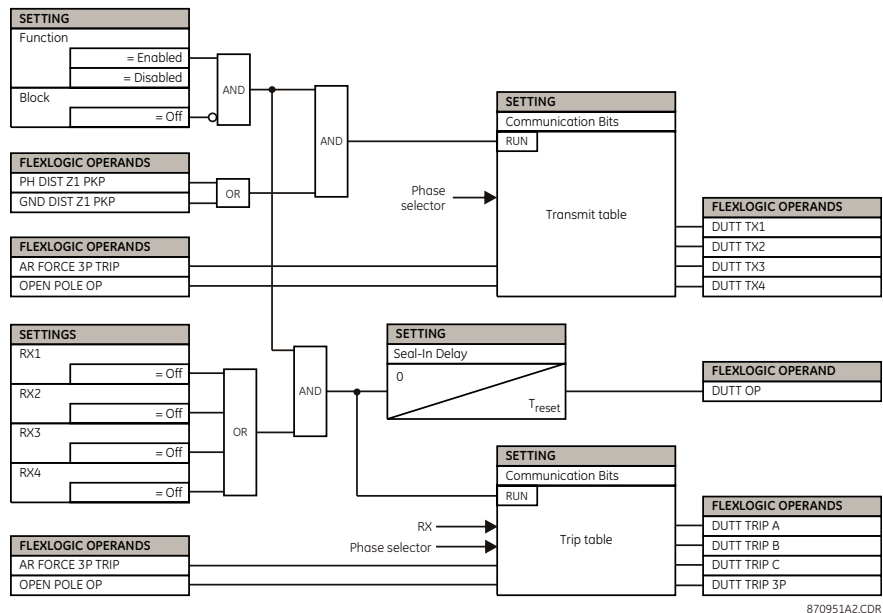
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of direct under-reaching transfer trip (DUTT) scheme events in the sequence of events recorder.

The figure shows the DUTT scheme logic.

Figure 253: DUTT logic



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Permissive under-reaching transfer trip

The permissive under-reaching transfer trip (PUTT) scheme uses an under-reaching zone 1 distance element to key the transfer trip signal to the remote terminals where they are supervised by an over-reaching zone 2 distance element. For proper operation, the zone 1 and 2 phase and ground distance elements must be enabled, configured, and set as per the principles of distance relaying.

In single-pole tripping applications, the PUTT scheme uses local fault type identification provided by the phase selector together with information received from the remote terminals. The scheme generates output operands (PUTT TX1 through PUTT TX4) that are used to transmit the signal to the remote ends. Choices of communications channel include remote inputs, remote outputs, and telecommunications interfaces. When used with telecommunications facilities the output operands need to be assigned to operate output contacts connected to assert the individual bits at the interface.

To make the PUTT scheme a fully operational stand-alone feature, the scheme output operands must be configured to interface with other relay functions, in particular the output contacts. The output operands are typically programmed to initiate a trip, breaker fail, and autoreclose, and drive an annunciator indication as per user requirements. When used in conjunction with the trip output element, the scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > PUTT Scheme** menu to access the permissive under-reaching transfer trip settings.

Figure 254: PUTT scheme configuration settings

SETTING	PARAMETER
Function	Disabled
Block	OFF
RX Pickup Delay	0.000 s
Seal-In Delay	0.000 s
Rx1	OFF
Event	Enabled

Distance 1 | Settings: Protection: Control: Pilot Schemes

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the permissive under-reaching transfer trip (PUTT) scheme.

RX Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting enables the relay to cope with spurious receive signals. Set this delay value to be longer than the longest spurious TX signal that can be received simultaneously with the zone 1 pickup. The selected delay increases the response time of the scheme.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.010 seconds

The **PUTT OP** FlexLogic operand is produced according to the scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels, such as a power line carrier. This setting specifies a minimum guaranteed duration of the **PUTT OP** pulse. As this operand activates the trip table of the PUTT scheme, the **PUTT TRIP A**, **PUTT TRIP B**, **PUTT TRIP C**, and **PUTT TRIP 3P** trip operands are sealed-in for the same period of time.

Communication Bits

Range: 1, 2, 4

Default: 1

This setting specifies the number of bits of the communications channel available for the scheme. With only one bit available, the scheme sends the permissive under-reaching transfer trip command on bit 1 (the **PUTT TX1** operand) and responds to the direct trip command received on bit 1 (the **RX1** setting). The scheme uses only local fault type identification provided by the phase selector to assert the trip operands (**PUTT TRIP A**, **PUTT TRIP B**, **PUTT TRIP C**, and **PUTT TRIP 3P**).

RX1 through RX4

Range: any FlexLogic operand

Default: OFF

These settings select the FlexLogic operands to represent the receive signals for the scheme. Input contacts interfacing with a signaling system typically are used. These settings are used in the following manner:

- In single-bit applications, **RX1** must be used
- In two-bit applications, **RX1** and **RX2** must be used
- In four-bit applications, **RX1** through **RX4** must be used

In multi-terminal applications, the RX signals from two or more remote terminals need to be connected through OR gates in the FlexLogic and the resulting signals configured as RX inputs.

Events

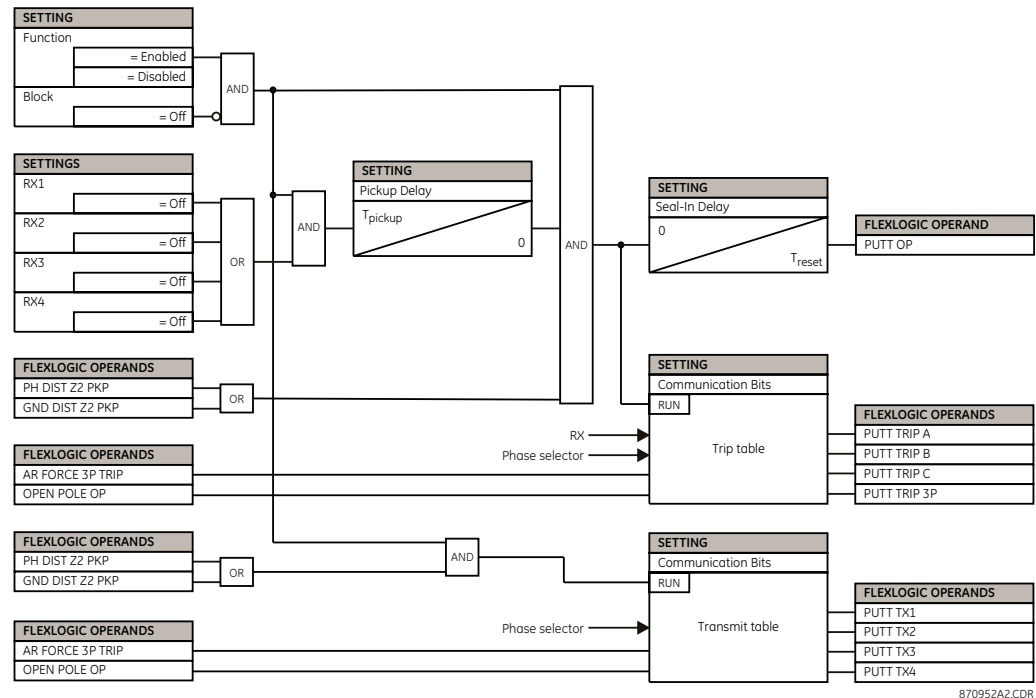
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of permissive under-reaching transfer trip (PUTT) scheme events in the sequence of events recorder.

The figure shows the PUTT scheme logic.

Figure 255: PUTT logic



Permissive over-reaching transfer trip

The permissive over-reaching transfer trip (POTT) scheme is for two-terminal line applications. This scheme uses an over-reaching zone 2 distance element to compare the direction to a fault at both terminals of the line. Ground directional overcurrent functions available in the relay can be used in conjunction with the zone 2 distance element to key the scheme and initiate its operation. This provides increased coverage for high-resistance faults.

For proper operation, the zone 2 phase and ground distance elements must be enabled and configured as per the principles of distance relaying. The line pickup element also needs to be enabled and configured to detect line-end-open or weak-infeed conditions. If used by this scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

In single-pole tripping applications, the scheme uses local fault type identification provided by the Phase Selector together with information received from the remote terminal. The scheme generates output operands (POTT TX1 through POTT TX4) that are used to transmit the signal to the remote end. Choices of communications channel include remote inputs, remote outputs, and telecommunications interfaces. When used with telecommunications facilities the output operands need to be assigned to operate output contacts connected to assert the individual bits at the interface.

To make the scheme fully operational as a stand-alone feature, the output operands must be configured to interface with other relay functions, in particular the output contacts. The output operands are typically programmed to initiate a trip, breaker fail, and autoreclose, and drive an annunciator indication as per user requirements.

When used in conjunction with the trip output element, the POTT scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > POTT Scheme** menu to access the permissive over-reaching transfer trip settings.

Figure 256: POTT scheme configuration settings

SETTING	PARAMETER
Function	Disabled
Permissive Echo	Disabled
Echo Condition	OFF
RX Pickup Delay	0.000 s
Transient Block Pickup Delay	0.020 s
Trans Block Reset Delay	0.090 s
Echo Duration	0.100 s
Echo Lockout	0.250 s
Line End Open Pickup Delay	0.050 s
Seal-In Delay	0.000 s
Ground Directional OC Forward	OFF
Communication Bits	1
Rx1	OFF
Rx2	OFF
Rx3	OFF
Rx4	OFF
Event	Disabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the permissive over-reaching transfer trip (POTT) scheme.

Permissive Echo

Range: Enabled, Custom, Disabled

Default: Disabled

If this setting is “Enabled,” the scheme sends a permissive echo signal to the remote ends using pre-programmed logic (refer to the following logic diagram). If set to “Custom,” the echo signal is sent if a condition selected via the **Echo Condition** setting is satisfied. The echo is sent only once and then the logic locks out for the time specified by the **Echo Lockout** setting. The duration of the echo pulse is specified by the Echo Duration setting. Operation of the overreaching protection elements (distance zone 2 or the **Ground Directional OC Forward** setting) inhibits the echo.

Echo Condition

Range: any FlexLogic operand

Default: OFF

This setting selects and applies an echo condition and only if the **Permissive Echo** setting is “Custom.”

RX Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting enables the relay to cope with spurious receive signals. Set this delay value to be longer than the longest spurious TX signal that can be received simultaneously with the zone 2 pickup. The selected delay increases the response time of the scheme.

Transient Block Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.020 seconds

This setting defines a transient blocking mechanism embedded in the POTT scheme for coping with the exposure of a ground directional overcurrent function (if used) to current reversal conditions. The transient blocking mechanism applies to the ground overcurrent path only as the reach settings for the zone 2 distance functions is not expected to be long for two-terminal applications, and the security of the distance functions is not endangered by the current reversal conditions.

Upon receiving the **POTT RX** signal, the transient blocking mechanism allows the signal to be passed and aligned with the indication specified by the **Ground Directional OC Forward** setting for a period of time specified by the **Transient Block Pickup Delay** setting. After this, the ground directional overcurrent path is virtually disabled for the time specified by the **Transient Block Reset Delay** setting.

When determining the delay to use, make it large enough to allow the selected ground directional overcurrent function to operate, but not greater than the fastest possible operation time of the protection system that can create current reversal conditions within the reach of the selected ground directional overcurrent function.

When determining the delay to use, take into account the value of the **RX Pickup Delay** setting. The **POTT RX** signal is shaped for aligning with the ground directional indication. The original **POTT RX** signal is delayed by the value of the **RX Pickup Delay** setting, then terminated at the time specified by the **Transient Block Pickup Delay** setting after the pickup of the original **POTT TX** signal, and eventually locked-out for the time specified by the **Transient Block Reset Delay** setting.

Transient Block Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.090 seconds

This setting specifies a transient blocking mechanism embedded in the POTT scheme for coping with the exposure of a ground directional overcurrent function (if used) to current reversal conditions (see the **Transient Block Pickup Delay** setting). This delay needs to be long enough to cope with transient conditions, including not only current reversals but also spurious negative and zero-sequence currents occurring during breaker operations. The breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the POTT scheme can be considered to ensure that the ground directional function is not jeopardized during delayed breaker operations.

Echo Duration

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.100 seconds

This setting specifies the guaranteed and exact duration of the echo pulse. The duration does not depend on the duration and shape of the received RX signal. This setting enables the relay to avoid a permanent lock-up of the transmit-receive loop.

Echo Lockout

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.250 seconds

This setting specifies the lockout period for the echo logic after sending the echo pulse.

Line End Open Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.050 seconds

This setting specifies the pickup value for validation of the line end open conditions as detected by the line pickup logic through the [LINE PICKUP LEO PKP](#) FlexLogic operand. The validated line end open condition is a requirement for the POTT scheme to return a received echo signal (if the echo feature is enabled). This value should take into account the principle of operation and settings of the line pickup element.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

The [POTT OP](#) FlexLogic operand is produced according to the POTT scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels. This setting defines a minimum guaranteed duration of the [POTT OP](#) pulse. As this operand activates the trip table of the POTT scheme, the [POTT TRIP A](#), [POTT TRIP B](#), [POTT TRIP C](#), and [POTT TRIP 3P](#) trip operands are sealed-in for the same period of time.

Ground Directional OC Forward

Range: any FlexLogic operand

Default: OFF

This setting defines the FlexLogic operand (if any) of a protection element that is used in addition to zone 2 for identifying faults on the protected line, and thus, for keying the communication channel and initiating operation of the scheme. Good directional integrity is the key requirement for an over-reaching forward-looking protection element used for this setting. Even though any FlexLogic operand can be assigned to this setting, allowing the user to combine responses of various protection elements or apply extra conditions through FlexLogic equations, this extra signal is meant to be the output operand from either the negative-sequence directional overcurrent or neutral directional overcurrent element. Both of these elements have separate forward and reverse output operands. The forward indication needs to be used ([NEG SEQ DIR OC1 FWD](#) or [NEUTRAL DIR OC1 FWD](#)).

Communication Bits

Range: 1, 2, 4

Default: 1

This setting specifies the number of bits of the communications channel available for the scheme. With only one bit available, the scheme sends the permissive over-reaching transfer trip command on bit 1 (the [POTT TX1](#) operand) and responds to the direct trip command received on bit 1 (the [RX1](#) setting). The scheme uses only local fault type identification provided by the phase selector to assert the trip operands ([POTT TRIP A](#), [POTT TRIP B](#), [POTT TRIP C](#), and [POTT TRIP 3P](#)).

RX1, RX2, RX3, RX4

Range: any FlexLogic operand

Default: OFF

These settings select the FlexLogic operands that represent the receive signals for the scheme. Typically input contacts interfacing with a signaling system are used in the following manner:

- In single-bit applications, [RX1](#) must be used
- In two-bit applications, [RX1](#) and [RX2](#) must be used
- In four-bit applications, [RX1](#) through [RX4](#) must be used

Events

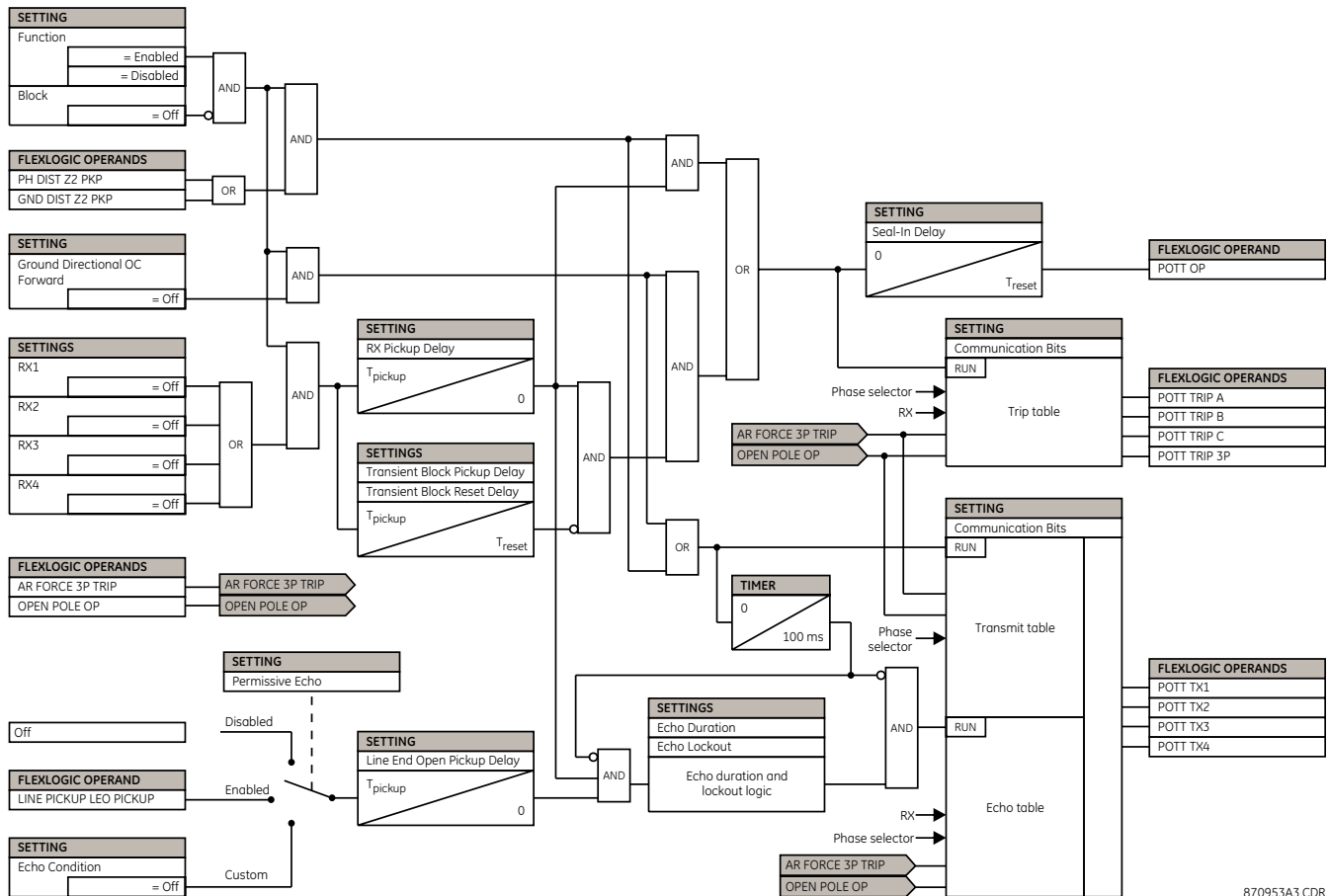
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of permissive over-reaching transfer trip (POTT) scheme events in the sequence of events recorder.

The figure shows the POTT scheme logic.

Figure 257: POTT logic



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Hybrid permissive over-reaching transfer trip

The hybrid permissive over-reaching transfer trip (hybrid POTT) scheme uses an overreaching zone 2 distance element to compare the direction to a fault at all terminals of the line. Ground directional overcurrent functions available in the D90^{Plus} can be used in conjunction with the zone 2 distance element to key the scheme and initiate operation. This increases the coverage for high resistance faults.

The scheme is intended for three-terminal applications and for weak-infeed conditions. As a long reach of the overreaching distance element can be required for three-terminal applications, transient blocking logic is provided for both distance and ground directional overcurrent elements. An echo feature is available to cope with weak-infeed conditions.

By default, the hybrid POTT scheme uses the reverse-looking zone 4 distance element to identify reverse faults. Additionally, reverse-looking ground directional overcurrent functions can be used in conjunction with zone 4.

For proper operation, the zone 2 and 4 phase and ground distance elements must be enabled and configured according to the principles of distance relaying. The line pickup element needs to be enabled and configured to detect line-end-open or weak-infeed and undervoltage conditions. If used by the scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

In single-pole tripping applications, the hybrid POTT scheme uses local fault type identification provided by the phase selector together with information received from the remote terminal. The scheme generates output operands (HYBRID POTT TX1 through HYBRID POTT TX4) that are used to transmit the signal to the remote terminals. Choices of communications channel include remote inputs, remote outputs, and telecommunications interfaces. When used with telecommunications facilities the output operands need to be assigned to operate an output contact connected to key the transmitter and assert the individual bits at the interface.

To make the scheme fully operational as a stand-alone feature, the output operands must be configured to interface with other relay functions, in particular the output contacts. The output operands are programmed to initiate a trip, breaker fail, and autoreclose, and drive an annunciator indication as per user requirements.

When used in conjunction with the trip output element, the hybrid POTT scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > Hybrid POTT Scheme** menu to access the hybrid permissive over-reaching transfer trip settings.

Figure 258: Hybrid POTT configuration settings

SETTING	PARAMETER
Function	Disabled
Permissive Echo	Disabled
RX Pickup Delay	0.000 s
Transient Block Pickup Delay	0.020 s
Trans Block Reset Delay	0.090 s
Echo Duration	0.100 s
Echo Lockout	0.250 s
Seal-In Delay	0.000 s
Ground Directional OC Forward	OFF
Ground Directional OC Reverse	OFF
Communication Bits	1
Rx1	OFF
Rx2	OFF
Rx3	OFF
Rx4	OFF
Event	Disabled
Echo Condition	OFF
Weak Infeed	Enabled
Weak Infeed Condition	OFF

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the hybrid permissive over-reaching transfer trip (hybrid POTT) scheme.

Permissive Echo

Range: Enabled, Custom, Disabled

Default: Disabled

If this setting is “Enabled,” the hybrid POTT scheme sends a permissive echo signal to the remote ends using pre-programmed logic (see the logic diagram). If set to “Custom,” the echo signal is sent if the condition selected by the **Echo Condition** setting is satisfied. The echo is sent only once and then the logic locks out for the time specified by the **Echo Lockout** setting. The duration of the echo pulse is specified by the **Echo Duration** setting. Operation of the over-reaching protection elements (distance zone 2 or the **Ground Directional OC Forward** setting) inhibits the echo.

RX Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting enables the relay to cope with spurious received signals. Set the delay longer than the longest spurious TX signal that can be received simultaneously with the zone 2 pickup. The selected delay increases the response time of the scheme.

Transient Block Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.020 seconds

This setting defines a transient blocking mechanism embedded in the hybrid POTT scheme for coping with the exposure of both the over-reaching zone 2 and ground directional overcurrent function to current reversal conditions.

The transient blocking logic applies to both operate (trip) and send (transmit) paths. Identifying the fault as a reverse fault prevents the scheme from both operating and keying the channel. If the reverse fault condition prevails for the time specified by this setting, the blocking operation is extended by the transient blocking timer for the time specified by the **Transient Block Reset Delay** setting. This allows riding through current reversal conditions.

However, if distance zone 1 picks up during the transient blocking condition, the blocking action is removed. This allows the IED to cope with evolving faults when an external fault is followed by an internal fault. Without zone 1 feedback, the trip is delayed unnecessarily.

When determining this delay value, make it not greater than the fastest possible trip time for faults on an adjacent line so that extended blocking action can be established. Take into account the pickup time of the reverse-looking elements of the scheme. Also, the delay specified by this setting cannot be too short in order to avoid locking up a spurious reverse fault indication that can occur during internal fault conditions.

Transient Block Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.090 seconds

This setting specifies a transient blocking mechanism embedded in the hybrid POTT scheme for coping with the exposure of the overreaching protection functions to current reversal conditions (see also the **Transient Block Pickup Delay** setting).

Make this delay long enough to cope with transient conditions, including current reversals as well as spurious negative and zero-sequence currents occurring during breaker operations (in the case when neutral directional or negative-sequence directional overcurrent functions are used). The breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the hybrid POTT scheme need to be considered to make sure that the ground directional function is not jeopardized during delayed breaker operations.

Echo Duration

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.100 seconds

This setting specifies the guaranteed and exact duration of the echo pulse. The duration is not dependent on the duration and shape of received RX signals. This setting enables the relay to avoid a permanent lock-up of the transmit-receive loop.

Echo Lockout

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.250 seconds

This setting specifies the lockout period for the echo logic after sending the echo pulse. This enables the relay to avoid oscillations of the echo pulses during an autoreclosure dead-time after clearing an internal fault.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

The **HYB POTT OP** FlexLogic operand is produced according to the hybrid POTT scheme logic. This setting specifies a minimum guaranteed duration for the **HYB POTT OP** pulse. As this operand runs the trip table of the hybrid POTT scheme, the **HYB POTT TRIP A**, **HYB POTT TRIP B**, **HYB POTT TRIP C**, and **HYB POTT TRIP 3P** trip operands are sealed-in for the same period of time.

Ground Directional OC Forward

Range: any FlexLogic operand

Default: OFF

This setting defines the FlexLogic operand (if any) of a protection element used in addition to zone 2 for identifying faults on the protected line, and thus, for keying the communication channel and initiating operation of the scheme (both through the transient blocking logic). Good directional integrity is the key requirement for an over-reaching forward-looking protection element used for this feature.

Even though any operand can be used for this setting, enabling the user to combine responses of various protection elements or apply extra conditions through FlexLogic equations, this extra signal is primarily meant to be the output operand from either the negative-sequence directional or neutral directional overcurrent elements. Both these elements have separate forward and reverse output operands. Use the forward indication (that is, **NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**).

Coordinate the selected protection element (or elements in combination) with the selection of the **Ground Directional OC Reverse** setting. For all the forward external faults seen by an element selected by the **Ground Directional OC Forward** at one end of the line, the reverse-looking element at the other end selected by **Ground Directional OC Reverse** picks up and provides a blocking signal.

Ground Directional OC Reverse

Range: any FlexLogic operand

Default: OFF

This setting defines the FlexLogic operand (if any) of a protection element used in addition to zone 4 for identifying reverse faults, and thus, for stopping the transmit signal and initiating the transient blocking timer. Good directional integrity is the key requirement for a reverse-looking protection element used for this feature.

Even though any operand can be used for this setting, enabling the user to combine responses of various protection elements or to apply extra conditions through FlexLogic equations, this extra signal is meant to be the output operand from either the negative

sequence directional or neutral directional overcurrent element. Both these elements have separate forward and reverse output operands. Use the reverse indication ([NEG SEQ DIR OC1 REV](#) or [NEUTRAL DIR OC1 REV](#)).

Coordinate the selected protection element (or elements in combination) with the selection of the [Ground Directional OC Forward](#) setting. For all the forward external faults seen by an element selected by the [Ground Directional OC Forward](#) setting at one end of the line, the reverse-looking element at the other selected by the [Ground Directional OC Forward](#) setting end picks up and provide a blocking signal.

Communication Bits

Range: 1, 2, 4

Default: 1

This setting specifies the number of bits of the communications channel available for the scheme. With only one bit available, the scheme sends the hybrid permissive over-reaching transfer trip command on bit 1 (the [HYB POTT TX1](#) operand) and responds to the direct trip command received on bit 1 (the [RX1](#) setting). The scheme uses only local fault type identification provided by the phase selector to assert the trip operands ([HYB POTT TRIP A](#), [HYB POTT TRIP B](#), [HYB POTT TRIP C](#), and [HYB POTT TRIP 3P](#)).

RX1, RX2, RX3, RX4

Range: any FlexLogic operand

Default: OFF

These settings allow the user to select the FlexLogic operands that represent the receive signals for the scheme. Typically input contacts interfacing with a signaling system are used as follows:

- In single-bit applications, [RX1](#) must be used
- In two-bit applications, [RX1](#) and [RX2](#) must be used
- In four-bit applications, [RX1](#) through [RX4](#) must be used

Events

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of hybrid permissive over-reaching transfer trip (hybrid POTT) scheme events in the sequence of events recorder.

Echo Condition

Range: any FlexLogic operand

Default: OFF

This setting specifies and applies an echo condition when the [Permissive Echo](#) setting is "Custom."

Weak Infeed

Range: Enabled, Custom, Disabled

Default: Disabled

If this setting is "Enabled," the scheme activates both the keying and operating paths using a pre-programmed weak infeed logic (see the logic diagram). If this setting is "Custom," the weak infeed condition is to be specified by the user via the [Weak Infeed Condition](#) setting.

Weak Infeed Condition

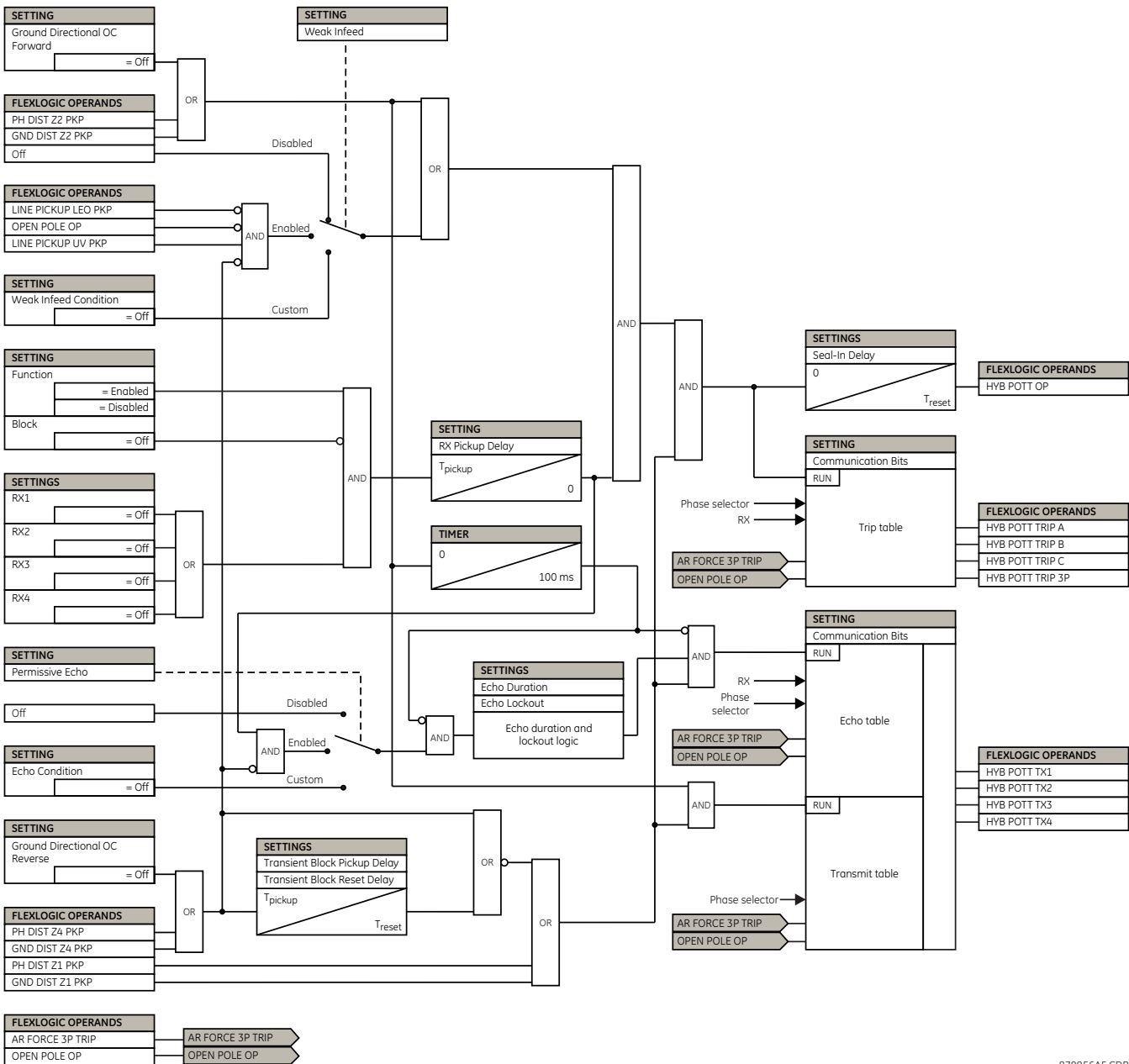
Range: any FlexLogic operand

Default: OFF

This setting specifies and applies a weak infeed condition when the [Weak Infeed](#) setting is "Custom."

The figure shows the hybrid POTT scheme logic.

Figure 259: Hybrid POTT logic



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Directional comparison blocking

The directional comparison blocking scheme compares the direction to a fault at all terminals of the line. Unlike the permissive schemes, the absence of a blocking signal permits operation of the scheme. Consequently, the scheme is biased toward dependability and requires an on-off type of signaling.

By default, the directional comparison blocking scheme uses only a forward-looking overreaching zone 2 distance element to identify forward faults. Ground directional overcurrent functions available in the relay can be used in conjunction with the zone 2 distance element to increase the coverage for high resistance faults. Also by default, only a

reverse-looking zone 4 distance element identifies reverse faults. The ground directional overcurrent functions can be used in conjunction with the zone 4 distance element for better time and sensitivity coordination.

For proper operation, the zone 2 and 4 phase and ground distance elements must be enabled and configured according to the principles of distance relaying. If used by the directional comparison blocking scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

In single-pole tripping applications, the directional comparison blocking scheme uses local fault type identification provided by the phase selector together with information received from the remote terminal.

The directional comparison blocking scheme generates output operands ([DIR BLOCK TX INIT](#) and [DIR BLOCK TX1 STOP](#) through [DIR BLOCK TX4 STOP](#)) that control the transmission of signals to the remote ends. When used with telecommunications facilities the output operands need to be assigned to operate output contacts connected to key the transmitter at the interface.

The [DIR BLOCK A](#), [DIR BLOCK B](#), [DIR BLOCK C](#), and [DIR BLOCK 3P](#) output operands must be configured to interface with other relay functions, in particular the output contacts, to make the scheme fully operational. The output operand is programmed to initiate a trip, breaker fail, and autoreclose, and drive an annunciator indication as per user requirements.

When used in conjunction with the trip output element, the directional comparison blocking scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > Blocking Scheme** menu to access the directional comparison blocking scheme settings.

Figure 260: Directional comparison blocking configuration settings

SETTING	PARAMETER
Function	Disabled
RX Coordination Pickup Delay	0.010 s
Transient Block Pickup Delay	0.030 s
Transient Block Reset Delay	0.090 s
Seal-In Delay	0.000 s
Ground Directional OC Forward	OFF
Ground Directional OC Reverse	OFF
Communication Bits	1
Rx1	OFF
Rx2	OFF
Rx3	OFF
Rx4	OFF
Event	Disabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the directional comparison blocking scheme.

RX Coordination Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.010 seconds

This setting specifies a time delay for the forward-looking protection elements used by the scheme for coordination with the blocking response from the remote ends. This setting is to include both the response time of the protection elements used to establish a blocking signal and the total transmission time of that signal including the relay communications equipment interfacing and the communications channel itself.

Transient Block Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.030 seconds

This setting specifies a transient blocking mechanism embedded in the directional comparison blocking scheme for coping with the exposure of both the over-reaching zone 2 and ground directional overcurrent function to current reversal conditions.

The transient blocking logic applies to the send path only. Identifying the fault as a reverse fault establishes the blocking signal. If the reverse fault condition prevails for the time specified by this setting, the blocking operation is extended by the transient blocking timer for time specified by the **Transient Block Reset Delay** setting. This allows riding through current reversal conditions. However, if zone 1 picks up during the transient blocking condition, the blocking action is removed. This is done to cope with evolving faults when an external fault is followed by an internal fault. Without the zone 1 feedback, the trip is delayed unnecessarily.

Make the delay shorter than the fastest possible trip time for faults on an adjacent line so that the extended blocking action can be established. Take into account the pickup time of the reverse-looking elements of the scheme. Also make the delay defined by this setting not too short in order to avoid locking up a spurious reverse fault indication that can occur during internal fault conditions.

Transient Block Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.090 seconds

This setting specifies a transient blocking mechanism embedded in the directional comparison blocking scheme for coping with the exposure of the overreaching protection functions to current reversal conditions (see also the **Transient Block Pickup Delay** setting).

Make the delay long enough to cope with transient conditions including not only current reversals but also spurious negative and zero-sequence currents occurring during breaker operations (in the case when neutral directional or negative-sequence directional overcurrent functions are used). Breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the blocking scheme should be considered to make sure that the ground directional function is not jeopardized during delayed breaker operations.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

The **DIR BLOCK OP** operand is produced according to the directional comparison blocking scheme logic. This setting defines a minimum guaranteed duration of the **DIR BLOCK OP** pulse. As this operand runs the trip table of the blocking scheme, the **DIR BLOCK TRIP A**, **DIR BLOCK TRIP B**, **DIR BLOCK TRIP C**, and **DIR BLOCK TRIP 3P** trip operands are sealed-in for the same period of time.

Ground Directional OC Forward

Range: any FlexLogic operand

Default: OFF

This setting selects the FlexLogic operand (if any) of a protection element used in addition to zone 2 for identifying faults on the protected line, and thus, for initiating operation of the scheme. Good directional integrity is the key requirement for an over-reaching forward-looking protection element used for this feature.

Even though any operand can be used, enabling the user to combine responses of various protection elements or to apply extra conditions through FlexLogic equations, this extra signal is primarily meant to be the output operand from either the negative-sequence directional or neutral directional overcurrent elements. Both these elements have separate forward and reverse output operands.

Use the forward indication (that is, **NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**). Coordinate the selected protection element (or elements in combination) with this setting. For all the forward external faults seen by an element selected by the **Ground Directional OC Forward** setting at one end of the line, the reverse-looking element selected by the **Ground Directional OC Reverse** setting at the other end picks up and provides a blocking signal.

Ground Directional OC Reverse

Range: any FlexLogic operand

Default: OFF

This setting selects the FlexLogic operand (if any) of a protection element that is used in addition to zone 4 for identifying reverse faults, and thus, for initiating the blocking signal. Either reverse-looking directional or non-directional overcurrent protection element can be used for this feature.

Even though any operand can be used, enabling the user to combine responses of various protection elements or to apply extra conditions through FlexLogic equations, this extra signal is meant to be the output operand from either the negative-sequence directional, neutral directional, or a non-directional instantaneous overcurrent element.

Coordinate the selected protection element (or elements in combination) with the selection of the **Ground Directional OC Forward** setting. For all the forward external faults seen by an element selected by the **Ground Directional OC Forward** setting at one end of the line, the reverse-looking element selected by the **Ground Directional OC Reverse** setting at the other end picks up and provides a blocking signal.

Communication Bits

Range: 1, 2, 4

Default: 1

This setting specifies the number of bits of the communications channel available for the directional comparison blocking scheme. With only one bit available, the scheme sends the blocking signal by asserting the **DIR BLOCK TX INIT** operand. Use this operand to start the channel (set the blocking signal). On internal faults, the scheme removes the blocking signal by asserting the **DIR BLOCK TX1** FlexLogic operand.

For tripping, the directional comparison blocking scheme responds to lack of the blocking signal on bit 1 (selected by the **RX1** setting). The scheme uses only local fault type identification provided by the phase selector to assert the **DIR BLOCK TRIP A**, **DIR BLOCK TRIP B**, **DIR BLOCK TRIP C**, and **DIR BLOCK TRIP 3P** output operands.

To take advantage of the four-bit blocking scheme, initiate the blocking signals from a disturbance detector. This can be accomplished by using both 50DD and the **DIR BLOCK TX INIT** operand to assert the blocking signal. Subsequently, specific bits are de-asserted by the scheme based on the phase selection providing the peer device with more information on the fault type. Otherwise, the peer device issues a three-pole trip upon receiving the [0, 0, 0, 0] bit pattern.

RX1, RX2, RX3, RX4

Range: any FlexLogic operand
 Default: OFF

These settings allow the user to select the FlexLogic operands that represent the receive signals for the directional comparison blocking scheme. Typically input contacts interfacing with a signaling system are used as follows:

- In single-bit applications, **RX1** must be used
- In two-bit applications, **RX1** and **RX2** must be used
- In four-bit applications, **RX1** through **RX4** must be used

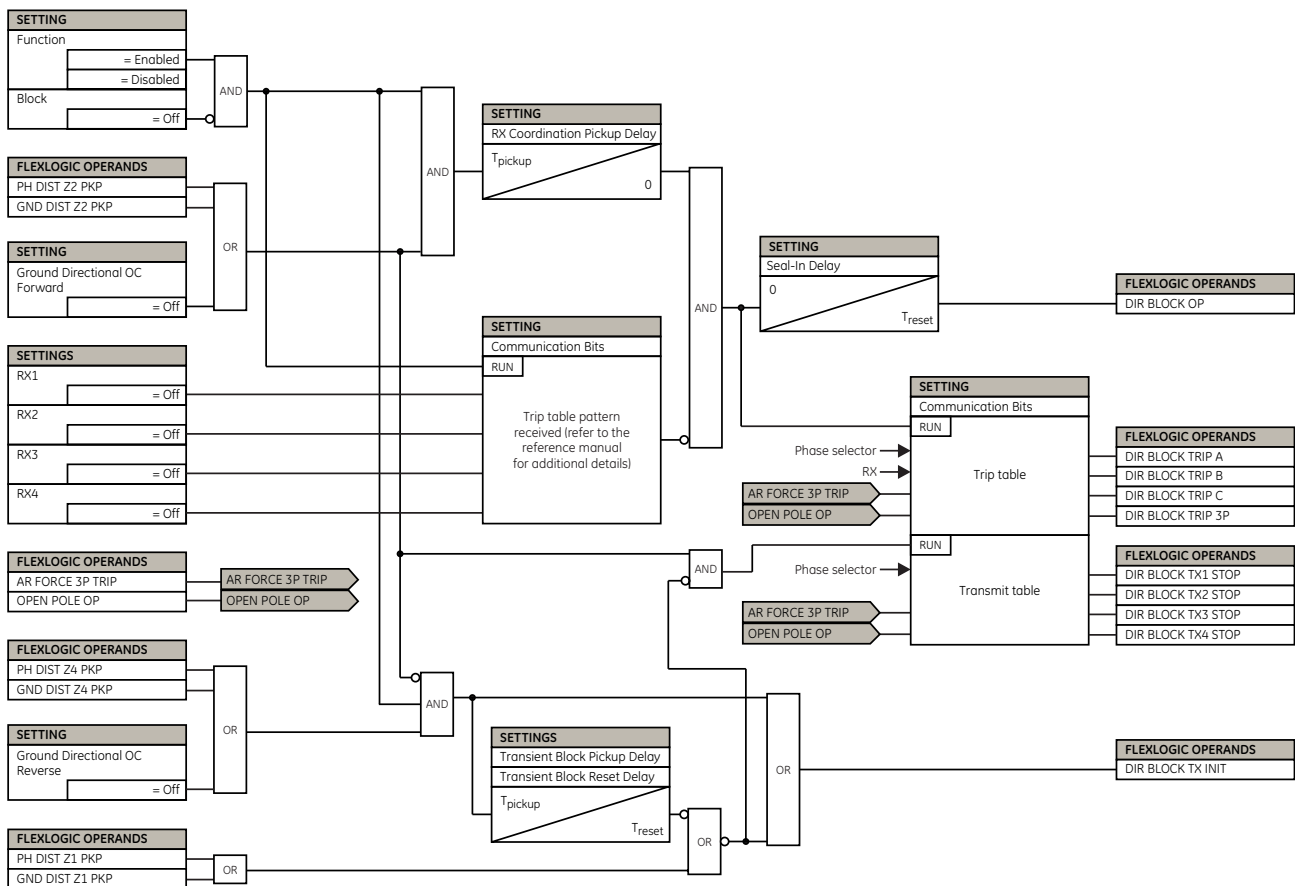
Events

Range: Enabled, Disabled
 Default: Enabled

This setting enables and disables the logging of directional comparison blocking scheme events in the sequence of events recorder.

The figure shows the directional comparison blocking scheme logic.

Figure 261: Directional comparison blocking scheme logic



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Directional comparison unblocking

The directional comparison unblocking scheme is available for single-pole tripping applications and can be used with one, two, or four bit communications channels. Choices of communications channel include remote inputs, remote outputs, and telecommunications interfaces.

The directional comparison unblocking scheme typically uses an over-reaching zone 2 distance element to compare the direction to a fault at all terminals of the line. Ground directional overcurrent functions available in the device can be used in conjunction with the zone 2 distance element to key the scheme and initiate its operation. This increases the coverage for high resistance faults. The scheme is intended for two or three-terminal applications. As a long reach of the overreaching distance element can be required for three-terminal applications, transient blocking logic is provided for both distance and ground directional overcurrent elements. An echo feature is made available to cope with line open conditions.

By default the scheme uses the reverse-looking zone 4 distance element to identify reverse faults. Additionally, reverse-looking ground directional overcurrent functions can be used in conjunction with zone 4.

For proper operation, the zones 2 and 4 phase and ground distance elements must be enabled and configured according to the principles of distance relaying. Also enable and configure the line pickup element to detect line-end-open conditions. If used by the directional comparison unblocking scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

In single-pole tripping applications, the directional comparison unblocking scheme uses local fault type identification provided by the phase selector together with information received from the remote terminal. The scheme generates output operands (DCUB TX1 through DCUB TX4) that are used to transmit the signal to the remote terminals. The directional comparison unblocking scheme was developed for use with frequency shift keying communications channels, though different telecommunications interfaces can be used (for example, digital communication channels utilizing the D90^{PLUS} teleprotection inputs and outputs).

To make the directional comparison unblocking scheme fully operational as a stand-alone feature, the scheme output operands must be configured to interface with other relay functions, in particular the output contacts. Typically, program the output operands to initiate a trip, breaker fail, and autoreclose, and to drive an annunciator indication as per the intended application.

When used in conjunction with the trip output element, the directional comparison unblocking scheme is pre-configured to initiate trip, breaker fail, and autoreclose actions.

Select the **Settings > Protection > Control > Pilot Schemes > DCUB Scheme** menu to access the directional comparison unblocking scheme settings.

Figure 262: Directional comparison unblocking scheme configuration settings

SETTING	PARAMETER
Scheme Function	Disabled
Block	OFF
Permissive Echo	Disabled
Echo Condition	OFF
Ground Directional OC Forward	OFF
Ground Directional OC Reverse	OFF
Transient Block Pickup Delay	0.020 s
Transient Block Reset Delay	0.090 s
Echo Duration	0.100 s
Echo Lockout	0.250 s
Line End Open Pickup Delay	0.050 s
Loss Of Guard Pickup Delay	0.008 s
Guard Healthy Reset Delay	0.015 s
Loss Of Guard Trip Window	0.150 s
Seal In Delay	0.010 s
Rx1	OFF
Loss Of Guard 1	OFF
Event	Enabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the directional comparison unblocking scheme.

Block

Range: any FlexLogic operand

Default: OFF

This setting allows the user to assign any FlexLogic operand to block the directional comparison unblocking scheme. Contact inputs from a pilot cut-out switch are typically used for this purpose.

Permissive Echo

Range: Disabled, Enabled, Custom

Default: Disabled

Enabling this setting sends a permissive echo signal to the remote ends under certain conditions (see the logic diagram). If set to "Custom," the echo signal is sent if a condition selected with the **Echo Condition** setting is satisfied. The echo is sent only once and then the echo logic locks out for the time specified by the **Echo Lockout** setting. The duration of the echo pulse is programmable by the **Echo Duration** setting. The echo is returned only if no overreaching and reverse protection elements operate.

Echo Condition

Range: any FlexLogic operand

Default: OFF

This setting specifies and applies an echo condition when the **Permissive Echo** setting is "Custom."

Ground Directional OC Forward*Range: any FlexLogic operand**Default: OFF*

This setting selects the FlexLogic operand (if any) of a protection element used in addition to zone 2 for identifying faults on the protected line, and thus, for keying the communication channels and initiating operation of the scheme (both through the transient blocking logic).

Good directional integrity is the key requirement for an over-reaching forward-looking protection element selected with this setting. Even though any operand can be selected for this feature, thereby enabling the user to combine responses of various protection elements or to apply extra conditions through FlexLogic equations, this extra signal is primarily meant to be the output operand from either the negative-sequence directional or neutral directional overcurrent elements. As both these elements have separate forward and reverse output operands, use the forward indication (that is, [NEG SEQ DIR OC1 FWD](#) or [NEUTRAL DIR OC1 FWD](#)).

Coordinate the selected protection element (or elements in combination) with this setting. For all forward external faults seen by an element set by the [Ground Directional OC Forward](#) setting at one end of the line, the reverse-looking element set by the [Ground Directional OC Reverse](#) setting at the other end picks up and provides a blocking signal.

Ground Directional OC Reverse*Range: any FlexLogic operand**Default: OFF*

This setting selects the FlexLogic operand (if any) of a protection element used in addition to zone 4 for identifying reverse faults, and thus, for stopping the transmit signal and initiating the transient blocking timer.

Good directional integrity is the key requirement for a reverse-looking protection element selected by this setting. Even though any operand can be selected, thereby enabling the user to combine responses of various protection elements or to apply extra conditions through FlexLogic equations, this extra signal is primarily meant to be the output operand from either the negative-sequence directional or neutral directional overcurrent element. As both these elements have separate forward and reverse output operands, use the reverse indication ([NEG SEQ DIR OC1 REV](#) or [NEUTRAL DIR OC1 REV](#)).

Coordinate the selected protection element (or elements in combination) with the [Ground Directional OC Forward](#) setting. For all the forward external faults seen by an element set by the [Ground Directional OC Forward](#) setting at one end of the line, the reverse-looking element set as the [Ground Directional OC Reverse](#) setting at the other end picks up and provides a blocking signal.

Transient Block Pickup Delay*Range: 0.000 to 65.535 seconds in steps of 0.001**Default: 0.020 seconds*

This setting specifies a transient blocking mechanism embedded in the directional comparison unblocking scheme for coping with the exposure of both the over-reaching zone 2 and ground directional overcurrent function to current reversal conditions.

The transient blocking logic applies to both operate (trip) and send (transmit) paths. Identifying the fault as a reverse fault prevents the scheme from both operating and keying the channel. If the reverse fault condition prevails for the time specified by this setting, the blocking operation is extended by the transient blocking time specified by the [Transient Block Reset Delay](#) setting. This allows riding through current reversal conditions.

However, if distance zone 1 picks up during the transient blocking condition, the blocking action is removed. This allows the D90^{PLUS} to cope with evolving faults when an external fault is followed by an internal fault. Without the zone 1 feedback, the trip is delayed unnecessarily.

Make this setting less than the fastest possible trip time for faults on an adjacent line so that extended blocking action can be established. Take into account the pickup time of the reverse-looking elements of the scheme. To avoid locking up a spurious reverse fault indication that can occur during internal fault conditions, do not make the delay defined by this setting too short.

Transient Block Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.090 seconds

This setting specifies a transient blocking mechanism embedded in the directional comparison unblocking scheme for coping with the exposure of the overreaching protection functions to current reversal conditions (see also the [Transient Block Pickup Delay](#) setting).

Make this delay long enough to cope with transient conditions including not only current reversals but also spurious negative and zero-sequence currents occurring during breaker operations (in the case when neutral directional or negative-sequence directional overcurrent functions are used). Consider the breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the directional comparison unblocking scheme, to make sure that the ground directional function is not jeopardized during delayed breaker operations.

Echo Duration

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.100 seconds

This setting specifies the guaranteed and exact duration of the echo pulse. The duration does not depend on the duration and shape of the received RX signals. This setting enables the relay to avoid a permanent lock-up of the transmit-receive loop.

Echo Lockout

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.250 seconds

This setting specifies the lockout period for the echo logic after sending the echo pulse. This setting enables the relay to avoid oscillations of the echo pulses during an autoreclosure dead-time after clearing an internal fault.

Line End Open Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.050 seconds

This setting specifies the pickup value for validation of the line end open conditions as detected by the line pickup logic via the [LINE PICKUP LEO PKP](#) operand. The validated line end open condition is a requirement for the directional comparison unblocking scheme to return a received echo signal (if the echo feature is enabled).

When determining the delay value, take into account the principle of operation and settings of the line pickup element, which needs to be enabled.

Loss of Guard Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.008 seconds

This setting specifies the directional comparison unblocking duration time delay. This is the amount of time that the loss-of-guard without receipt of permissive trip must be present before the logic provides permission to operate if a forward fault is detected. It is

set relatively short, but long enough to ride through the transition period of loss-of-guard with the receipt of a permissive signal that occurs with a normal trip. Typical settings are from 4 to 32 ms. For most cases, a value of 8 ms can be used.

The tripping or unblocking window for loss-of-guard without permission is the difference between the timers specified by the **Loss of Guard Trip Window** and **Loss of Guard Pickup** delay settings. For the default settings, this difference is $150 - 8 = 142$ ms and occurs 8 ms after loss-of-guard was received, when the timer specified by this setting has timed out. During this interval, the scheme has permission to operate if a forward fault is sensed, and no reverse faults or transient blocking.

Guard Healthy Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.015 seconds

This setting specifies the guard healthy security time delay. This is the time after the channel is restored that the guard signal must be present before the directional comparison unblocking scheme is put back in service. This reset timer allows the scheme to ride through any chattering in the channel. Typical values are from 100 to 500 ms, with 150 ms commonly used.

Loss of Guard Trip Window

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.015 seconds

This setting specifies the directional comparison unblocking lockout time delay. This is the amount of time from when any loss-of-guard signal is received until the directional comparison unblocking scheme is locked out without the presence of any RX1 to RX4 receive signal or any forward element. This timer seals-in when it expires, creating a blocking signal for all scheme functions and disabling the scheme until the guard signal is restored and the timer specified by the **Guard Healthy Reset Delay** setting expires. Typical values for this setting are from 160 to 180 ms; for most cases, a setting of about 150 ms can be used.

Seal-In Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.010 seconds

The **DCUB OP** output operand is produced according to the directional comparison unblocking scheme logic. This setting specifies a minimum guaranteed duration for the **DCUB OP** pulse. As this operand runs the trip table of the directional comparison unblocking scheme, the **DCUB TRIP A**, **DCUB TRIP B**, **DCUB TRIP C**, and **DCUB TRIP 3P** trip operands are sealed-in for the same period of time.

Communication Bits

Range: 1, 2, 4

Default: 1

This setting specifies the number of bits available on the communications channel for the scheme. With only one bit available, the scheme sends the direct under-reaching transfer trip command on bit 1 (via the **DCUB TX1** operand) and responds to the direct trip command received on bit 1 (**RX1** setting). The scheme uses only local fault type identification provided by the phase selector to assert the **DCUB TRIP A**, **DCUB TRIP B**, **DCUB TRIP C**, and **DCUB TRIP 3P** output operands.

RX1, RX2, RX3, RX4

Range: any FlexLogic operand

Default: OFF

These settings select FlexLogic operands to represent the permission receive signals for the scheme. Contact inputs interfacing with a signaling system typically are used. These settings must be used in conjunction with the loss-of-guard signals, otherwise the scheme does not unblock and thus fails to operate. These settings are used as follows:

- In single-bit applications, **RX1** must be used
- In two-bit applications, **RX1** and **RX2** must be used
- In four-bit applications, **RX1** through **RX4** must be used

Loss of Guard 1, Loss of Guard 2, Loss of Guard 3, Loss of Guard 4

Range: any FlexLogic operand

Default: OFF

These settings select FlexLogic operands to represent the loss-of-guard receive signals for the scheme. Contact inputs interfacing with a signaling system typically are used. Each loss-of-guard signal must correspond to the same receive signal from the same communications channel (that is, **RX1** and **Loss of Guard 1** must be from the same communications channel, and the same for channels 2, 3 and 4, if used). These settings are used as follows:

- In single-bit applications, **Loss of Guard 1** and **RX1** must be used
- In two-bit applications, **Loss of Guard 1** with **RX1** and **Loss of Guard 2** with **RX2** must be used
- In four-bit applications, all receive and loss-of-guard signals must be used

Events

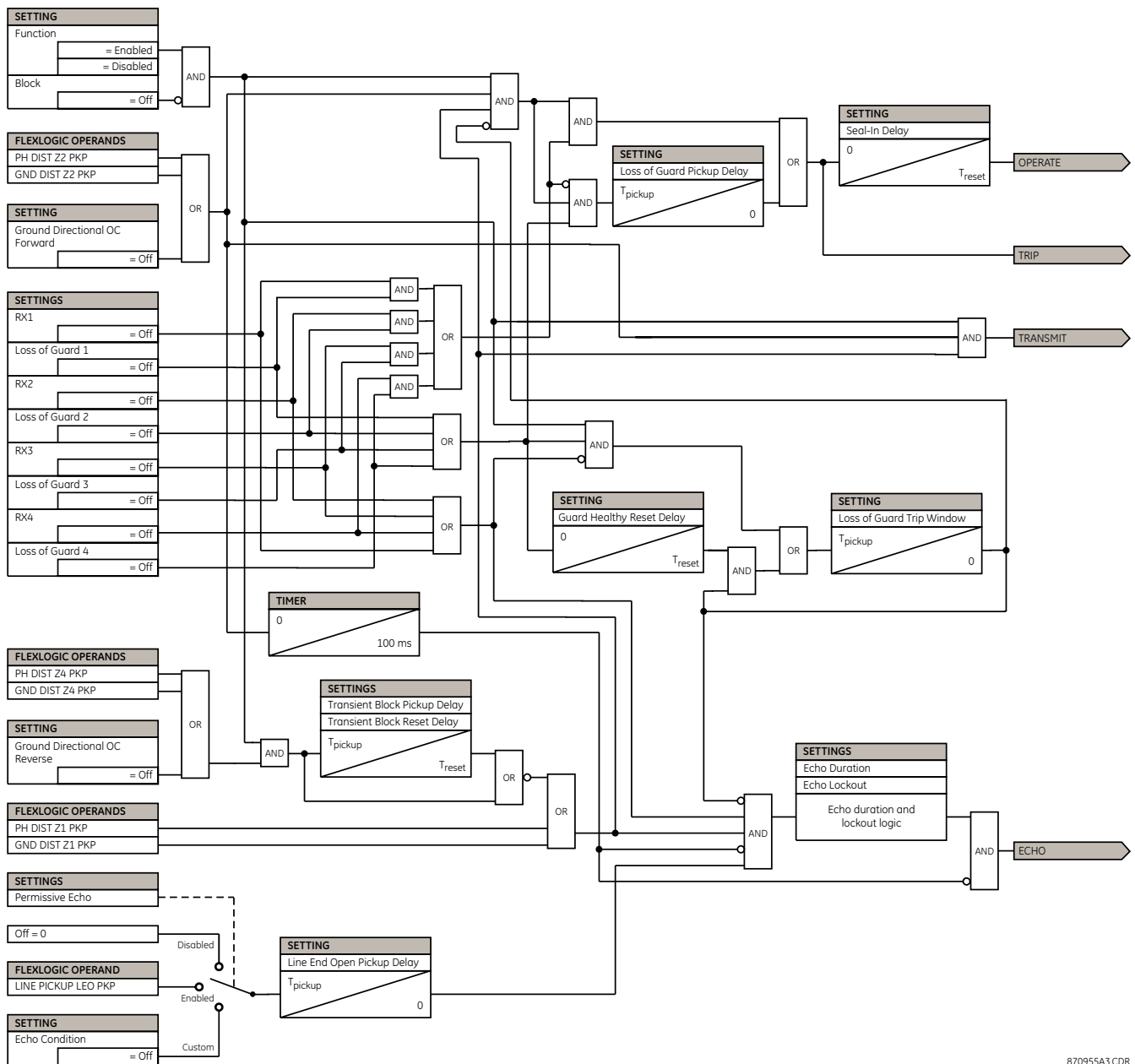
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of directional comparison unblocking scheme events in the sequence of events recorder.

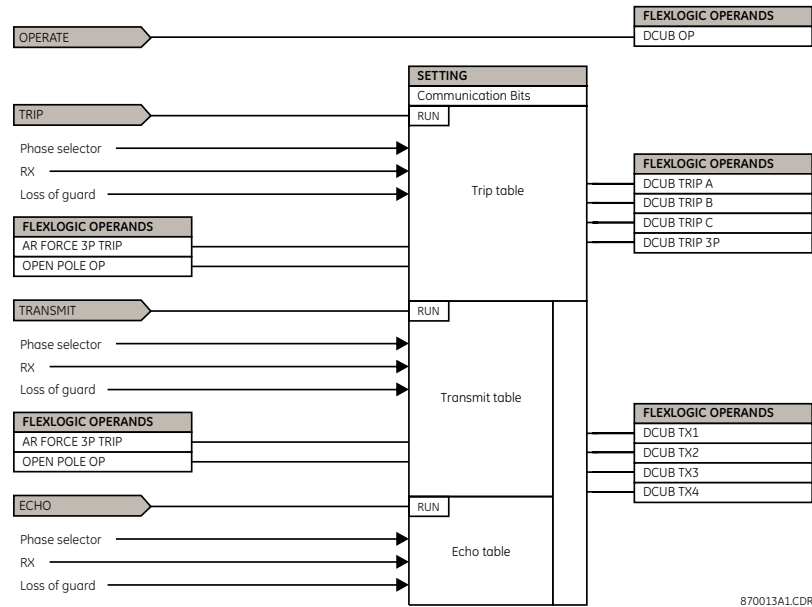
The figures show the directional comparison unblocking scheme logic.

Figure 263: Directional comparison unblocking scheme logic, sheet 1 of 2



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Figure 264: Directional comparison unblocking scheme logic, sheet 2 of 2



Pilot-aided scheme application guidelines

This section provides guidelines for implementing pilot-aided schemes with the D90^{Plus}.

Direct underreaching transfer trip (DUTT) application guidelines

The direct underreaching transfer trip (DUTT) scheme uses an under-reaching zone 1 distance element to key a transfer trip signal to the remote end or ends, where on receipt, the DUTT pilot scheme operates without any additional supervision.

For proper operation of the scheme, the zone 1 phase and ground distance elements must be enabled and configured per the standard rules of distance relaying.

The DUTT scheme generates an output operand (**DUTT TX**) that is used to transmit the signal to the remote end. Choices of communications channel include remote inputs and outputs and telecommunications interfaces. When used with telecommunications facilities, assign the output operand to operate an output contact connected to key the transmitter at the interface.

Note that the same protection signaling can be used by a breaker failure scheme, in which case the signal can be sealed in by breaker failure for a time longer than the autoreclose “reclaim” time that then prevents autoreclose when not required.

A provision for an optional seal-in of the send signal is made to cover those situations where power line carrier (PLC) signaling is used and the signal must be transmitted in a potentially noisy situation due to the fault.

The scheme output operand (**DUTT OP**) must be configured to interface with other D90^{Plus} functions (output contacts in particular) to make the scheme fully operational. Typically, program the output operand to initiate a trip, breaker fail, and autoreclose, and to drive a user-programmable LED as per user requirements.

Permissive underreaching transfer trip (PUTT) application guidelines

The permissive underreaching transfer trip (PUTT) scheme uses an underreaching zone 1 distance element to key a transfer trip signal to the remote end where it is supervised by the overreaching zone 2 distance elements.

For proper operation of the scheme the zone 1 and 2 phase and ground distance elements must be enabled and configured per the standard rules of distance relaying.

The scheme generates an output operand (**PUTT TX**) that is used to transmit the signal to the remote end. Choices of communications channel include remote inputs and outputs and telecommunications interfaces. When used with telecommunications facilities, assign the output operand to operate an output contact connected to key the transmitter at the interface.

The **Pickup Delay** timer setting can be used to ride through spurious PLC receive signals.

The scheme output operand (**PUTT OP**) must be configured to interface with other D90^{Plus} functions (output contacts in particular) to make the scheme fully operational.

Typically, program the output operand to initiate a trip, breaker fail, and autoreclose, and to drive a user-programmable LED as per user requirements.

Permissive overreaching transfer trip (POTT) application guidelines

The permissive overreaching transfer trip (POTT) scheme is for two-terminal line applications. It uses an overreaching zone 2 distance element to compare the direction to a fault at both the ends of the line.

Ground directional overcurrent functions available in the D90^{Plus} can be used in conjunction with the zone 2 distance element to key the POTT scheme and initiate its operation. This provides increased coverage for high-resistance faults.

Good directional integrity is the key requirement for an overreaching forward-looking protection element used to supplement zone 2. Even though any FlexLogic operand can be used for this purpose—allowing the user to combine responses of various protection elements or apply extra conditions through FlexLogic equations—this extra signal is primarily meant to be the output operand from either the negative-sequence directional overcurrent element or neutral directional overcurrent element. Both of these elements have separate forward (FWD) and reverse (REV) output operands. Use the forward indication (**NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD** operand).

An important consideration occurs when one of the line terminals is open. In this case, it is necessary to identify the line terminal open condition and arrange for a continuous sending of the permissive signal or use a slower but more secure echo feature to send a signal to the other terminal that is producing the fault infeed. However, with any echo scheme, a means must be provided to avoid a permanent lock up of the transmit/receive loop. The echo duration timer (via the **Echo Duration** setting) and echo lockout timer (via the **Echo Lockout** setting) perform this function by ensuring that the permissive signal is echoed once for a guaranteed duration of time before going to a lockout for a user-specified length of time.

Note that in ring bus or breaker-and-a-half situations, it can be the line disconnect or a combination of the disconnect status, the breaker status, or both, that is the indication that the terminal is open.

The timer specified by the **RX Pickup Delay** setting is included in the permissive receive path to ride through spurious receive outputs that can be produced during external faults when power line carrier is utilized as the communications medium.

No current reversal logic is included for the overreaching phase and ground distance elements, because long reaches are not usually required for two-terminal lines. However, a situation can occur where the ground distance elements have an extended reach. This situation is encountered when you want to account for the zero-sequence inter-circuit mutual coupling. This is not a problem for the ground distance elements in the D90^{Plus} that have current reversal logic built into their design as part of the technique used to improve ground fault directionality.

Unlike the distance protection elements, the ground directional overcurrent functions do not have a well-defined reach. As such, the current reversal logic is incorporated for the extra signal supplementing zone 2 in the scheme. The transient blocking approach for this POTT scheme is to recognize that a permissive signal has been received and then allow the time specified by the **Transient Block Pickup Delay** setting for the local forward looking directional element to pick up.

The POTT scheme generates an output operand (**POTT TX**) that is used to transmit the signal to the remote end. Choices of communications channel include remote inputs and outputs and telecommunications interfaces. When used with telecommunications facilities the output operand needs to be assigned to operate an output contact connected to key the transmitter at the interface. Power line carrier (PLC) channels are not recommended for this scheme because the PLC signal can be interrupted by a fault.

For proper operation of the POTT scheme, the zone 2 phase and ground distance elements must be enabled and configured per the standard rules of distance relaying. The line pickup element also needs to be enabled and configured to detect line-end open and weak-infeed conditions.

If used by the POTT scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly. The output operand from the scheme (**POTT OP**) must be configured to interface with other D90^{PLUS} functions (output contacts in particular) to make the scheme fully operational. Typically, you program the output operand to initiate a trip, breaker failure, and autoreclose, as well as to drive a user-programmable LED as per user requirements.

Hybrid permissive overreaching transfer trip (hybrid POTT) application guidelines

The hybrid permissive overreaching transfer trip (hybrid POTT) scheme typically uses an overreaching zone 2 distance element to essentially compare the direction to a fault at both ends of the line. Ground directional overcurrent functions available in the D90^{PLUS} can be used in conjunction with the zone 2 distance element to key the scheme and initiate its operation. This increases the coverage for high-resistance faults.

The hybrid POTT scheme is intended for three-terminal applications and for weak-infeed conditions. As a long reach of the overreaching distance element can be required for three-terminal applications, transient blocking logic is provided for both distance and ground directional overcurrent elements. An echo feature is made available to cope with weak-infeed conditions.

By default the scheme uses the reverse-looking zone 4 distance element to identify reverse faults. Additionally, reverse-looking ground directional overcurrent functions can be used in conjunction with zone 4.

For proper operation of the scheme, the zone 2 and zone 4 phase and ground distance elements must be enabled and configured per the standard rules of distance relaying. The line pickup element also needs to be enabled and configured to detect line-end-open, weak-infeed, and undervoltage conditions.

If used by the hybrid POTT scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

The hybrid POTT scheme generates an output operand (**HYBRID POTT TX**) that is used to transmit the signal to the remote end. Choices of communications channel include remote inputs and outputs and telecommunications interfaces. When used with telecommunications facilities the output operand needs to be assigned to operate an output contact connected to key the transmitter at the interface.

The output operand from the hybrid POTT scheme (**HYBRID POTT OP**) must be configured to interface with other D90^{PLUS} functions (output contacts in particular) to make the scheme fully operational. Typically, you program the output operand to initiate a trip, breaker failure, and autoreclose, as well as drive a user-programmable LED as per user requirements.

For additional application recommendations, see the [Permissive overreaching transfer trip \(POTT\) application guidelines](#) on page 317.

Directional comparison blocking application guidelines

The directional comparison blocking scheme typically compares the direction to a fault at both ends of the line. Unlike the permissive schemes, the absence of a blocking signal permits operation of the scheme. Consequently, the scheme is biased toward dependability and requires an “on/off” type of signaling.

By default, the directional comparison blocking scheme uses only a forward-looking overreaching zone 2 distance element to identify forward faults. Ground directional overcurrent functions available in the D90^{PLUS} can be used in conjunction with the zone 2 distance element to increase the coverage for high-resistance faults.

By default, the directional comparison blocking scheme also uses only a reverse-looking zone 4 distance element to identify reverse faults. Ground directional overcurrent functions available in the D90^{PLUS} can be used in conjunction with the zone 4 distance element for better time and sensitivity coordination.

For proper operation of the directional comparison blocking scheme, the zones 2 and 4 phase and ground distance elements must be enabled and configured per the standard rules of distance relaying. If used by this scheme, the selected ground directional overcurrent functions must be enabled and configured accordingly.

The directional comparison blocking scheme generates two output operands (**DIR BLOCK TX INIT** and **DIR BLOCK TX STOP**) that are used control the transmission of signals to the remote end. Choices of communications channel include remote inputs and outputs and telecommunications interfaces. When used with telecommunications facilities, assign the output operand to operate an output contact connected to key the transmitter at the interface.

The directional comparison blocking scheme can be preferred over a hybrid POTT scheme because of shorter reach settings for the zone 2 elements. This follows from the fundamental difference that all zone 2 elements are required to see an internal fault for the POTT approach, under all system conditions, which in turn means that the reversed zone 4 block initiate elements must also have an increased reach. On the other hand, a directional comparison blocking scheme can have much shorter zone 2 reach settings if sequential clearance can be accepted. The simple rule to ensure that all faults can be cleared is for each terminal to have a reach setting equal to the distance to the tap plus twice the distance from the tap to the remote terminal.

The zone 2 element must have a coordinating timer specified by the **RX Coordination Pickup Delay** setting to ensure that the blocking signal is received for all external faults that are within the set reach of the local overreaching zone 2.

Transient blocking logic is implemented via the timer specified by the transient blocking timer. This timer continues to send a blocking signal for the time specified by the **Transient Block Reset Delay** setting if it was being sent for at least 30 ms during the initial reverse fault specified via the **Transient Block Pickup Delay** setting.

The output operand from the directional comparison blocking scheme (**DIR BLOCK OP**) must be configured to interface with other D90^{PLUS} functions (output contacts in particular) to make the scheme fully operational. Typically, you program the output operand to initiate a trip, breaker failure, and autoreclose, as well as to drive a user-programmable LED as per user requirements.

Directional comparison unblocking (DCUB) application guidelines

The directional comparison unblocking (DCUB) scheme is used with a frequency shift keying (FSK) PLC that produces a loss-of-guard output during an actual loss-of-guard signal condition and during reception of the permissive keyed frequency when the received carrier signal changed from guard to permissive frequency. The loss-of-guard signal is preferably a normally-closed contact, allowing the scheme to get this signal if the communications equipment fails. This loss-of-guard output connects to a contact input of the D90^{Plus}. The power line carrier should also provide an output contact when the permissive frequency is received. Wire this output to any other contact input of the D90^{Plus}.

The directional comparison unblocking scheme allows a window of opportunity for fast tripping of the breaker if the permissive signal gets attenuated by the fault to a level less than the receiver's threshold. The guard signal is monitored and relay allowed to trip for a loss-of-guard without receipt of the permissive signal if the D90^{Plus} sees the fault in the forward and not reverse direction by means of the forward looking distance zone 2 and ground directional forward function (if configured) and reverse looking distance zone 4 and ground directional reverse function (if configured).

The directional comparison unblocking scheme is active and ready for operation when the **Block** setting is "Off" and the **Scheme Function** setting is "Enabled." The user can disable or block the scheme by assigning any FlexLogic operand to the **Block** setting. This operand can consist of any pre-defined logic equation, including a pilot cutout switch connected to any contact input of the D90^{Plus}. As such, the scheme can be disabled with this pilot cutout switch and the pre-defined logic state on and assigned to the **Block** setting. The directional comparison unblocking scheme supervises the operation and keying of all scheme functions. The lockout feature also supervises all scheme functions. All timers are fully adjustable, with typical values shown as defaults.

Lockout of the scheme is started for a time duration specified by the **Loss of Guard Trip Window** setting if all of the following conditions hold:

- The directional comparison unblocking scheme is enabled and not blocked (that is, the scheme is active)
- No permissive RX signal is received
- Any loss-of-guard signal is received

Lockout is sealed-in through an AND gate with the directional comparison unblocking scheme active and any loss-of-guard through the **Guard Healthy Reset Delay** timer. The scheme remains blocked during longer loss-of-guard or channel conditions for any of the configured channels. The time specified by the **Guard Healthy Reset Delay** timer ensures that the scheme remains locked out slightly longer after the loss-of-guard signal is reset. This allows for all channel stabilizing and contact denouncing. This timer determines how long the logic waits before enabling the directional comparison unblocking scheme when the communications channel is restored.

Operating of the directional comparison unblocking scheme consists of two parts: *normal operation* and *loss-of-guard operation*.

Normal operation picks up if all of the following conditions hold:

- The directional comparison unblocking scheme is enabled and not blocked (that is, the scheme is active)
- Any permissive signal is received with its associated loss-of-guard signal (for example, **DCUB RX1** and **DCUB LOG1**)
- A fault is seen in the forward zone 2 distance elements or ground directional forward function (if configured)
- The reverse zone 4 distance elements or ground directional reverse function (if configured) did not pickup to set the transient blocking
- The directional comparison unblocking scheme is not locked out

The trip table is run if all of these conditions are met. This operates the scheme and asserts the **DCUB OP** FlexLogic operand. The trip table, with the aid of the local phase selector and received RX signals, determine which tripping operands operate. During normal operation, the loss-of-guard signal is seen momentarily before the permissive **DCUB RX** signal is received for each channel being operated, as the channel transitions from guard to permissive frequency, but the scheme operates instantaneously after any **DCUB RX** signal is received.

The loss-of-guard operation picks up if all of the following conditions hold:

- The directional comparison unblocking scheme is enabled and not blocked (that is, the scheme is active)
- Any loss-of-guard signal is received without its associated RX signal
- A fault is seen in the forward zone 2 distance elements or ground directional forward function (if configured)
- The reverse zone 4 distance elements or ground directional reverse function (if configured) did not pickup to set the transient blocking

If all of these conditions are met, then the timer specified by the **Loss Of Guard Pickup Delay** setting is started. After this timer times out, the trip table is run, operating the scheme and asserting the **DCUB OP** FlexLogic operand. The trip table, with the aid of the local phase selector and loss-of-guard signals, determine which tripping operands operate. The timer specified by the **Loss Of Guard Pickup Delay** setting allows for any and all channels to transition from guard to permissive before operating due to loss-of-guard in the presence of a forward fault. The time window of allowing the scheme to operate when no **DCUB RX** signal is received when any loss-of-guard was received is the difference between the timers specified by the **Loss of Guard Trip Window** and **Loss Of Guard Pickup Delay** settings. For the default settings, this value is $150 - 8 = 142$ ms. This means the scheme is unblocked and can trip during this time window if a forward fault is sensed.

The keying signals, which allows the relay to key the permissive channel during normal permissive scheme operation by means of the **DCUB TX1** through **DCUB TX4** signals, are established when all of the following conditions hold:

- The directional comparison unblocking scheme is enabled and not blocked (that is, the scheme is active)
- A fault is seen in the forward zone 2 distance elements or ground directional forward function (if configured)
- The reverse zone 4 distance elements or ground directional reverse function (if configured) did not pickup to set the transient blocking

If all of these conditions are met, then the directional comparison unblocking scheme keys the channels by means of asserting transmit signals **DCUB TX1** through **DCUB TX4** with the aid of the local phase selector or zone 2 distance elements.

The echo signal, which allows the D90^{PLUS} to key the permissive channels through the **DCUB TX1** through **DCUB TX4** transmit operands during echo conditions when the local breaker opened, keys the carrier(s) if all of the following conditions hold:

- The directional comparison unblocking scheme is enabled and not blocked (that is, the scheme is active)
- The **Permissive Echo** setting is "Enabled"
- The **LINE PICKUP LEO PKP** operand that detects the local breaker to be open picks up for the time specified by **Line End Open Pickup Delay** setting
- Any permissive signal **DCUB RX1** through **DCUB RX4** is received and any **DCUB LOG1** to **DCUB LOG4** signal is received
- A fault is not seen in the forward zone 2 distance elements or ground directional forward function (if configured) for at least 100 ms

- The reverse zone 4 distance elements or ground directional reverse function (if configured) did not pickup to set the transient blocking

If all of these conditions are met, then the directional comparison unblocking scheme echoes (transmits the DCUB TX1 through DCUB TX4 operands) the received permissive DCUB RX signals back to the remote relay based on the echo table.

The keying or transmit signals DCUB TX1 through DCUB TX4 consist of all normal keying or echo keying conditions.

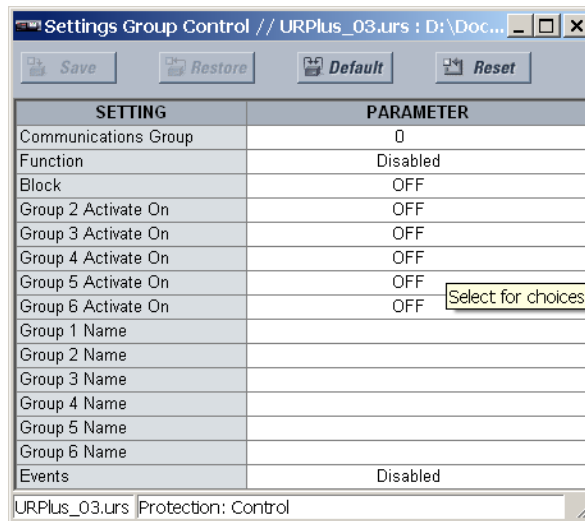
The DCUB TRIP A, DCUB TRIP B, DCUB TRIP C, and DCUB TRIP 3P output operands are hard-wired to the trip output scheme. As such, if the trip output or breaker control operands (if the breaker control function is used) are used for tripping, the scheme fully operational. The permissive key carrier signals DCUB TX1 through DCUB TX4 must still be assigned to the tripping or operating logic, and to output contacts as per the usual D90^{PLUS} logic and output assignments.

Setting group control

The setting groups control function activates and deactivates up to six setting groups.

Select the **Settings > Protection > Control > Setting Group Control** menu to access the setting group control settings.

Figure 265: Setting group control configuration



The following settings are available for setting groups control. The **Current Setting Group** actual value also displays in this menu.

Function

Range: Enabled, Disabled

Default: Disabled

This setting is used to enable and disable the setting groups control functionality.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

This setting prevents the active setting group from changing when the assigned operand is asserted. This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

Group 2 Activate On, Group 3 Activate On, Group 4 Activate On, Group 5 Activate On, Group 6 Activate On

Range: any FlexLogic operand or shared operand

Default: OFF

Each of these settings selects an operand which, when set, activates the corresponding setting group for use by any grouped element. A priority scheme ensures that only one group is active at a given time. The highest-numbered group activated by these settings takes priority over the lower-numbered groups. There is no activation setting group 1 (the default active group) since group 1 automatically becomes active when there is no other group active.

Group 1 Name, Group 2 Name, Group 3 Name, Group 4 Name, Group 5 Name, Group 6 Name

Range: up to 16 alphanumeric characters

Default: empty

These settings allow the user to assign a name to each of the six settings groups.

Events

Range: Enabled, Disabled

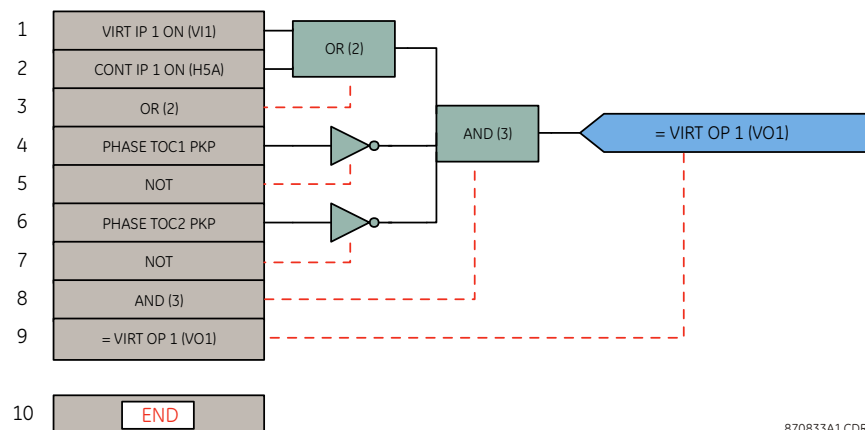
Default: Disabled

This setting enables and disables logging of setting group control events in the sequence of events recorder.

FlexLogic control of a settings group

The relay can be set up via a protection FlexLogic equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic equation illustrates requests via remote communications (for example, **VIRT IP 1 ON**) or from a local contact input (for example, **CONT IP 1 ON**) to initiate the use of a particular settings group, and requests from several overcurrent pickup measuring elements to inhibit the use of the particular settings group. The assigned **VIRT OP 1** operand is used to control the “On” state of a particular settings group.

Figure 266: FlexLogic control of a settings group



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Trip output

The trip output element is primarily used to collect trip requests from protection elements and other inputs to generate output operands that initiate trip operations. Three-pole trips only initiate reclosure if programmed to do so, whereas single-pole trips always automatically initiate reclosure. The **TRIP 3-POLE** and **TRIP 1-POLE** output operands can also be used as inputs to a FlexLogic OR gate to operate the front panel annunciator.

Three-pole operation

In applications where single-pole tripping is not required, the trip output element provides a convenient method of collecting inputs to initiate tripping of circuit breakers, the reclose element, and breaker failure elements.

Single-pole operation



NOTE

This element must be used in single-pole operation applications.

The trip output element performs the following applications for single-pole operations:

- Determines if a single-pole operation is performed
- Collects inputs to initiate three-pole tripping, the autorecloser, and breaker failure elements
- Collects inputs to initiate single-pole tripping, the autorecloser, and breaker failure elements
- Assigns a higher priority to pilot-aided scheme outputs than to exclusively local inputs

The trip output element works in association with the following D90^{PLUS} elements:

- Autoreclose
- Breaker control
- Open pole detector
- Phase selector

These elements must be programmed and in-service for successful operation of the trip output. The autorecloser must also be in the reset state before a single-pole trip can be issued. Outputs from this element are also directly connected as initiate signals to the breaker failure elements.

At least one internal protection element or digital input representing detection of a fault must be available as an input to this element. In pilot-aided scheme applications, a timer can be used to delay the output decision until data from a remote terminal is received from communications facilities. This prevents a three-pole operation when a single-pole operation is permitted.

Trip output settings

Select the **Settings > Protection > Control > Trip Output** menu to access the trip output settings.

Figure 267: Trip output configuration settings

SETTING	PARAMETER
Trip Mode	Disabled
Trip 3-Pole Input 1	OFF
Trip 3-Pole Input 2	OFF
Trip 3-Pole Input 3	OFF
Trip 3-Pole Input 4	OFF
Trip 3-Pole Input 5	OFF
Trip 3-Pole Input 6	OFF
Trip 1-Pole Input 1	OFF
Trip 1-Pole Input 2	OFF
Trip 1-Pole Input 3	OFF
Trip 1-Pole Input 4	OFF
Trip 1-Pole Input 5	OFF
Trip 1-Pole Input 6	OFF
Trip Reclose Input 1	OFF
Trip Reclose Input 2	OFF
Trip Reclose Input 3	OFF
Trip Reclose Input 4	OFF
Trip Reclose Input 5	OFF
Trip Reclose Input 6	OFF
Trip Force 3-Pole	OFF
Trip Pilot Priority	0.000 s
Reverse Fault	OFF
Trip Delay On Evolving Faults	0.000 s
Breaker Phase A Open	OFF
Breaker Phase B Open	OFF
Breaker Phase C Open	OFF
Events	Disabled

The following settings are available.

Trip Mode

Range: Disabled, 3 Pole Only, 3 Pole & 1 Pole

Default: Disabled

This setting selects the required mode of operation. If selected to “3 Pole Only,” outputs for all three phases are always set simultaneously. If selected to “3 Pole & 1 Pole,” outputs for all three phases are set simultaneously unless the phase selector or a pilot aided scheme determines the fault is single-phase-to-ground. If the fault is identified as being AG, BG, or CG only the operands for the faulted phase are asserted.

Trip 3-Pole Input 1, Trip 3-Pole Input 2, Trip 3-Pole Input 3, Trip 3-Pole Input 4, Trip 3-Pole Input 5, Trip 3-Pole Input 6

Range: any FlexLogic operand

Default: OFF

These settings select an operand representing an unwanted fault condition to initiate a single pole operation (for example, phase undervoltage). A FlexLogic OR-gate can be used if more than six inputs are required.

Trip 1-Pole Input 1, Trip 1-Pole Input 2, Trip 1-Pole Input 3, Trip 1-Pole Input 4, Trip 1-Pole Input 5, Trip 1-Pole Input 6

Range: any FlexLogic operand

Default: OFF

These settings select an operand representing a fault condition that is required to initiate a single pole trip-and-reclose if the fault is single phase to ground (for example, phase distance zone 1). Use a FlexLogic OR-gate if more than six inputs are required. The inputs do not have to be phase-specific, as the phase selector determines the fault type.

The **AR FORCE 3-P TRIP** operand is asserted by the autorecloser 1.5 cycles after single-pole reclosing is initiated. This operand calls for a three-pole trip if any protection element configured under which this setting remains picked-up. The open pole detector provides blocking inputs to distance elements; as such, the distance elements immediately reset after the **TRIP 1-POLE** operand is asserted. For other protection elements used in single-pole tripping, the user must ensure that they reset immediately after tripping; otherwise they are detected as an evolving fault if they remained picked up and the relay then executes a three-pole trip.

For example, if a high-set phase instantaneous overcurrent is used (**Trip 1-Pole Input 1** is set to "PHASE IOC1 OP"), then the **OPEN POLE OP ?A** operand is used for blocking phase A of the instantaneous overcurrent element. In this case, after tripping phase A, the phase A instantaneous overcurrent element is forced to reset. Phases B and C remain operational and can detect an evolving fault as soon as 8 ms after tripping phase A. The neutral and negative-sequence instantaneous overcurrent elements shall be blocked from the **OPEN POLE BLK N** operand unless the pickup setting is sufficiently large to prevent pickup during single-pole reclosing.

Trip Reclose Input 1, Trip Reclose Input 2, Trip Reclose Input 3, Trip Reclose Input 4, Trip Reclose Input 5, Trip Reclose Input 6

Range: any FlexLogic operand or shared operand

Default: OFF

These settings select an operand representing a fault condition that initiates three pole reclosing (for example, phase distance zone 1). Use an OR-gate if more than six inputs are required.

Trip Force 3-Pole

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand that forces an input selected for single-pole operation to produce a three-pole operation. The **AR DISABLED** FlexLogic operand is the recommended value for this setting. Power system configurations or conditions that require such operations can also be considered.

Trip Pilot Priority

Range: 0 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies an interval equal to the inter-relay channel communications time, plus an appropriate margin, during which outputs are not asserted. This delay permits fault identification information from a remote terminal to be used instead of local data only.

Reverse Fault

Range: any FlexLogic operand or shared operand

Default: OFF

Use this setting to guarantee accuracy of single-pole tripping under evolving external-to-internal faults. When a close-in external fault occurs, the relay is biased toward very fast operation on a following internal fault. This is primarily due to depressed voltages and elevated currents in response to the first, external fault. The phase selector can exhibit some time lag compared to the main protection elements. This can potentially result in a spurious three-pole operation on a single-line-to-ground internal fault. Delaying tripping on internal faults that follow detection of reverse faults solves the problem.

As long as the operand selected with this setting remains asserted, the trip action is delayed by the time specified by the **Trip Delay on Evolving Faults** setting. Typically, this operand is to combine reverse zone indications (such as zone 4 pickup) with a half-cycle

pickup delay, and a two-cycle dropout delay. Use this setting only in single-pole tripping applications when evolving faults are of importance and slightly delayed operation on evolving faults can be traded for enhanced accuracy of single-pole tripping.

Trip Delay on Evolving Faults

Range: 0 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

Use this setting in conjunction with the **Reverse Fault** setting. Set it typically to around one-half a power system cycle. Use this setting only in single-pole tripping applications when evolving faults are of importance and slightly delayed operation on evolving faults can be traded for enhanced accuracy of single-pole tripping.

Breaker Phase A Open, Breaker Phase B Open, Breaker Phase C Open

Range: any FlexLogic operand or shared operand

Default: OFF

Protection elements that are assigned to the trip output scheme assert appropriate outputs (the **TRIP PHASE A**, **TRIP PHASE B**, **TRIP PHASE C**, **TRIP 1-POLE**, and **TRIP 3-POLE** operands) based on the mode setting and the fault type. These outputs are latched until the D90^{Plus} detects that the breaker has opened via the open pole logic. A user-defined signal can also be assigned with these settings to reset the outputs.

Events

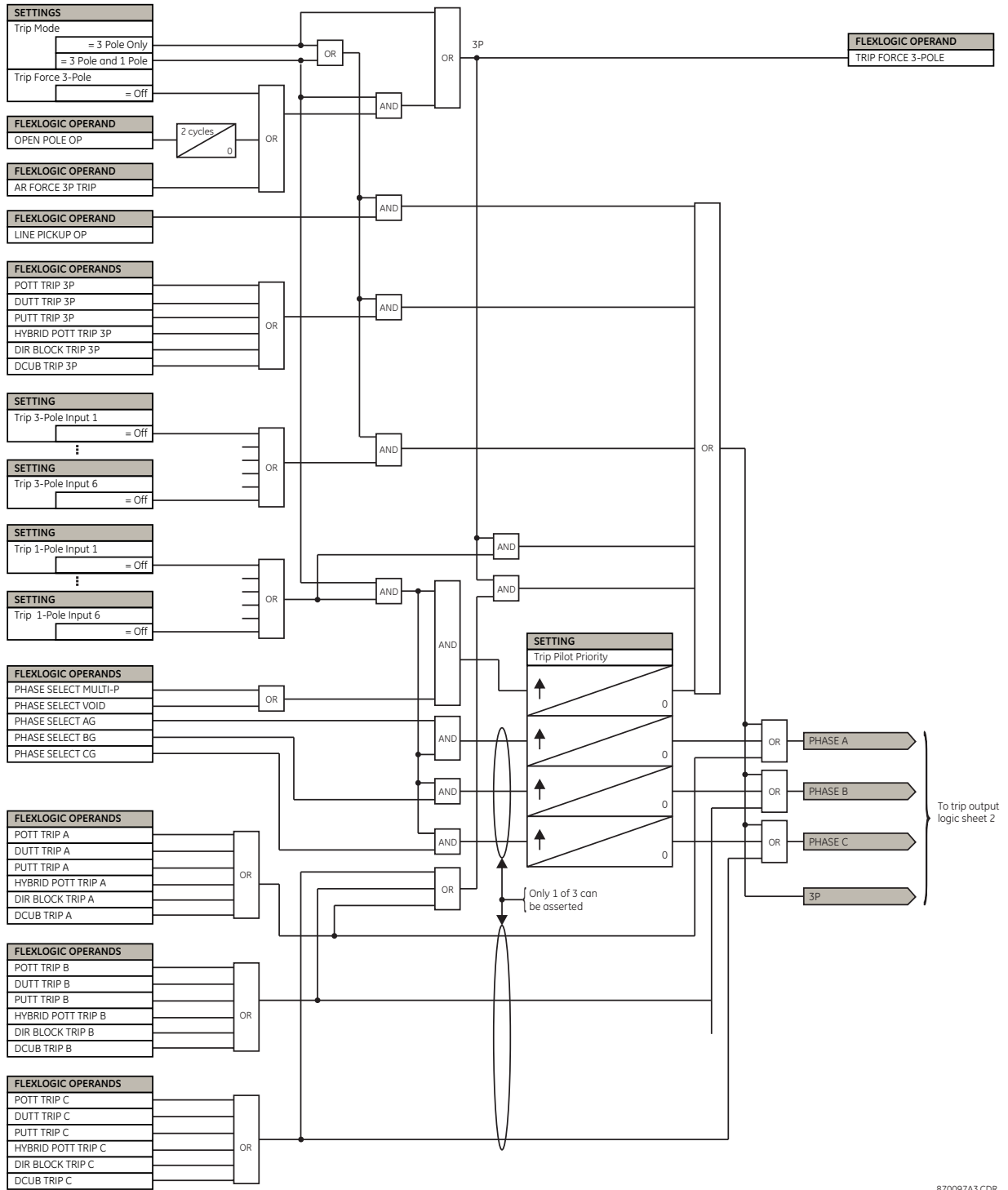
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of trip output events in the sequence of events recorder.

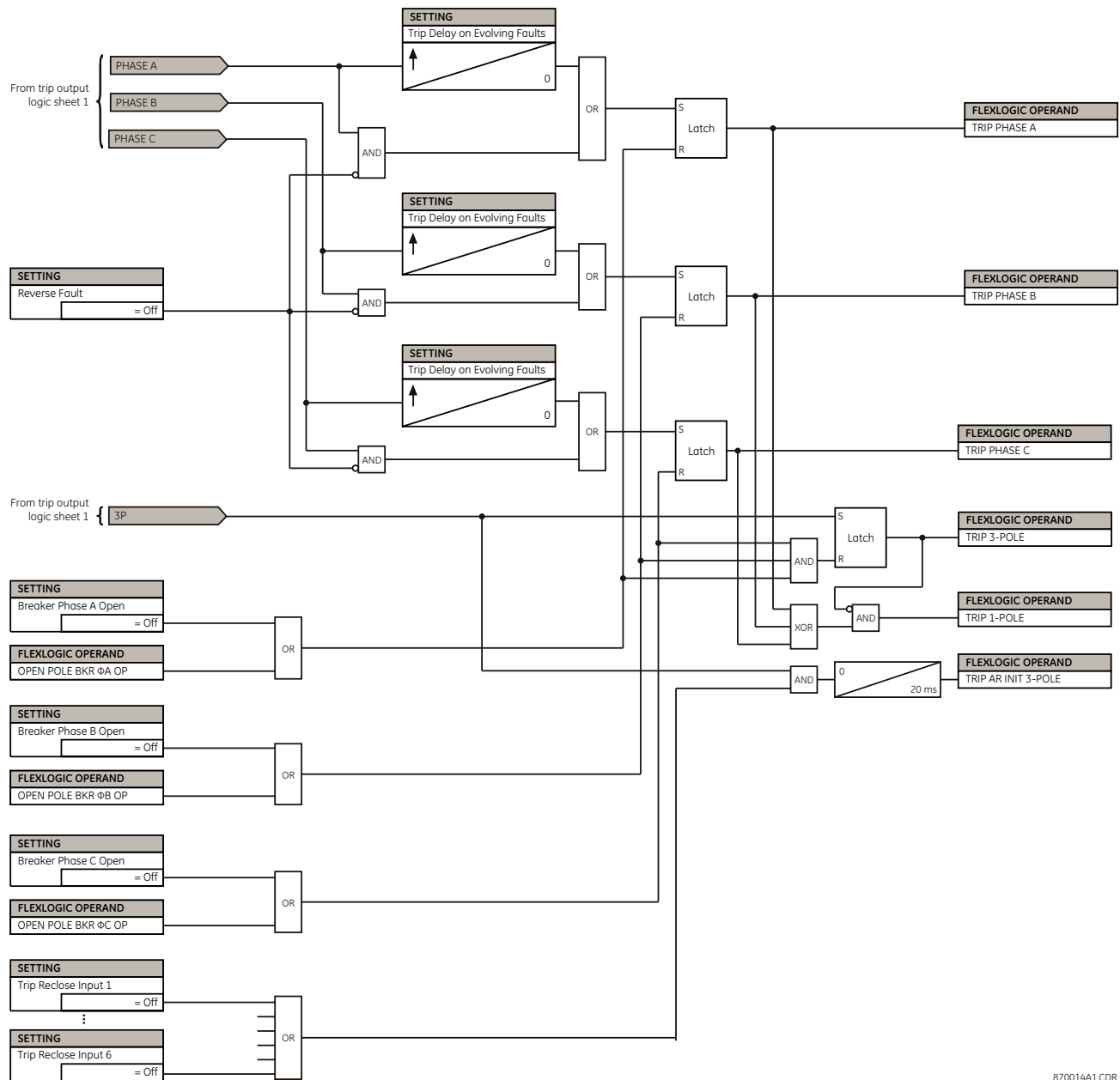
The figure shows trip output scheme logic.

Figure 268: Trip output logic, sheet 1 of 2



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Figure 269: Trip output logic, sheet 2 of 2



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FlexMatrix

The FlexMatrix™ allows up to 16 inputs to be aggregated and conditioned for tripping or auxiliary functions. Up to eight output signals can be derived from the input signals. Outputs can be configured for latching (lockout) and can also have a programmable pickup and dropout delay.

In a typical application, the FlexLogic operands from protection functions are assigned as inputs to the FlexMatrix. Each output can be assigned to a specific task, such as tripping the breaker or blocking a protection element.

FlexMatrix inputs

Select the **Settings > Protection > Control > FlexMatrix > FlexMatrix Inputs** menu to access the FlexMatrix input settings.

Figure 270: FlexMatrix input configuration settings

SETTING	PARAMETER
Input 1	OFF
Input 2	OFF
Input 3	OFF
Input 4	OFF
Input 5	OFF
Input 6	OFF
Input 7	OFF
Input 8	OFF
Input 9	OFF
Input 10	OFF
Input 11	OFF
Input 12	OFF
Input 13	OFF
Input 14	OFF
Input 15	OFF
Input 16	OFF

The following setting is available for each of the 16 FlexMatrix inputs.

Input 1, Input 2, ..., Input 16

Range: any FlexLogic operand or shared operand

Default: OFF

The operand assigned to this setting can be re-assigned to any or all of the FlexMatrix outputs.

FlexMatrix configuration

Select the **Settings > Protection > Control > FlexMatrix > FlexMatrix** menu to access the FlexMatrix configuration settings.

Figure 271: FlexMatrix configuration settings

PARAMETER	FLEX MATRIX 1	FLEX MATRIX 2	FLEX MATRIX 3
Function	Disabled	Disabled	Disabled
Name	Flexmat 1	Flexmat 2	Flexmat 3
Input 1 Enable	Disabled	Disabled	Disabled
Input 2 Enable	Disabled	Disabled	Disabled
Input 3 Enable	Disabled	Disabled	Disabled
Input 4 Enable	Disabled	Disabled	Disabled
Input 5 Enable	Disabled	Disabled	Disabled
Input 6 Enable	Disabled	Disabled	Disabled
Input 7 Enable	Disabled	Disabled	Disabled
Input 8 Enable	Disabled	Disabled	Disabled
Input 9 Enable	Disabled	Disabled	Disabled
Input 10 Enable	Disabled	Disabled	Disabled
Input 11 Enable	Disabled	Disabled	Disabled
Input 12 Enable	Disabled	Disabled	Disabled
Input 13 Enable	Disabled	Disabled	Disabled
Input 14 Enable	Disabled	Disabled	Disabled
Input 15 Enable	Disabled	Disabled	Disabled
Input 16 Enable	Disabled	Disabled	Disabled
Block	OFF	OFF	OFF
Pickup Delay	0.000	0.000	0.000
Dropout Delay	0.000	0.000	0.000
Latching	Disabled	Disabled	Disabled
Reset	OFF	OFF	OFF
Events	Enabled	Enabled	Enabled

The following settings are available for each of the eight FlexMatrix elements.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables or disables the FlexMatrix element.

Name

Range: 12 alphanumeric characters

Default: Flexmat 1

This setting specifies the name associated with a particular FlexMatrix element.

Input 1 Enable, Input 2 Enable,..., Input 16 Enable

Range: Enabled, Disabled

Default: Disabled

These settings enable and disable the 16 FlexMatrix inputs for each FlexMatrix. These inputs can be assigned FlexLogic operands or shared operands, which can then be assigned to any or all of the FlexMatrix outputs.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the FlexMatrix element.

Pickup Delay

Range: 0.000 to 60.000 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies the delay by which to extend the FlexMatrix pickup.

The VT fuse failure detector can be used to raise an alarm or block elements that can operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that can be blocked (via the Block setting) include voltage restrained overcurrent and directional current.

There are two classes of fuse failure that can occur, as follows:

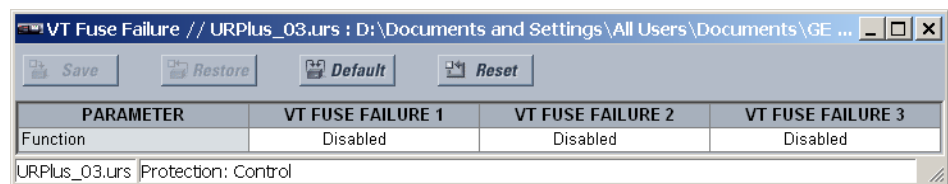
- Class A — Loss of one or two phases
- Class B — Loss of all three phases

Different means of detection are required for each class. An indication of class A failures is a significant level of negative-sequence voltage, whereas an indication of class B failures is when positive-sequence current is present and there is an insignificant amount of positive-sequence voltage. These noted indications of fuse failure can also be present when faults are present on the system, so a means of detecting faults and inhibiting fuse failure declarations during these events is provided. Once the fuse failure condition is declared, it is sealed-in until the cause that generated it disappears.

An additional condition is introduced to inhibit a fuse failure declaration when the monitored circuit is de-energized; positive-sequence voltage and current are both below threshold levels.

Select the **Settings > Protection > Control > VT Fuse Failure** menu to access the VT fuse failure settings.

Figure 273: VT fuse failure configuration settings



The following setting is available for each VT fuse failure element.

Function

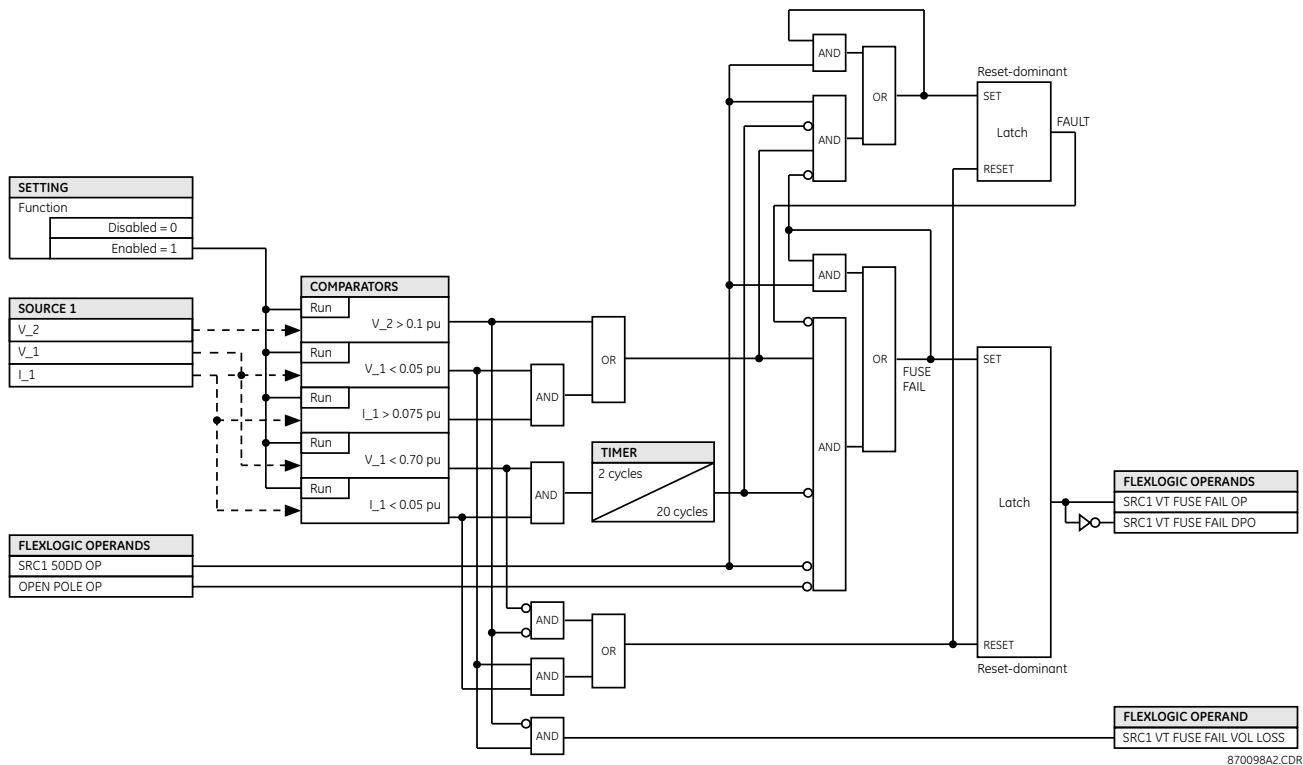
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the fuse failure feature for each source.

The figure shows the VT fuse failure logic.

Figure 274: VT fuse failure logic



Open pole detector

The open pole detector identifies an open pole of the line circuit breaker. It monitors the breaker's auxiliary contacts, current in the circuit, and voltage (optional) on the line. The scheme generates output operands used to block the phase selector and some specific protection elements, thus preventing maloperation during the dead time of a single pole autoreclose cycle or any other open pole conditions.

The scheme declares an open pole at the moment a single-pole trip is issued.

In two-breaker and breaker-and-a-half applications, an open pole condition is declared when any of the following occur:

- Both breakers have an open pole on the same phase
- The current on the line drops below a threshold
- The current and voltage on the line drop below a threshold

The open pole feature uses signals defined by the breaker control, distance, and trip output features. Voltage supervision can be used only with wye VTs on the line-side of the breakers.

For convenience, the position of the breaker poles defined in the breaker control feature and available as FlexLogic operands [BREAKER 1 ?A CLSD](#) through [BREAKER 1 ?C CLSD](#) and [BREAKER 1 OOS](#) are used by the open pole feature (these operands are also available for breaker 2). For correct operation of the open pole detector, the breaker control, trip output, and single-pole autoreclose features must be enabled and properly configured. When used in configuration with only one breaker, enable breaker 2 and set the breaker 2 **Out of Service** setting to "On."

Select the **Settings > Protection > Control > Open Pole** menu to access the open pole detector settings.

Figure 275: Open pole detector configuration settings

SETTING	PARAMETER
Function	Disabled
Block	OFF
Voltage Supervision	Disabled
Current Pickup	0.050 pu
Open Pole Line XC1	9999.9 ohms
Open Pole Line XCO	9999.9 ohms
Remote Current Pickup	0.050 pu
Events	Disabled

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the open pole detector feature.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the open pole detector element.

Voltage Supervision

Range: Disabled, Enabled

Default: Disabled

If this setting is enabled, an open pole condition is declared when the current in a particular phase is less than its pickup setting and the voltage of the same phase is less than or equal to 0.7 pu.

Current Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting specifies the current threshold below which an open pole is declared.

Open Pole Line XC1

Range: 300.0 to 9999.9 ohms in steps of 0.001

Default: 9999.9 ohms

This setting specifies the positive-sequence reactance of the entire line. If shunt reactors are applied, make this value the net capacitive reactance of the line and the reactors installed between the line breakers. Enter the value in secondary ohms. This setting is relevant if the open pole condition at the remote end of the line is to be sensed and utilized by the relay.

Open Pole Line XCO

Range: 300.0 to 9999.9 ohms in steps of 0.001

Default: 9999.9 ohms

This setting specifies the zero-sequence reactance of the entire line. If shunt reactors are applied, make this value the net capacitive reactance of the line and the reactors installed between the line breakers. Enter the value in secondary ohms. This setting is relevant if the open pole condition at the remote end of the line is to be sensed and utilized by the relay (via the [OPEN POLE REM OP](#) operand).

Open Pole Remote Current Pickup

Range: 0.000 to 30.000 pu in steps of 0.001

Default: 0.050 pu

This setting specifies the pickup level for the remote-end current estimated by the relay as the local current compensated by the calculated charging current. The latter is calculated based on the local voltages and the capacitive reactances of the line. This setting is relevant if the open pole condition at the remote end of the line is to be sensed and utilized by the relay (via the OPEN POLE REM OP operand).

Events

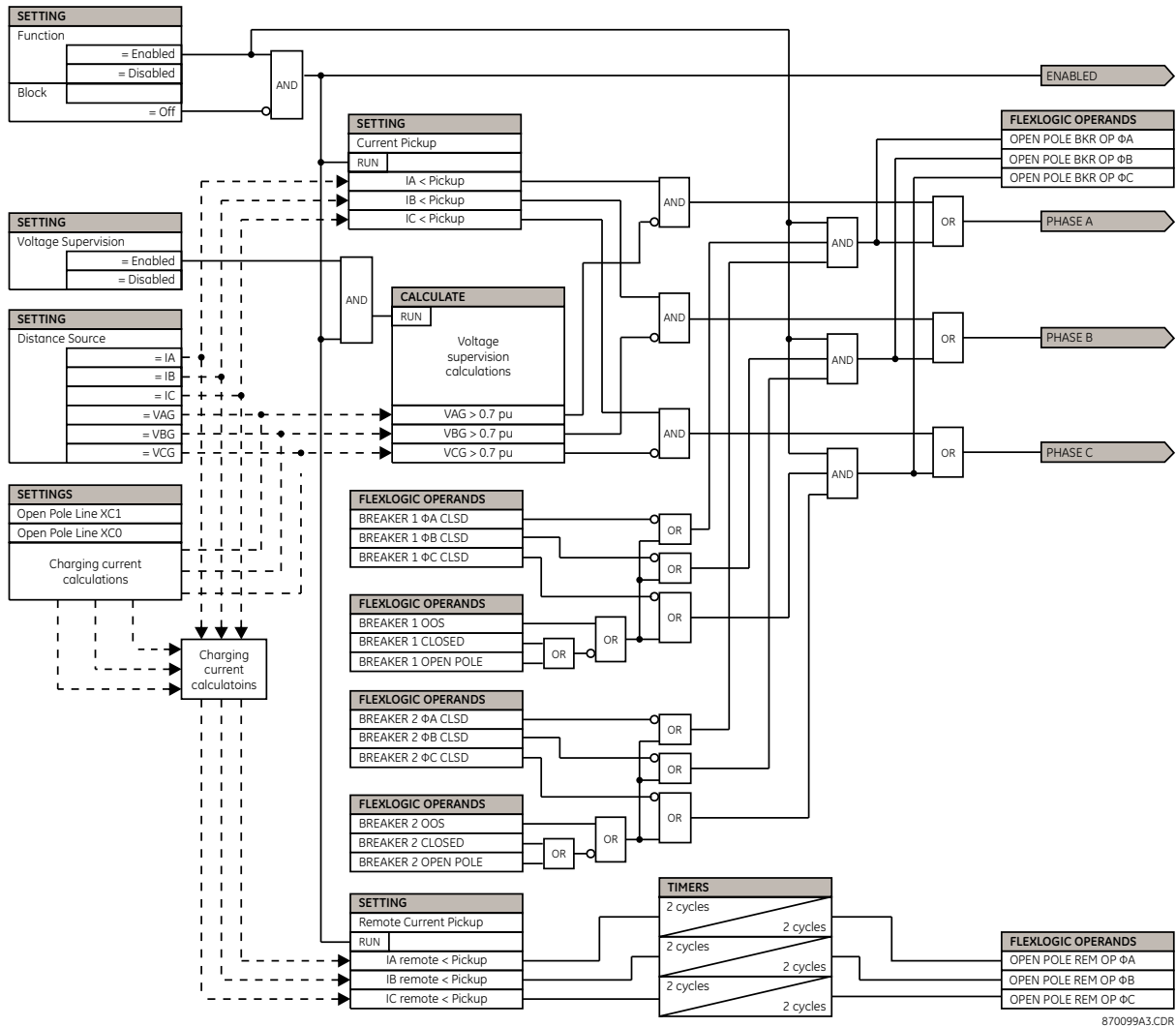
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of open pole detector events in the sequence of events recorder.

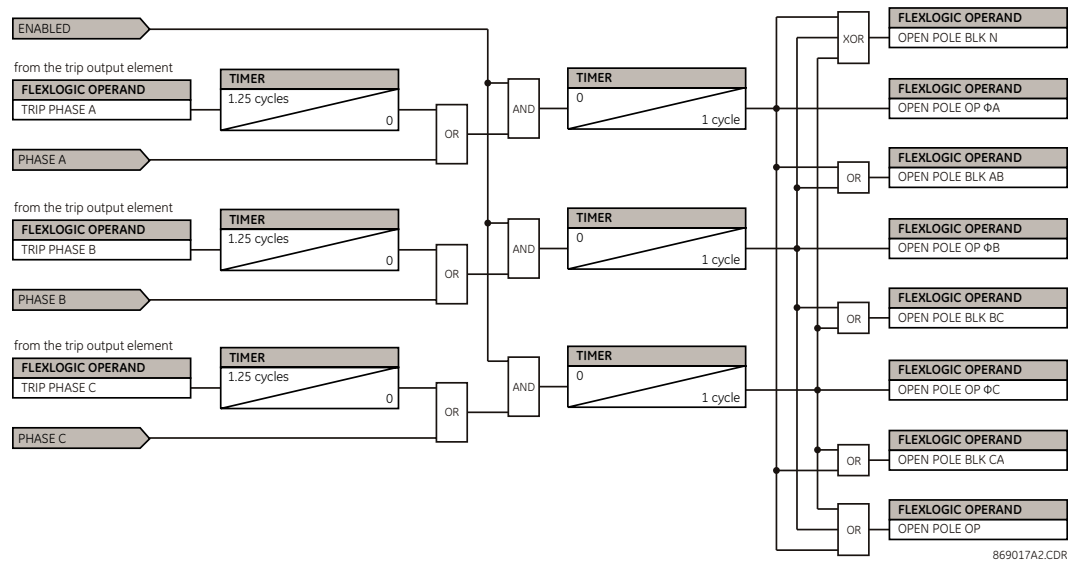
The figures show open pole detector logic.

Figure 276: Open pole detector logic, sheet 1 of 2



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Figure 277: Open pole detector logic, sheet 2 of 2



Autoreclose

The autoreclose scheme is for use on transmission lines with circuit breakers operated in both the single-pole and three-pole modes, in one or two breaker arrangements. The autoreclose scheme provides four programs with different operating cycles, depending on the fault type. Each of the four programs can be set to trigger up to four reclosing attempts. The second, third, and fourth attempts always perform three-pole reclosing and have independent dead time delays.

When used in two breaker applications, the reclosing sequence is selectable. The reclose signal can be sent to one selected breaker only, to both breakers simultaneously or to both breakers in sequence (one breaker first and then, after a delay to check that the reclose was successful, to the second breaker). When reclosing in sequence, the first breaker recloses with either the single-pole or three-pole dead time according to the fault type and reclose mode; the second breaker follows the successful reclosure of the first breaker. When reclosing simultaneously, for the first shot both breakers reclose with either the single-pole or three-pole dead time, according to the fault type and the reclose mode.

The autoreclose function differs from that implemented in the UR series and needs to be enabled. Do this setup on the front panel or using the software.

The signal used to initiate the autoreclose scheme is the trip output from protection. This signal can be single-pole tripping for single-phase faults and three phase tripping for multiphase faults. The autoreclose scheme has five operating states.

Table 18: Autoreclose operating states

State	Characteristics
Enabled	Scheme is permitted to operate
Disabled	Scheme is not permitted to operate
Reset	Scheme is permitted to operate and shot count is reset to 0
Reclose in progress	Scheme has been initiated but the reclose cycle is not finished (successful or not)
Lockout	Scheme is not permitted to operate until reset received

Autoreclose programs

The autorecloser provides four programs that can cause from one to four reclose attempts (shots). After the first shot, all subsequent reclosings are always three-pole. If the maximum number of shots selected is 1 (only one reclose attempt) and the fault is persistent, after the first reclose the scheme goes to lockout upon another initiate signal.

For the three-pole reclose programs (the “3 Pole-A” and “3 Pole-B” mode values), an **AR FORCE 3-P** FlexLogic operand is set. This operand can be used in connection with the tripping logic to cause a three-pole trip for single-phase faults.

Table 19: Autoreclose programs

Mode setting	First shot		Second shot		Third shot		Fourth shot	
	Single-phase fault	Multi-phase fault	Single-phase fault	Multi-phase fault	Single-phase fault	Multi-phase fault	Single-phase fault	Multi-phase fault
“1 & 3 Pole”	1 POLE	3 POLE	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT
“1 Pole”	1 POLE	LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT
“3 Pole-A”	3 POLE	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT	3 POLE or LOCKOUT	LOCKOUT
“3 Pole-B”	3 POLE	3 POLE	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT	3 POLE or LOCKOUT

In the “1 & 3 Pole” mode, the autorecloser starts the **1-P Dead Time** timer for the first shot if the autoreclose is single-phase initiated, the **3-P Dead Time 1** timer if the autoreclose is three-pole initiated, and the **3-P Dead Time 2** timer if the autoreclose is three-phase time delay initiated. If two or more shots are enabled, the second, third, and fourth shots are always three-pole and start the **3-P Dead Time 2** through **3-P Dead Time 4** timers.

In the “1 Pole” mode, the autorecloser starts the **1-P Dead Time** for the first shot if the fault is single-phase. If the fault is three-phase or a three-pole trip on the breaker occurred during the single-pole initiation, the scheme goes to lockout without reclosing. If two or more shots are enabled, the second, third, and fourth shots are always three-pole and start the **3-P Dead Time 2** through **3-P Dead Time 4** timers.

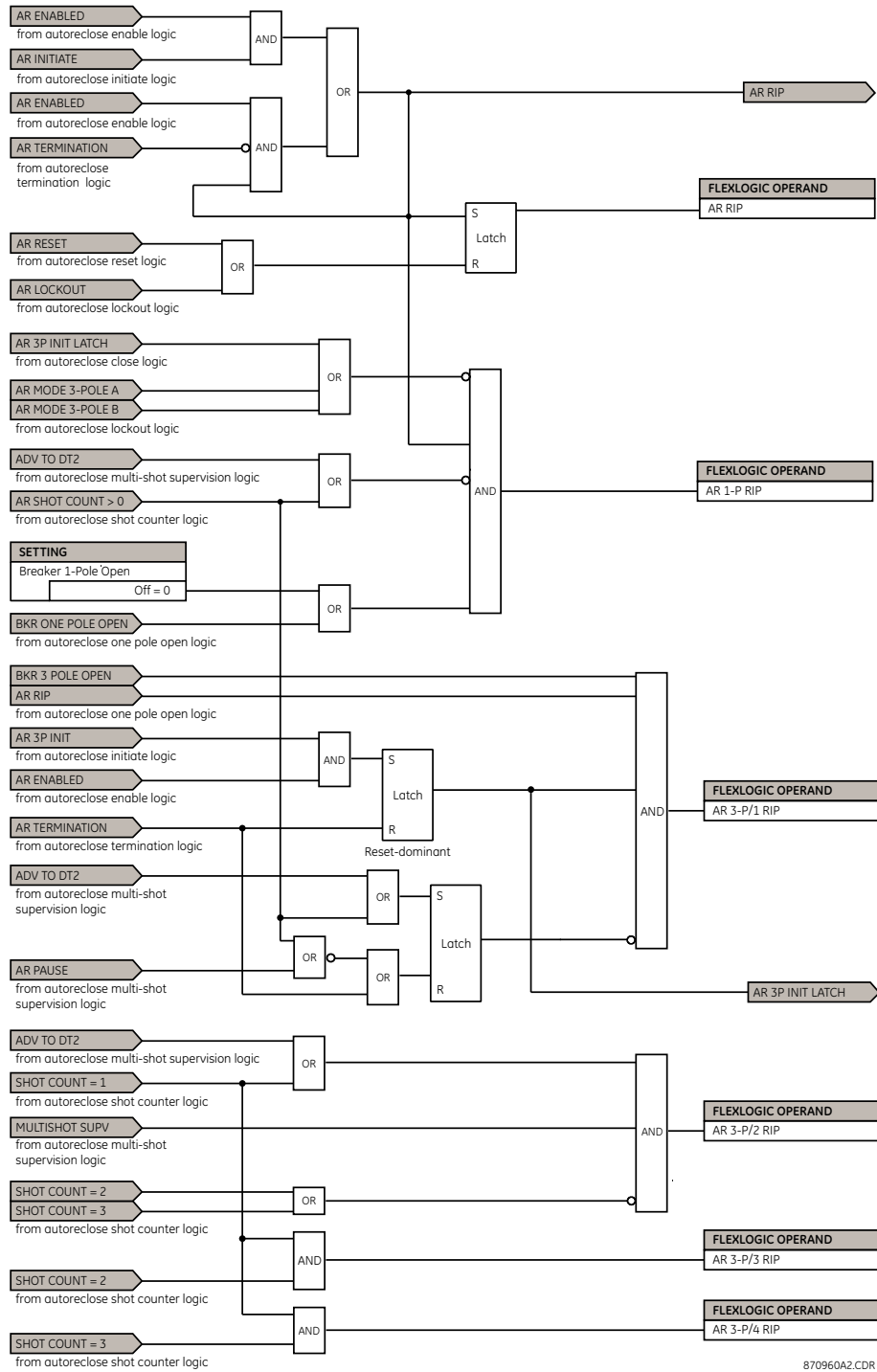
In the “3 Pole-A” mode, the autorecloser is initiated only for single-phase faults, although the trip is three-pole. The autorecloser uses the **3-P Dead Time 1** for the first shot if the fault is single-phase. If the fault is multi-phase the scheme goes to lockout without reclosing. If two or more shots are enabled, the second, third, and fourth shots are always three-phase and start the **3-P Dead Time 2** through **3-P Dead Time 4** timers.

In the “3 Pole-B” mode, the autorecloser is initiated for any type of fault and starts the **3-P Dead Time 1** for the first shot. If the initiating signal is **AR 3P TD INIT**, the scheme starts the **3-P Dead Time 2** for the first shot. If two or more shots are enabled, the second, third, and fourth shots are always three-phase and start the **3-P Dead Time 2** through **3-P Dead Time 4** timers.

Basic reclosing operation

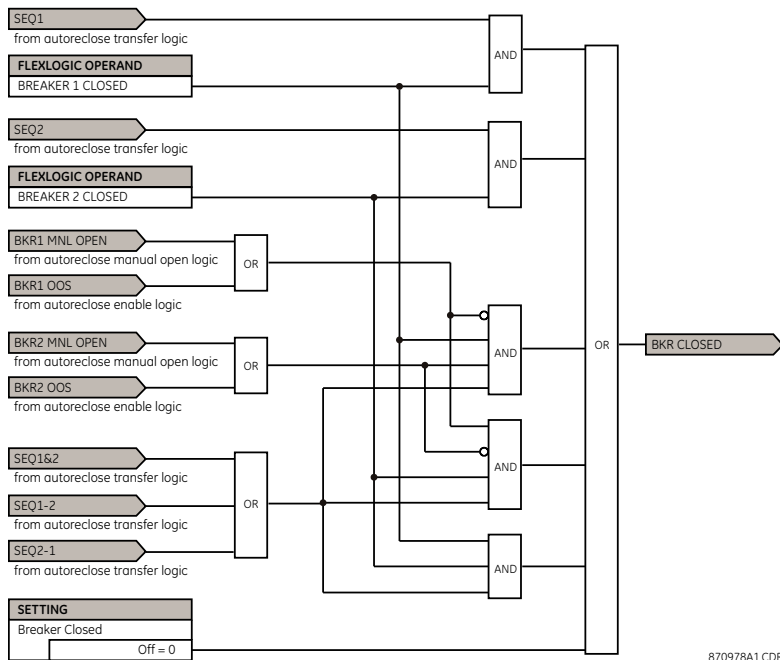
Reclosing is enabled via settings and dynamically disabled from a line pickup operation, a block signal, or a manual close. Once enabled, a reclose is initiated from the trip output scheme or through the **1-Pole Initiate** and **3-Pole Initiate** user-programmable inputs. There are three initiate programs: single-pole initiate, three-pole initiate, and three-pole time delay initiate. Any of these reclose initiate signals start the reclose cycle and set the reclose-in-progress (**AR RIP**) operand. The reclose-in-progress operand is sealed-in until the lockout or reset signal appears.

Figure 280: Autoreclose reclose-in-progress logic



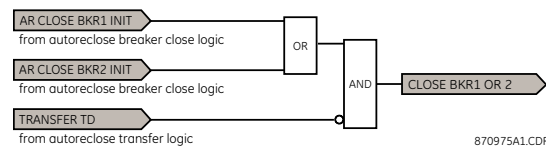
After entering the reclose-in-progress state, a close command is issued after the dead time delay. The dead time for the initial reclose operation is determined by either the **1-P Dead Time**, **3-P Dead Time 1**, or **3-P Dead Time 2** setting, depending on the fault type and the mode selected. After the dead time interval, the scheme asserts the **AR CLOSE BKR 1** or **AR CLOSE BKR 2** operands, as determined by the sequence selected. These operands are latched until the breaker closes or the scheme goes to reset or lockout.

Figure 281: Autoreclose breaker close logic



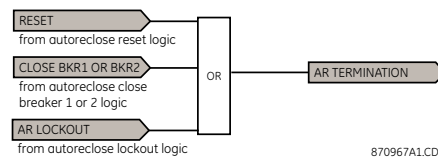
870978A1.CDR

Figure 282: Autoreclose close breaker 1 or 2 logic



870975A1.CDR

Figure 283: Autoreclose termination logic



870967A1.CDR

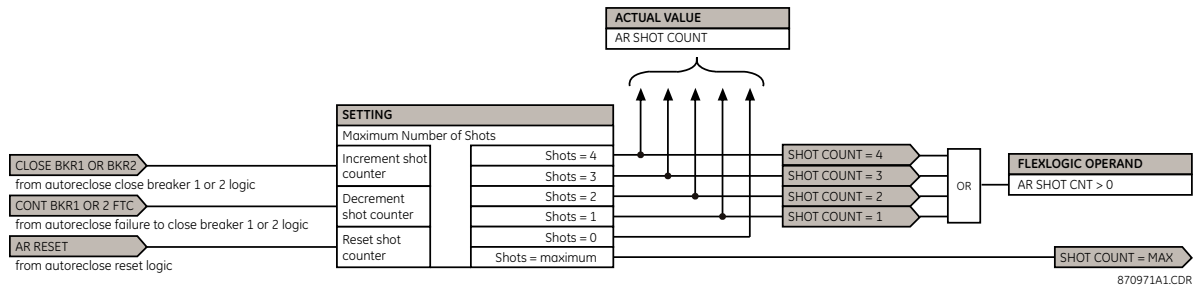
Multi-shot operation

The **Maximum Number of Shots** setting defines the number of reclose attempts. After each reclose, the shot counter increments.

If **Maximum Number of Shots** is set to "1," the shot counter is set to 1 upon the first reclose. At reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the **AR SHOT COUNT >0** operand that sets the **AR FORCE 3P** operand. Because the shot counter has reached the maximum number of shots permitted, the scheme is sent to the lockout state.

If **Maximum Number of Shots** is set to "2," the shot counter is set to 1 upon the first reclose. At reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the **AR SHOT COUNT >0** operand that sets the **AR FORCE 3P** operand. After the second reclose, the shot counter is set to 2. Upon reclosing, the fault is again detected by protection, the breaker is tripped three-pole, and reclose is initiated again. Because the shot counter has reached the maximum number of shots permitted, the scheme is sent to the lockout state.

Figure 284: Autoreclose shot counter logic

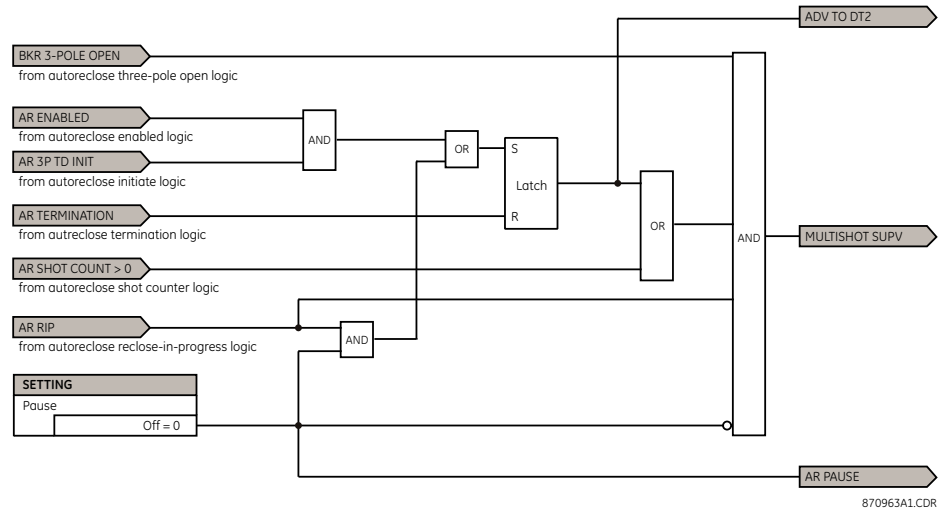


Autoreclose pause input

The autoreclose pause input offers the possibility of freezing the autoreclose cycle until the pause signal disappears. This can be done when a trip occurs and simultaneously or previously, some conditions are detected such as out-of step or loss of guard frequency, or a remote transfer trip signal is received. The pause signal blocks all three dead timers. When the pause signal disappears, the autoreclose cycle is resumed by initiating the **AR 3-P DEAD TIME 2** operand.

This feature can be also used when a transformer is tapped from the protected line and a reclose is not wanted until the transformer is removed from the line. In this case, the reclose scheme is paused until the transformer is disconnected. The **AR PAUSE** input forces a three-pole trip through the **3-P Dead Time 2** path.

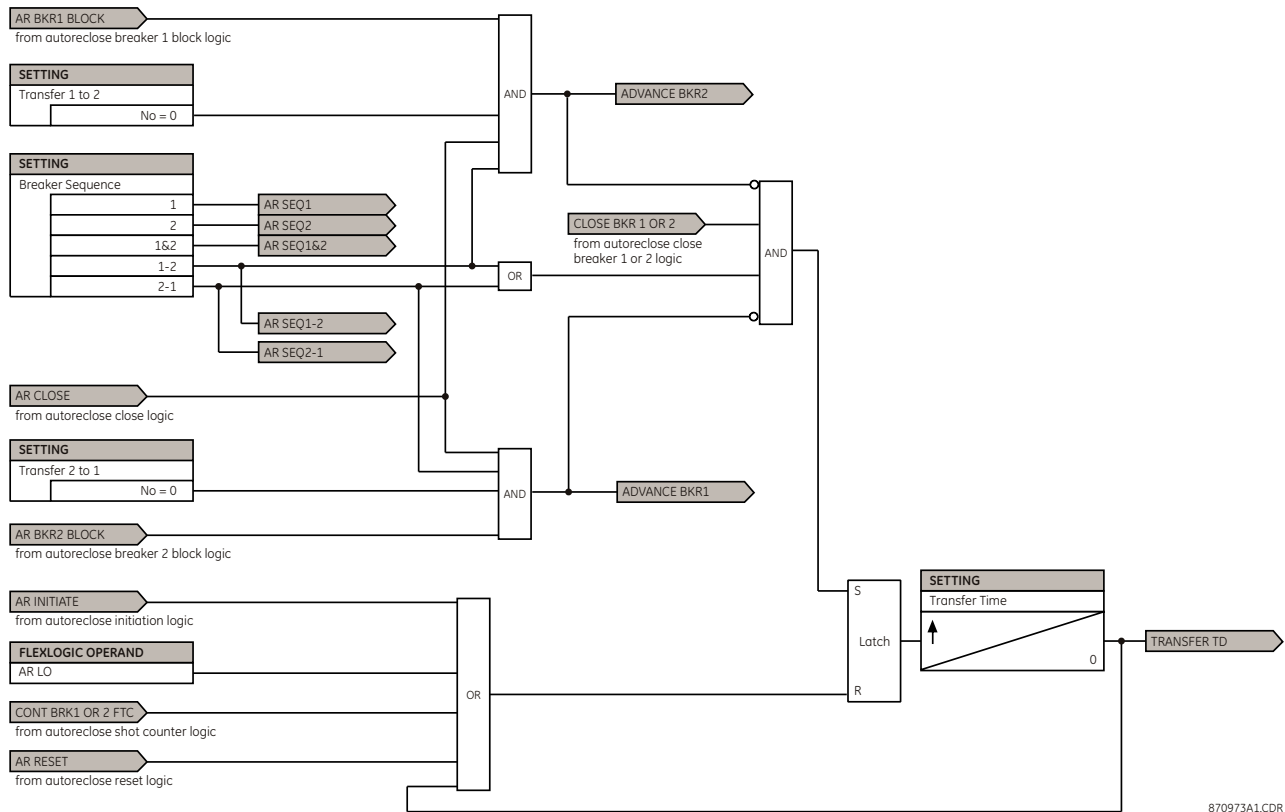
Figure 285: Autoreclose multi-shot supervision logic



Dual breaker operation

The operation for two-breaker reclosing on a permanent fault is the same as that outlined for the single-breaker application, except as follows, which assumes the **Breaker Sequence** setting is "1-2" (reclose breaker 1 before breaker 2). The signal output from the dead time timers passes through the breaker selection logic to initiate reclosing of breaker 1. The CLOSE BREAKER 1 signal initiates the transfer timer. After the reclose of the first breaker, the fault is again detected by the protection, the breaker is tripped three-pole, and the autoreclose scheme is initiated. The INITIATE signal stops the transfer timer. After the three-pole dead time times out, the CLOSE BREAKER 1 signal closes the first breaker again and starts the transfer timer. Since the fault is permanent, the protection trips again and initiates the autoreclose scheme that is sent to lockout by the SHOT COUNT = MAX signal.

Figure 286: Autoreclose transfer logic



When the 1-2 reclosing sequence is selected and breaker 1 is blocked (the **AR BKR1 BLK** operand is set), the reclose signal can be transferred direct to breaker 2 when the **Transfer 1 to 2** setting is “Yes.” When the setting is “No,” the scheme is sent to lockout by the incomplete sequence timer.

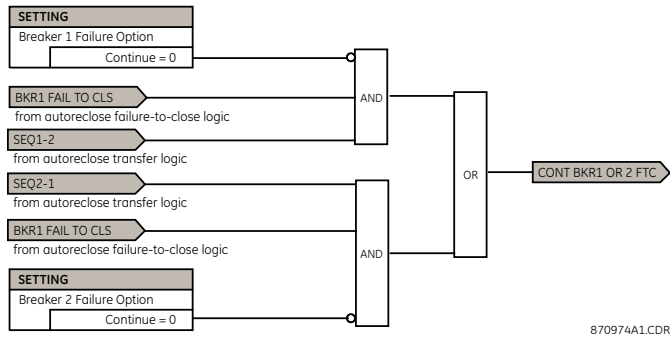
When the 2-1 reclosing sequence is selected and breaker 2 is blocked (the **AR BKR2 BLK** operand is set), the reclose signal can be transferred direct to breaker 1 when the **Transfer 2 to 1** setting is “Yes.” If set to “No,” the scheme is sent to lockout by the incomplete sequence timer or if it is out-of-service or open prior to the reclose-in-progress. In this case, the scheme can be configured to transfer close command immediately to the second breaker via the **Transfer 1 to 2** and **Transfer 2 to 1** settings.

For two-breaker reclosing on a transient fault, the reset timer is started when the first reclose output signal is sent to close breaker 1. The **CLOSE BREAKER 1** signal initiates the transfer timer that times out and sends the close signal to the second breaker. If the reclosure sequence is successful (both breakers closed and there is no initiating signal), the reset timer times out and returns the scheme to the reset state with the shot counter set to 0. The scheme is now ready for a new reclose cycle.

A typical reclosing sequence for the “1 & 3 Pole” mode is shown below for a single-pole fault, two shots, with successful reclosure. The following two options are available if the selected breaker sequence is “1-2” or “2-1,” and the breaker fails to close after the first or second reclose attempt:

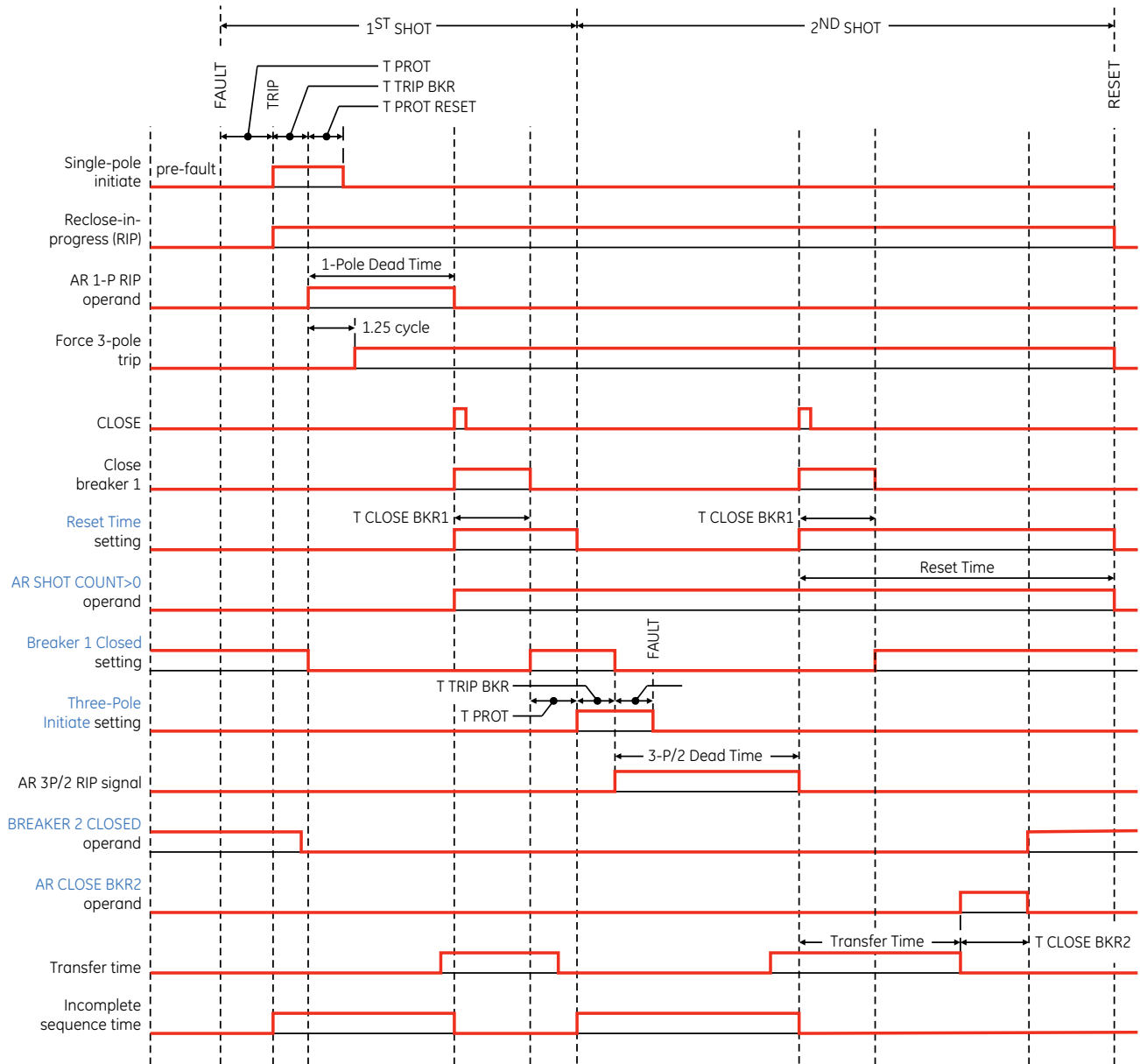
- When the **Breaker 1 Failure Option** or **Breaker 2 Failure Option** is set to “Lockout,” the scheme goes to lockout state.
- When the **Breaker 1 Failure Option** or **Breaker 2 Failure Option** is set to “Continue,” the reclose process continues with breaker 2. At the same time, the shot counter is decreased (since the closing process was not completed).

Figure 287: Autoreclose failure-to-close logic



870974A1.CDR

Figure 288: Typical autoreclose sequence

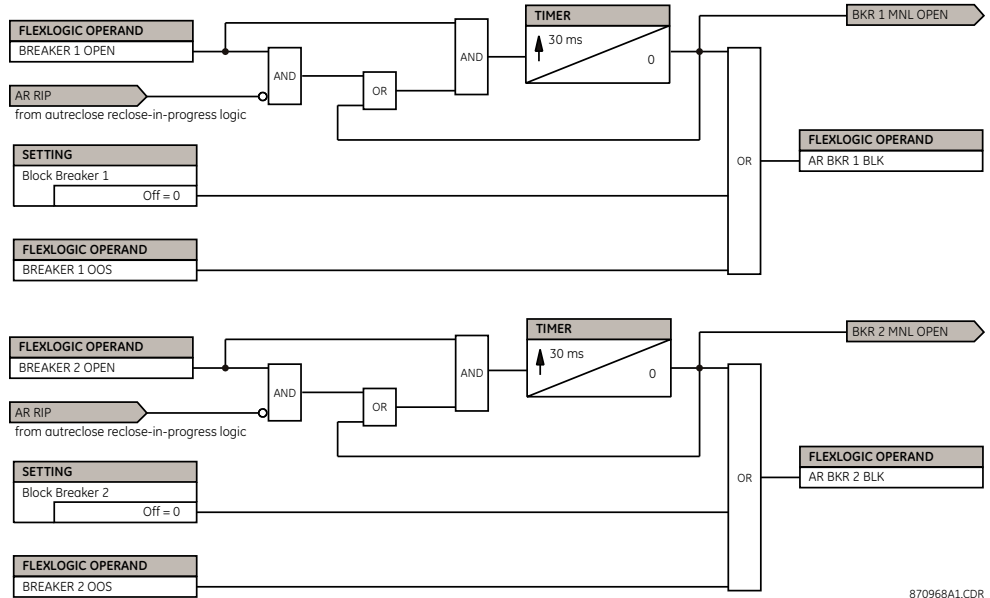


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Breaker block

A reclose command to a breaker is inhibited if it receives a user-defined block input or if it is out-of-service. A logic circuit also is provided that inhibits a breaker reclose if that breaker was open in advance of a reclose initiate input to the recloser. This logic circuit resets when the breaker is closed.

Figure 289: Autoreclose breaker block logic



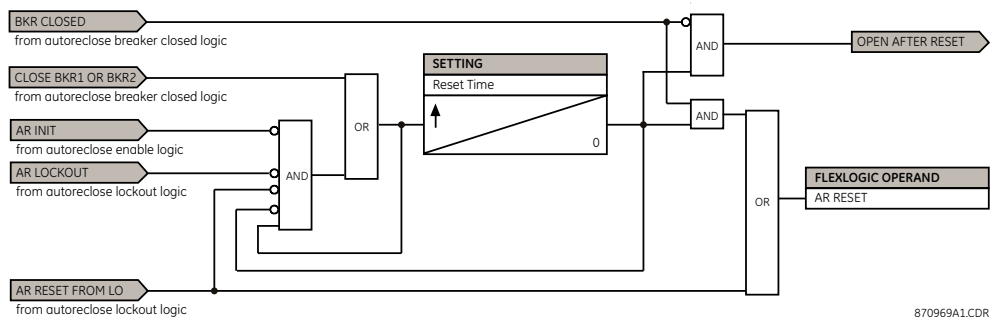
870968A1.CDR

Reset after reclosure

For single-breaker reclosing on a transient fault, the reset timer is started when a reclose output signal is sent to close the breaker. If the reclosure sequence is successful (there is no initiating signal and the breaker is closed) the reset timer times out, returning the scheme to the reset state with the shot counter set to 0 and ready for a new reclose cycle.

In two-breaker schemes, if one breaker is in the out-of-service state and the other is closed at the end of the reset time, the scheme is also reset. If at the end of the reset time at least one breaker, which is not in the out-of-service state, is open the scheme is sent to lockout. The reset timer is stopped if the reclosure sequence is not successful: an initiating signal present or the scheme is in lockout state. The reset timer is also stopped if the breaker is closed manually or the scheme is otherwise reset from lockout.

Figure 290: Autoreclose reset logic



870969A1.CDR

Autoreclose lockout

When a reclose sequence is started by an initiate signal, the autoreclose scheme moves into the reclose-in-progress state and starts the incomplete sequence timer. The setting of this timer determines the maximum time interval allowed for a single reclose shot. If a close breaker 1 or 2 signal is not present before this time expires, the scheme enters the lockout state.

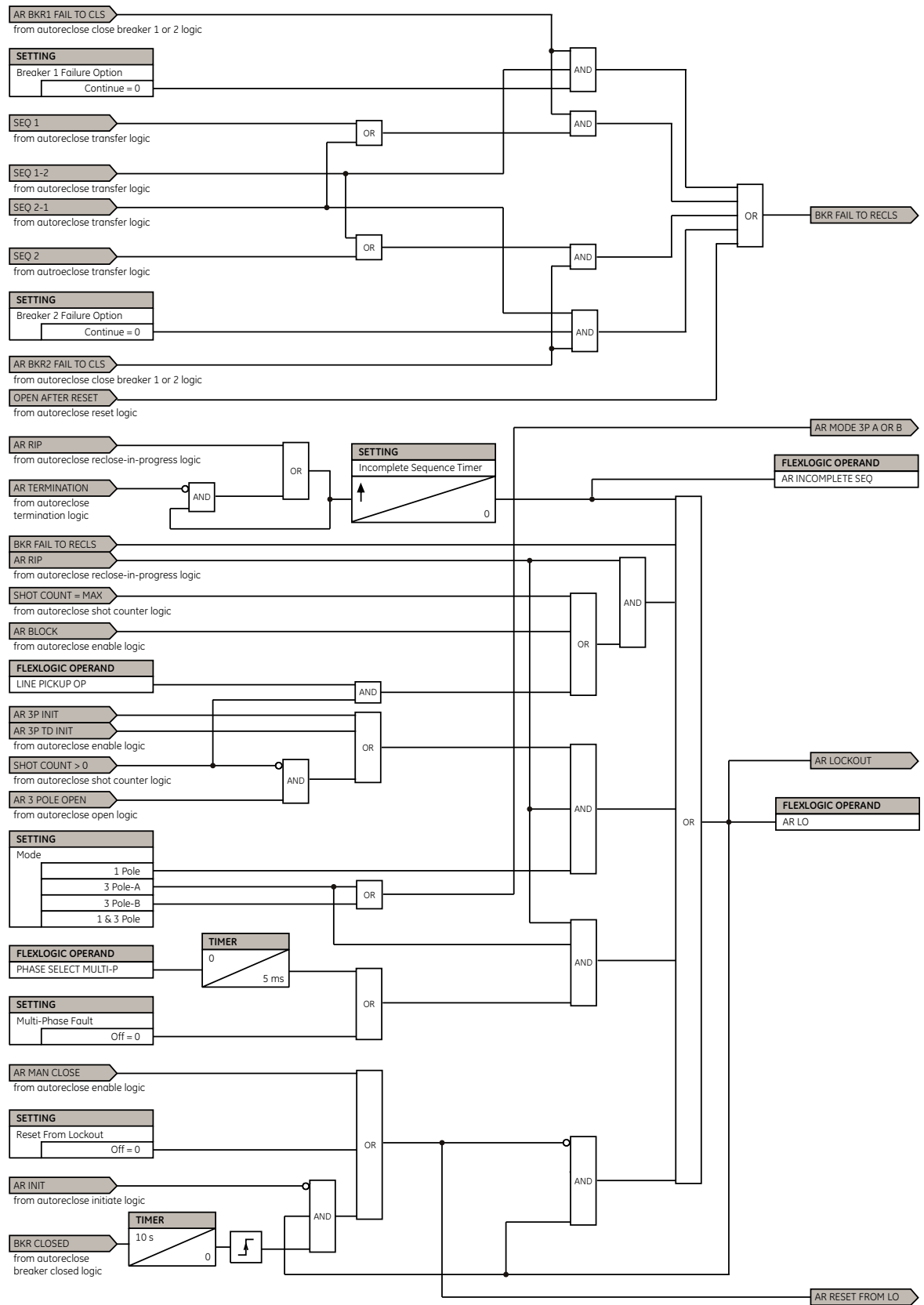
There are four other conditions that can take the scheme to the lockout state, as follows:

- Receipt of the **Block** input while in the reclose-in-progress state
- The reclosing program logic: when a three-phase initiate is present and the autoreclose mode is either "1 Pole" or "3 Pole-A" (three-pole autoreclose for single-pole faults only)
- Initiation of the scheme when the count is at the maximum allowed
- If at the end of the reset time at least one breaker, which is not in the out-of-service state, is open the scheme is sent to lockout. The scheme also is sent to lockout if one breaker fails to reclose and the setting **Breaker Failure Option** setting is "Lockout."

Once the lockout state is set, it remains latched until one or more of the following occurs:

- The scheme is intentionally reset from lockout, employing the **Reset** setting of the autorecloser
- The breaker or breakers are closed manually from the panel switch, SCADA, or other remote control through the **Breaker Manual Close** setting
- Ten seconds after breaker control detects that the breaker or breakers were closed

Figure 291: Autoreclose lockout logic



870964A1.CDR

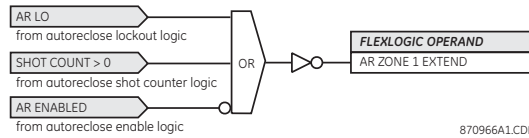
Zone 1 extension in the autoreclose scheme

Two approaches are available for implementation of zone 1 extension. The first method is to operate normally from an under-reaching zone and use an overreaching distance zone when reclosing the line with the other line end open. This method can be programmed via the line pickup scheme.

A second method applies an over-reaching zone as long as the relay is ready to reclose, then blocks this zone when reclosing. The autoreclose scheme provides an **AR ZONE 1 EXTEND** operand that can be used to supervise the over-reaching zone or change to a setting group where zone 1 is over-reaching.

The **AR ZONE 1 EXTEND** operand is set to logic 0 when autoreclose is in lockout or disabled and logic 1 when autoreclose is in reset. When extended zone 1 operand is logic 0, set the distance functions to the normal under-reach zone 1 setting. When extended zone 1 operand is logic 1, the distance functions can be set to the extended zone 1 reach. During a reclose cycle, the **AR ZONE 1 EXTEND** operand goes to logic 0 as soon as the first CLOSE BREAKER signal is issued (**AR SHOT COUNT > 0** operand) and remains at 0 until the recloser returns to reset.

Figure 292: Autoreclose zone 1 extension logic



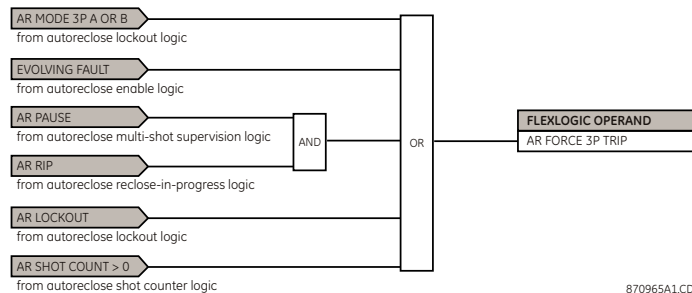
870966A1.CDR

Force three-pole tripping

The reclosing scheme contains logic that is used to signal trip logic that three-pole tripping is required for certain conditions. This signal is activated by any of the following conditions:

- The autoreclose scheme is paused after it was initiated
- The autoreclose scheme is paused
- The autoreclose scheme is in the lockout state
- The autoreclose mode is programmed for three-pole operation
- The shot counter is not at 0; that is, the scheme is not in the reset state. This ensures a second trip is three-pole when reclosing onto a permanent single phase fault.
- 1.25 cycles after the single-pole reclose is initiated by the AR 1P INIT signal

Figure 293: Autoreclose force three-pole trip logic



870965A1.CDR

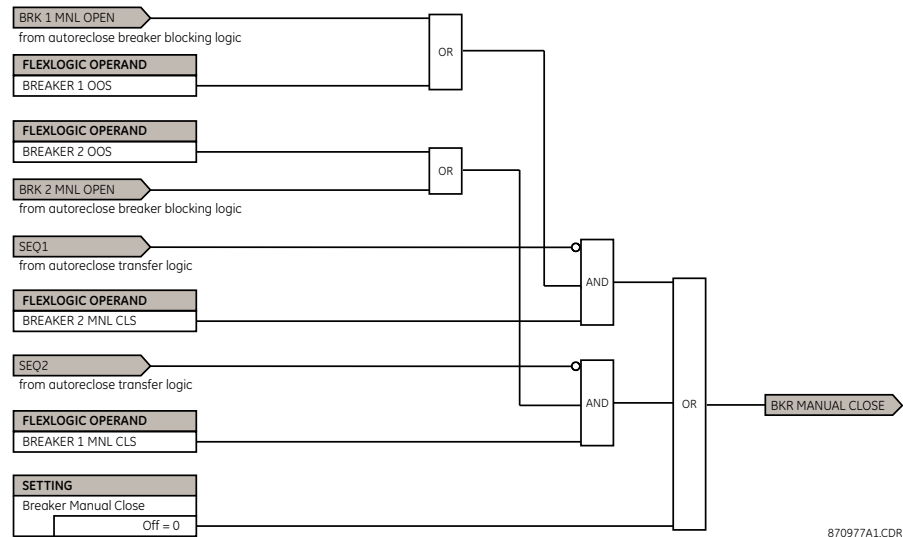
Terminal manual close

The manual close logic receives the manual close signal from each of the breakers and derives a manual close signal for the local terminal. The manual close is declared when

- Breaker 1 issues a manual close signal, sequence 2 is not selected, and breaker 2 is either open or out-of-service

- Breaker 2 issues a manual close signal, sequence 1 is not selected, and breaker 1 is either open or out-of-service
- Alternately, a user-defined setting is available to generate this signal.

Figure 294: Autoreclose manual close logic



Terminal closed

The close logic uses the status of each breaker to determine whether the terminal is closed. For single breaker applications, it is necessary to monitor the closed status of the particular breaker. For dual breaker applications, the logic checks that either or both breakers are closed and not out-of-service. Alternately, a user-defined setting is available to generate this signal.

Figure 295: Autoreclose closing logic, sheet 1 of 2

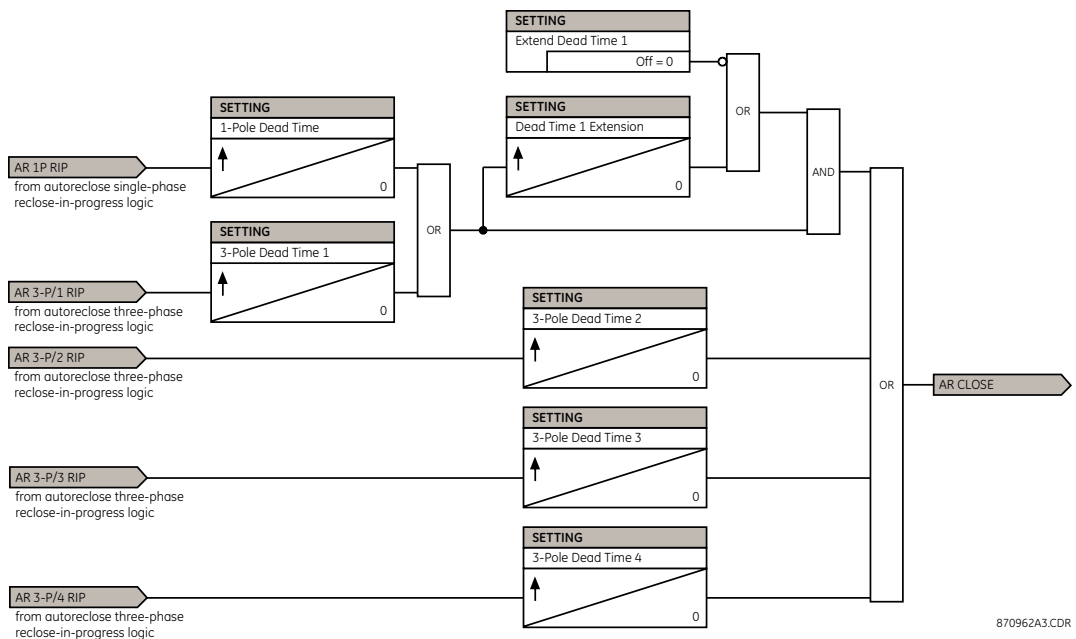
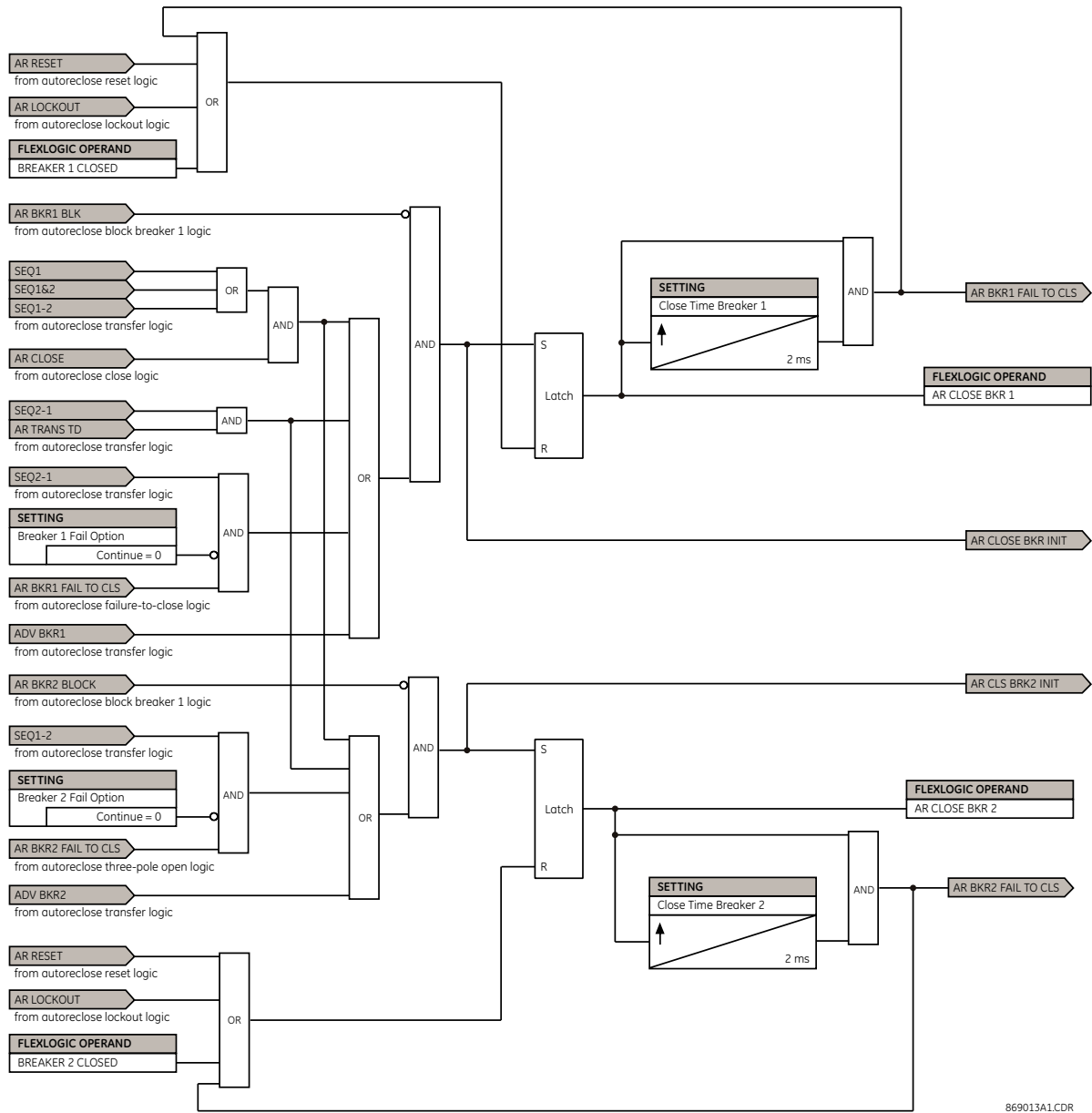


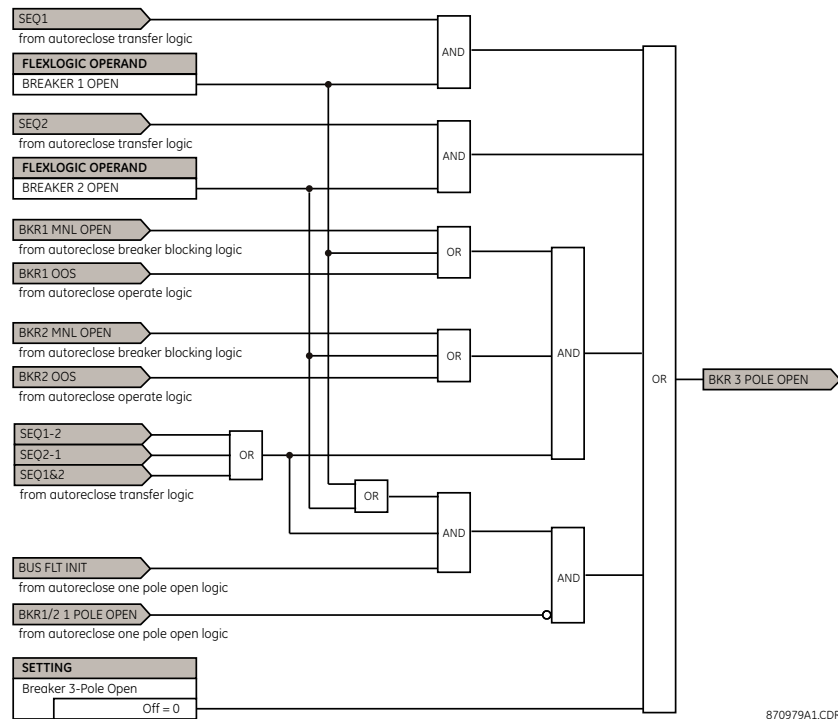
Figure 296: Autoreclose closing logic, sheet 2 of 2



Terminal three-pole open

The autoreclose scheme employs dedicated logic to determine if all three poles are opened at the local terminal. This signal is used in the preceding logic. For single-breaker operation, the breaker status is sufficient to derive this signal. For dual-breaker operation both breakers must either be open or out-of-service. If one breaker has been opened from a bus protection, the **Bus Fault Initiate** setting can be used to declare the terminal opened when either breaker is opened. Alternately, a user-defined setting is available to generate this signal.

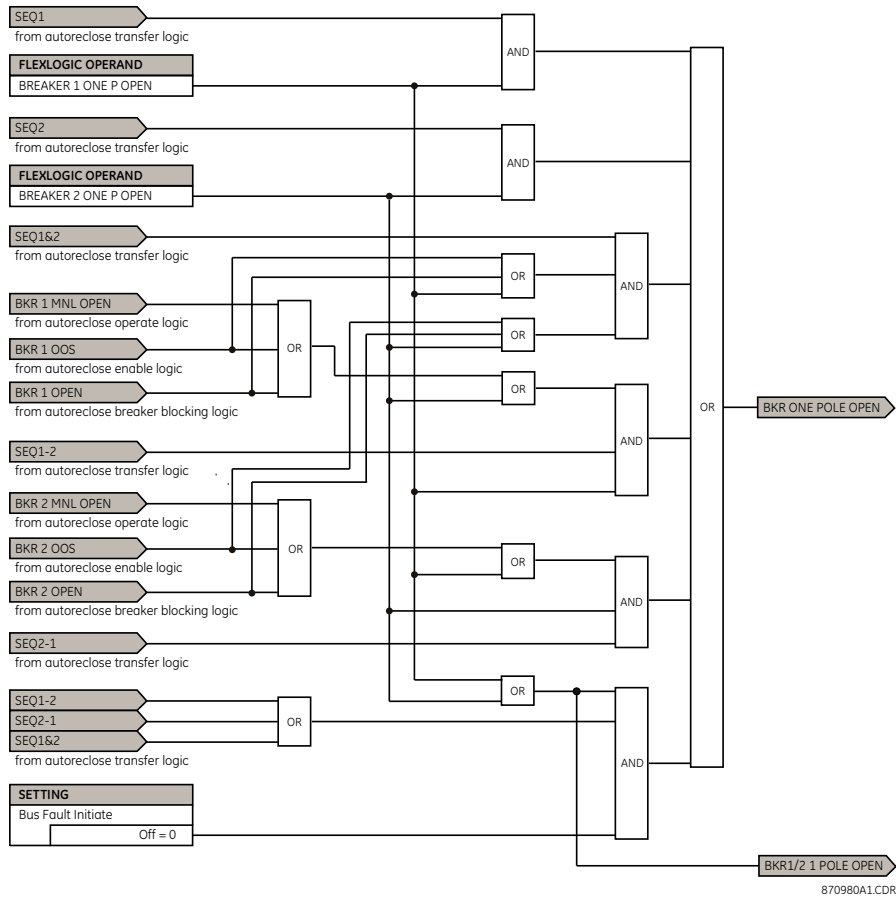
Figure 297: Terminal three-pole open logic



Terminal one-pole open

The autoreclose scheme also has dedicated logic to determine if one pole is opened at the local terminal. For single-breaker operation, the **BREAKER 1 ONE P OPEN** or **BREAKER 2 ONE P OPEN** operand is used to derive this signal. For the 1&2 sequence, both breakers must either declare one pole open or be open or out-of-service. For the 1-2 sequence, breaker 1 must declare one pole open and breaker 2 must declare one pole open or be open or out-of-service. For the 2-1 sequence, breaker 2 must declare one pole open and breaker 1 must declare one pole open or be open or out-of-service. Alternately, a user-defined setting is available to generate this signal.

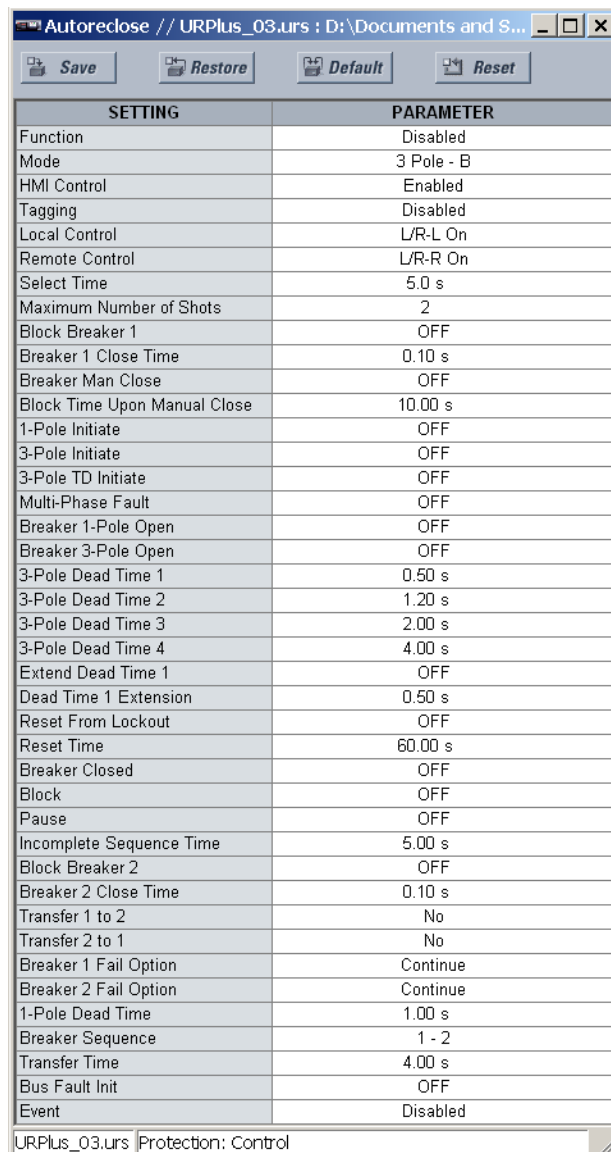
Figure 298: Terminal one-pole open logic



Autoreclose settings

Select the **Settings > Protection > Control > Autoreclose** menu to access the autoreclose settings.

Figure 299: Autoreclose settings window



SETTING	PARAMETER
Function	Disabled
Mode	3 Pole - B
HMI Control	Enabled
Tagging	Disabled
Local Control	L/R-L On
Remote Control	L/R-R On
Select Time	5.0 s
Maximum Number of Shots	2
Block Breaker 1	OFF
Breaker 1 Close Time	0.10 s
Breaker Man Close	OFF
Block Time Upon Manual Close	10.00 s
1-Pole Initiate	OFF
3-Pole Initiate	OFF
3-Pole TD Initiate	OFF
Multi-Phase Fault	OFF
Breaker 1-Pole Open	OFF
Breaker 3-Pole Open	OFF
3-Pole Dead Time 1	0.50 s
3-Pole Dead Time 2	1.20 s
3-Pole Dead Time 3	2.00 s
3-Pole Dead Time 4	4.00 s
Extend Dead Time 1	OFF
Dead Time 1 Extension	0.50 s
Reset From Lockout	OFF
Reset Time	60.00 s
Breaker Closed	OFF
Block	OFF
Pause	OFF
Incomplete Sequence Time	5.00 s
Block Breaker 2	OFF
Breaker 2 Close Time	0.10 s
Transfer 1 to 2	No
Transfer 2 to 1	No
Breaker 1 Fail Option	Continue
Breaker 2 Fail Option	Continue
1-Pole Dead Time	1.00 s
Breaker Sequence	1 - 2
Transfer Time	4.00 s
Bus Fault Init	OFF
Event	Disabled

URPlus_03.urs | Protection: Control

The following settings are available.

Function

Range: Disabled, Enabled

Default: Disabled

This setting enables and disables the autoreclose scheme.

Mode

Range: 1 & 3 Pole, 1 Pole, 3 Pole-A, 3 Pole-B

Default: 1 & 3 Pole

This setting selects the autoreclose operating mode, which functions in conjunction with signals received at the initiation inputs.

Select Time

Range: 1.0 to 30.0 seconds in steps of 0.1

Default: 5 seconds

This setting specifies the maximum permissible time from selection of autoreclose and a control action.

Maximum Number of Shots

Range: 1, 2, 3, 4

Default: 2

This setting specifies the number of reclosures attempted before reclosure goes to lockout when the fault is permanent.

Block Breaker 1

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand to block the reclose command for breaker 1. This condition can include breaker low air pressure, reclose in progress on another line (for the central breaker in a breaker and a half arrangement), or a sum of conditions combined in FlexLogic.

Close Time Breaker 1

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.10 seconds

This setting specifies the closing time for breaker 1 from the moment the **CLOSE** command is sent to the moment the contacts are closed.

Breaker Manual Close

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand that represents a manual close command to a breaker associated with the autoreclose scheme.

Block Time Upon Manual Close

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 10.00 seconds

The autoreclose scheme can be disabled for a programmable time delay after an associated circuit breaker is commanded manually to close, preventing reclosing onto an existing fault, such as grounds on the line. This delay must be longer than the slowest expected trip from any protection not blocked after manual closing. If the autoreclose scheme is not initiated after a manual close and this time expires, the autoreclose scheme is set to the reset state.

1-Pole Initiate

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand used to initiate single-pole autoreclosure.

3-Pole Initiate

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand used to initiate three-pole autoreclosure. The first timer (**3-Pole Dead Time 1**) can be used for a high-speed autoreclosure.

3-Pole TD Initiate

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand used to initiate three-pole autoreclosure. The second timer (**3-Pole Dead Time 2**) can be used for a time-delay autoreclosure.

Multi-Phase Fault

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand used to indicate a multi-phase fault. The operand value should be zero for single-phase to ground faults.

Breaker 1-Pole Open

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand to indicate that the breaker or breakers have opened correctly following a single-phase to ground fault. The autoreclose scheme can then start timing the single-pole dead time. For example, if the reclose sequence is "1-2," breaker 1 trips single-pole and breaker 2 trips three-pole.

The scheme has a pre-wired input that indicates breaker status.

Breaker 3-Pole Open

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand to indicate that the breaker or breakers have opened three-pole and the autoreclose scheme can start timing the three-pole dead time. The scheme has a pre-wired input that indicates breaker status.

3-Pole Dead Time 1

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.50 seconds

This setting specifies the dead time following the first three-pole trip. This intentional delay can be used for a high-speed three-pole autoreclose. However, set it longer than the estimated de-ionizing time following the three-pole trip.

3-Pole Dead Time 2

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 1.20 seconds

This setting specifies the dead time following the second three-pole trip or initiated by the **3-Pole Time Delay Initiate** setting. This intentional delay is used typically for a time delayed three-pole autoreclose (as opposed to high speed three-pole autoreclose).

3 Pole Dead Time 3

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 2.00 seconds

This setting specifies the dead time following the third three-pole trip.

3-Pole Dead Time 4

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 4.00 seconds

This setting specifies the dead time following the fourth three-pole trip.

Extend Dead Time 1

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand to adapt the duration of the dead time for the first shot to the possibility of non-simultaneous tripping at the two line ends. Typically this is the operand set when the communication channel is out-of-service.

Dead Time 1 Extension

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.50 seconds

This setting specifies the length of the dead time 1 extension for possible non-simultaneous tripping of the two ends of the line.

Reset

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that forces the autoreclose scheme from any state to reset. Typically this is a manual reset from lockout, local or remote.

Reset Time

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 60.00 seconds

A reset timer output resets the recloser following a successful reclosure sequence. The setting is based on the breaker time, which is the minimum time required between successive reclose sequences.

Breaker Closed

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand that indicates that the breaker(s) are closed at the end of the reset time and the scheme can reset.

Block

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects the operand that blocks the autoreclose scheme (it can be a sum of conditions such as time delayed tripping, breaker failure, and differential protection). If the block signal is present before autoreclose scheme initiation, the **AR DISABLED** FlexLogic operand is set. If the block signal occurs when the scheme is in the reclose-in-progress state, the scheme is sent to lockout.

Pause

Range: any FlexLogic operand or shared operand

Default: Off

This setting offers the ability to freeze the autoreclose cycle until the pause signal disappears. This can be done when a trip occurs and simultaneously or previously, some conditions are detected such as out-of step or loss of guard frequency, or a remote transfer trip signal is received. The autoreclose cycle is resumed when the pause signal disappears. This feature also can be used when a transformer is tapped from the protected line and a reclose is not wanted until it is disconnected from the line. In this situation, the reclose scheme is 'paused' until the transformer is disconnected.

Incomplete Sequence Time

Range: 0 to 655.35 seconds in steps of 0.01

Range: 5.00 seconds

This setting specifies the maximum time interval allowed for a single reclose shot. It is started whenever a reclosure is initiated and is active until the **CLOSE BKR1** or **CLOSE BKR2** signal is sent. If all conditions allowing a breaker closure are not satisfied when this time expires, the scheme goes to lockout. The minimum permissible setting is established by the **3-Pole Dead Time 2** timer setting. Settings beyond this determine the wait time for the breaker to open so that the reclose cycle can continue and/or for the **Pause** signal to reset and allow the reclose cycle to continue and/or for the **AR BKR1(2) BLK** signal to disappear and allow the **AR CLOSE BKR1(2)** signal to be sent.

Block Breaker 2

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand to block the reclose command for breaker 2. This condition can include breaker low air pressure, reclose in progress on another line (for the central breaker in a breaker and a half arrangement), or a sum of conditions combined in FlexLogic.

Close Time Breaker 2

Range: 0.00 to 655.35 seconds in steps of 0.01

Default: 0.10 seconds

This setting specifies the closing time for breaker 2 from the moment the **CLOSE** command is sent to the moment the contacts are closed.

Transfer 1 to 2

Range: Yes, No

Default: No

This setting establishes how the scheme performs when the breaker closing sequence is "1-2" and Breaker 1 is blocked. When set to "Yes," the closing command is transferred directly to breaker 2 without waiting for the set transfer time. When set to "No," the closing command is blocked by the **AR BKR1 BLK** signal and the scheme is sent to lockout by the incomplete sequence timer.

Transfer 2 to 1

Range: Yes, No

Default: No

This setting establishes how the scheme performs when the breaker closing sequence is "2-1" and breaker 2 is blocked. When set to "Yes," the closing command is transferred direct to breaker 1 without waiting the transfer time. When set to "No," the closing command is blocked by the **AR BKR2 BLK** signal and the scheme is sent to lockout by the incomplete sequence timer.

Breaker 1 Failure Option

Range: Continue, Lockout

Default: Continue

This setting establishes how the scheme performs when the breaker closing sequence is "1-2" and breaker 1 has failed to close. When set to "Continue," the closing command is transferred to breaker 2, which continues the reclosing cycle until successful (the scheme resets) or unsuccessful (the scheme goes to lockout). When set to "Lockout," the scheme goes to lockout without attempting to reclose breaker 2.

Breaker 2 Failure Option

Range: Continue, Lockout

Default: Continue

This setting establishes how the scheme performs when the breaker closing sequence is “2-1” and breaker 2 has failed to close. When set to “Continue,” the closing command is transferred to breaker 1, which continues the reclosing cycle until successful (the scheme resets) or unsuccessful (the scheme goes to lockout). When set to “Lockout,” the scheme goes to lockout without attempting to reclose breaker 1.

1-Pole Dead Time

Range: 0 to 655.35 seconds in steps of 0.01

Default: 1.00 seconds

Set this intentional delay setting greater than the estimated de-ionizing time after the first single-pole trip.

Breaker Sequence

Range: 1, 2, 1&2, 1-2, 2-1

Default: 1-2

This setting selects the breaker reclose sequence. Select “1” to reclose breaker 1 only, “2” for reclose breaker 2 only, “1&2” to reclose both breakers simultaneously, “1-2” to reclose breakers sequentially with breaker 1 first, and “2-1” to reclose breakers sequentially with breaker 2 first.

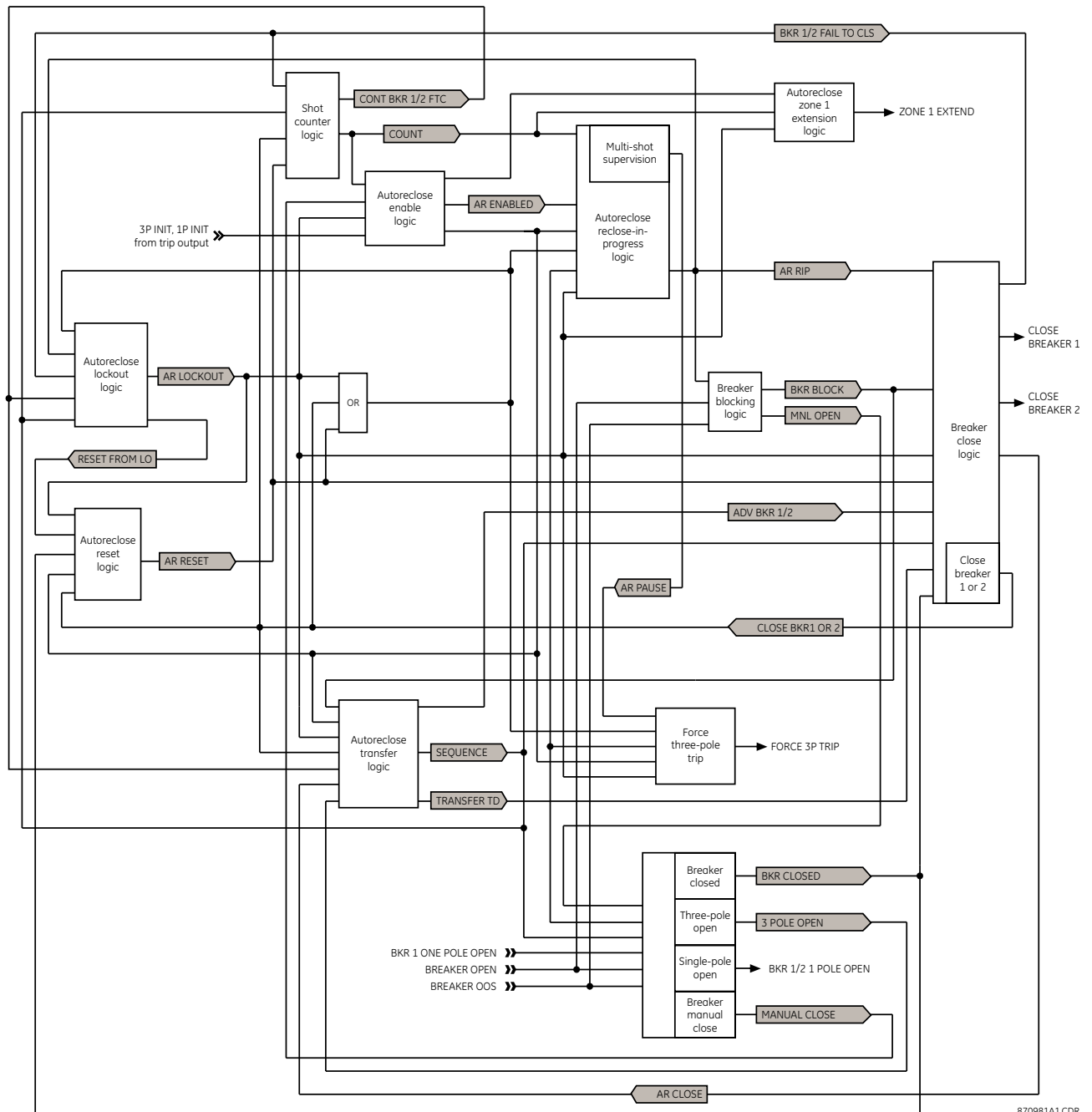
Bus Fault Initiate

Range: any FlexLogic operand or shared operand

Default: OFF

This setting is used in breaker-and-a-half applications to allow the autoreclose control function to perform reclosing with only one breaker previously opened by bus protection. For line faults, both breakers must open for the autoreclose reclosing cycles to take effect.

Figure 300: Final autoreclose signal flow logic



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Front panel status and control

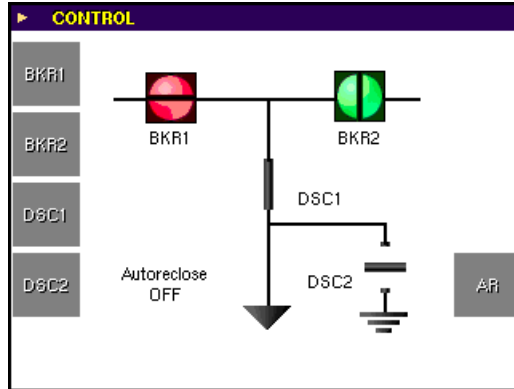
If the autoreclose function is enabled, a status indicator appears on the screen.

Table 20: Autoreclose front panel indications

Indication	FlexLogic operand
Autoreclose ON	AR ENABLED
Autoreclose OFF	AR DISABLED
Autoreclose In Progress	AR RIP
Autoreclose Locked Out	AR LO

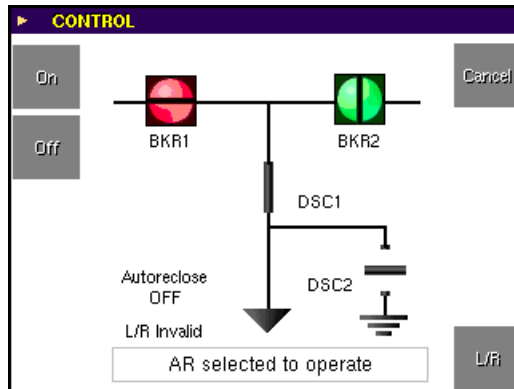
Autoreclose control is available at the top-level screen by pressing the **AR** pushbutton. If local control is not asserted for autoreclose, then the **AR** pushbutton is grey and inoperable. The local control status of a device is obtained from the autoreclose control logic.

Figure 301: Autoreclose control enabled display



Once autoreclose control is selected, the message **AR selected to operate** displays and pushbuttons appear for the autoreclose control options.

Figure 302: Autoreclose control selected display



If tagging has been enabled, a **TAG** pushbutton appears on this screen. When the **TAG** pushbutton is operated, a small T displays next to the autoreclose indication, and the on and off operations are inhibited. When a device is tagged, the **TAG** pushbutton changes to an **UNTAG** pushbutton.

Underfrequency

There are two identical underfrequency elements.

The steady-state frequency of a power system is a certain indicator of the existing balance between the generated power and the load. Whenever this balance is disrupted through the loss of an important generating unit or the isolation of part of the system from the rest of the system, the effect is a reduction in frequency. If the control systems of the system generators do not respond fast enough, the system can collapse. A reliable method to quickly restore the balance between load and generation is to disconnect automatically selected loads, based on the actual system frequency. This technique, called load-shedding, maintains system integrity and minimizes widespread outages. After the frequency returns to normal, the load can be automatically or manually restored.

Select the **Settings > Protection > Control > Underfrequency** menu to open the underfrequency settings window.

Figure 303: Underfrequency configuration settings

PARAMETER	UNDERFREQUENCY 1	UNDERFREQUENCY 2
Function	Disabled	Disabled
Block	OFF	OFF
Source	LINE (SRC 1)	LINE (SRC 1)
Min Volt/Amp	0.10 pu	0.10 pu
Pickup	59.50 Hz	59.50 Hz
Pickup Delay	2.000 s	2.000 s
Reset Delay	2.000 s	2.000 s
Events	Disabled	Disabled

D90P_2.urs Protection: Control

The following settings are available for each underfrequency element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the underfrequency function.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the source for the signal to be measured. The element first checks for a live phase voltage available from the selected source. If voltage is not available, the element attempts to use a phase current. If neither voltage nor current is available, the element does not operate, as it does not measure a parameter below the minimum voltage or current setting.

Minimum Voltage/Current

Range: 0.10 to 1.25 pu in steps of 0.01

Default: 0.10 pu

This setting selects the minimum per-unit voltage or current level required to allow the underfrequency element to operate. This threshold is used to prevent an incorrect operation because there is no signal to measure.

Pickup

Range: 20.00 to 65.00 Hz in steps of 0.01

Default: 59.50 Hz

This setting specifies the pickup level for the underfrequency element. For example, if the system frequency is 60 Hz and load shedding is required at 59.5 Hz, the setting is 59.50 Hz.

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 2.000 seconds

This setting specifies a time delay on pickup for the duration between the pickup and operate output states of the underfrequency element.

Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 2.000 seconds

This setting specifies a time delay on dropout for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the underfrequency element.

Events

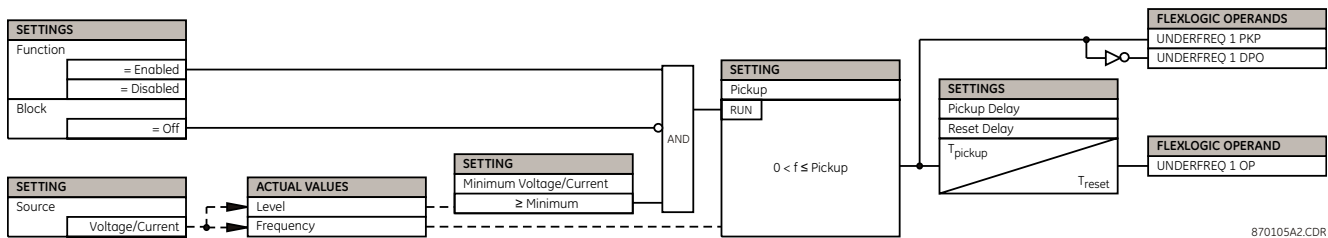
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of underfrequency events in the sequence of events recorder.

The figure shows the logic for the underfrequency function.

Figure 304: Underfrequency logic



Overfrequency

There are two identical overfrequency elements.

A frequency calculation for a given source is made on the input of a voltage or current channel, depending on which is available. The channels are searched for the signal input in the following order:

1. Voltage channel A
2. Auxiliary voltage channel
3. Current channel A
4. Ground current channel

The first available signal is used for frequency calculation.

The steady-state frequency of a power system is an indicator of the existing balance between the generated power and the load. Whenever this balance is disrupted through the disconnection of significant load or the isolation of a part of the system that has a surplus of generation, the effect is an increase in frequency. If the control systems of the generators do not respond fast enough, to quickly ramp the turbine speed back to normal, the overspeed can lead to the turbine trip. The overfrequency element can be used to control the turbine frequency ramp down at a generating location. This element can also be used for feeder reclosing as part of the after load shedding restoration.

Select the **Settings > Protection > Control > Overfrequency** menu to open the overfrequency settings window.

Figure 305: Overfrequency configuration settings

PARAMETER	OVERFREQUENCY 1	OVERFREQUENCY 2
Function	Disabled	Disabled
Block	OFF	OFF
Source	LINE (SRC 1)	LINE (SRC 1)
Pickup	60.50 Hz	60.50 Hz
Pickup Delay	0.500 s	0.500 s
Reset Delay	0.500 s	0.500 s
Events	Disabled	Disabled

D90P_2.urs Protection: Control

The following settings are available for each overfrequency element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the overfrequency function.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the source for the signal to be measured.

Pickup

Range: 20.00 to 65.00 Hz in steps of 0.01

Default: 60.50 Hz

This setting specifies the level at which the overfrequency element is to pick up.

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.500 seconds

This setting specifies a time delay on pickup for the duration between the pickup and operate output states of the overfrequency element.

Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.500 seconds

This setting specifies a time delay on dropout for the duration between the operate output state and the return to logic 0 after the input transits outside the defined pickup range.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the overfrequency element.

Events

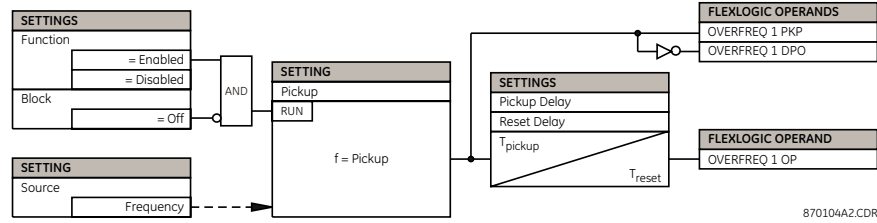
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of overfrequency events in the sequence of events recorder.

The figure shows the logic for the overfrequency function.

Figure 306: Overfrequency logic



Breaker configuration

The breaker configuration element contains the auxiliary logic for status and serves as the interface for opening and closing of the breaker from protection and automation functions. The logic also permits a manual substitution of the position indication.

Select the **Settings > Protection > Control > Breakers** menu to open the breaker control configuration window.

Figure 307: Breaker configuration settings

Settings	Breaker 1	Breaker 2
Function	Enabled	Enabled
Long Name	Breaker 1	Breaker 2
Short Name	BKR1	BKR2
Substitution	Disabled	Disabled
Combined Protection and Control	Enabled	Enabled
External Trip A	OFF	OFF
External Trip B	OFF	OFF
External Trip C	OFF	OFF
External Trip	OFF	OFF
External Open Command	OFF	OFF
Block Open Command	OFF	OFF
External Close Command	OFF	OFF
Autoreclose Close Supervision	SYNC 1 SYNC OP	SYNC 2 SYNC OP
Block Close Command	OFF	OFF
Breaker Local Input	OFF	OFF
Indication Mode	3-Pole	3-Pole
Phase A/3P Closed Status	BKR1 52a On(F5)	BKR2 52a On(F6)
Phase A/3P Opened Status	BKR1 52a Off(F5)	BKR2 52a Off(F6)
Phase B Closed Status	OFF	OFF
Phase B Opened Status	OFF	OFF
Phase C Closed Status	OFF	OFF
Phase C Opened Status	OFF	OFF
Operate Time	0.070 s	0.070 s
Discrepancy Time	0.070 s	0.070 s
Reset Counter	OFF	OFF
Events	Enabled	Enabled

The following settings are available to each of the breakers. The default values outlined apply to breaker 1.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables the breaker position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Long Name

Range: 20 alphanumeric characters

Default: Breaker 1

This setting identifies the primary device for control confirmations on the front panel interface and in the event record.

Short Name

Range: up to 6 alphanumeric characters

Default: BKR1

This setting identifies the primary device pushbuttons and indications on the front panel interface.

Substitution

Range: Enabled, Disabled

Default: Disabled

This setting allows the position indication of the breaker to be substituted with a manually entered value.

Combined Protection and Control

Range: Enabled, Disabled

Default: Enabled

If this setting is enabled, the tripping signals from the trip output scheme are logically ORed with the open signal from the breaker control scheme.

External Trip A, External Trip B, External Trip C

Range: any FlexLogic operand or shared operand

Default: Off

These settings assign an operand (usually an external contact input) to the breaker trip pole A, B, and C reporting contact.

External Open Command

Range: any FlexLogic operand or shared operand

Default: Off

This setting assigns an operand that creates a programmable signal to operate an output relay to open the breaker.

Block Open Command

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand that prevents opening of the breaker. This setting can be used for select-before-operate functionality or to block operation from a panel switch or from SCADA.

External Close Command

Range: any FlexLogic operand or shared operand

Default: Off

This setting assigns an operand that creates a programmable signal to operate an output relay to close the breaker.

Autoreclose Close Supervision

Range: any FlexLogic operand or shared operand

Default: SYNC 1 SYNC OP

This setting selects an operand to supervise the closing of the breaker from autoreclose. If no supervision is required, program this setting as "On."

Block Close Command

Range: any FlexLogic operand or shared operand

Default: Off

This setting selects an operand that prevents closing of the breaker. This setting can be used for select-before-operate functionality or to block operation from a panel switch or from SCADA.

Breaker Local Input

Range: any FlexLogic operand or shared operand

Default: OFF

Closing or opening of the breaker through the breaker interlock element is inhibited if the operand assigned to this setting is asserted.

Indication Mode

Range: 3 Pole, 1 Pole

Default: 3 Pole

If "3 Pole" is selected, the breaker indications are derived from a single status input (or pair of status inputs). If "1 Pole" is selected, the breaker indications are derived from three status inputs (or pairs of status inputs).

Phase A/3P Closed Status

Range: any FlexLogic operand or shared operand

Default: BKR1 52a On

The operand selected by this setting is used to derive three-pole or phase A breaker position indications from a normally-opened (52a) status input.

Phase A/3P Opened Status

Range: any FlexLogic operand or shared operand

Default: BKR1 52a Off

The operand selected by this setting is used to derive three-pole or phase A breaker position indications from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal.

Phase B Closed Status

Range: any FlexLogic operand or shared operand

Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-opened (52a) status input. This input is not required if the indication mode is single-pole.

Phase B Opened Status

Range: any FlexLogic operand or shared operand

Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This input is not required if the indication mode is single-pole.

Phase C Closed Status

Range: any FlexLogic operand or shared operand

Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-opened (52a) status input. This input is not required if the indication mode is single-pole.

Phase C Opened Status

Range: any FlexLogic operand or shared operand

Default: Off

The operand selected by this setting is used to derive the phase B breaker position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This input is not required if the indication mode is single-pole.

Operate Time

Range: 0.000 to 2.000 seconds in steps of 0.001

Default: 0.070 seconds

This setting specifies a timer that is asserted when both the normally open and normally closed breaker indications are reset. When the timer expires, a bad status is indicated for the breaker. Program this timer setting equal to the normal operating time for the breaker.

Discrepancy Time

Range: 0.000 to 2.000 seconds in steps of 0.001

Default: 0.070 seconds

This setting specifies a timer that is asserted when the three breaker poles are not all opened or not all closed. Program this timer setting to greater than the longest expected time for which the three breaker poles disagree.

Reset Counter

Range: any FlexLogic operand or shared operand

Default: Off

Assertion of the operand assigned to this setting resets the breaker operation counters.

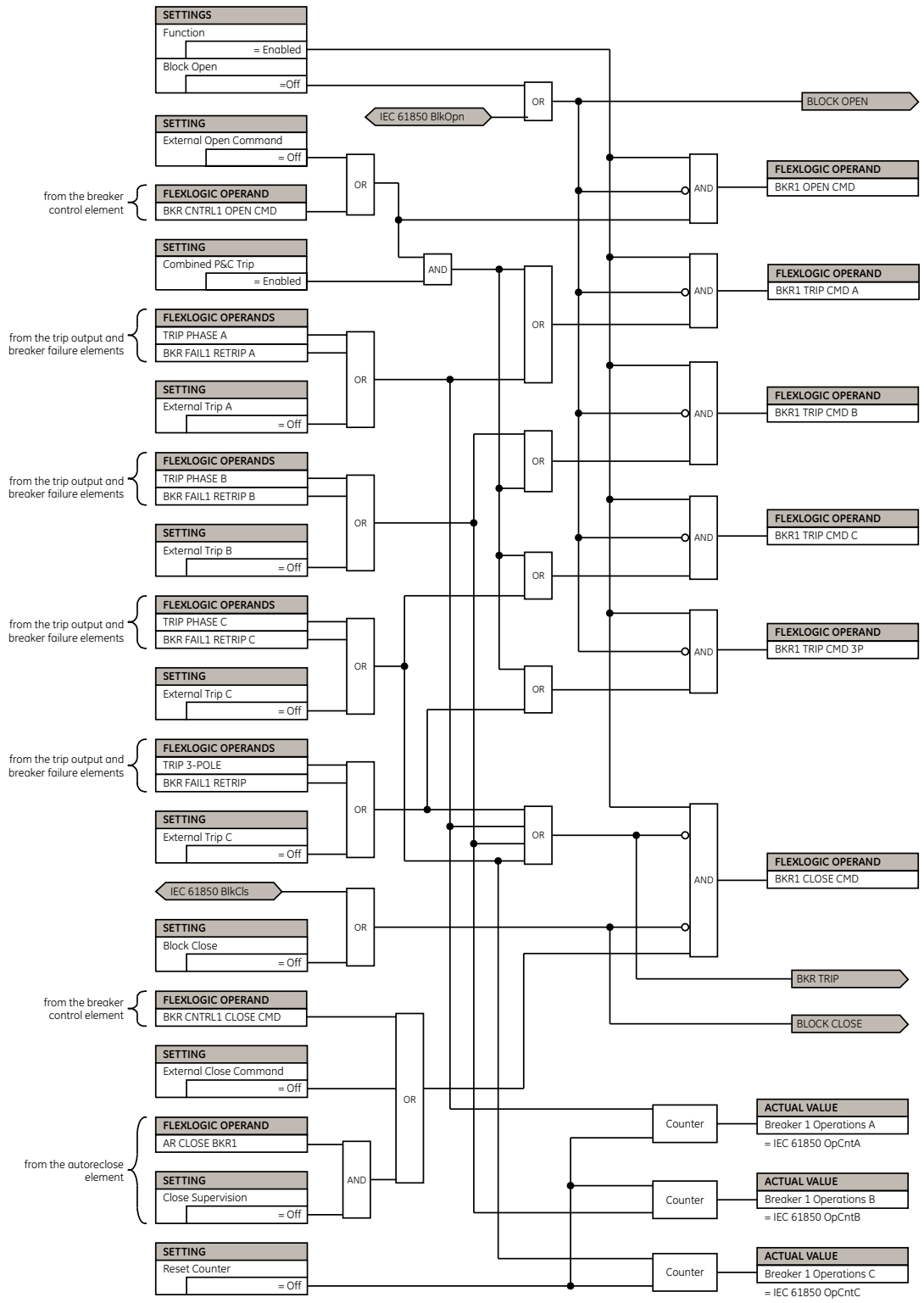
Events

Range: Enabled, Disabled

Default: Enabled

This settings enables the recording of breaker configuration events in the sequence of events record.

Figure 308: Breaker configuration logic, sheet 1 of 4



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Figure 309: Breaker configuration logic, sheet 2 of 4

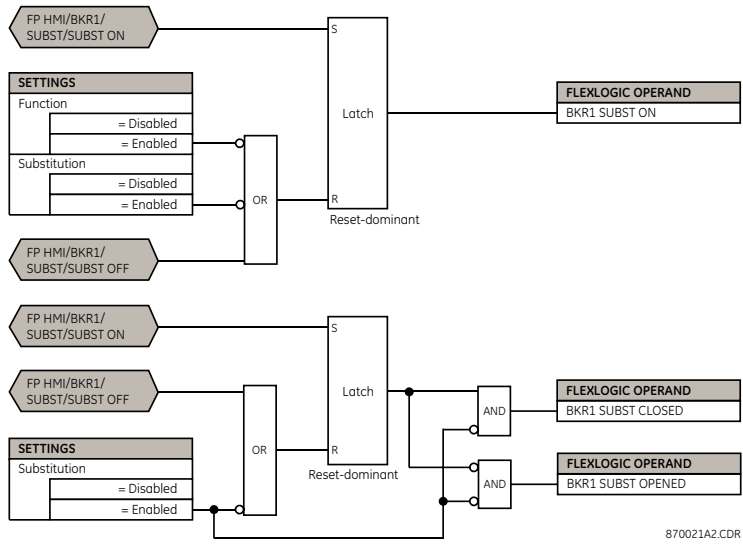


Figure 310: Breaker configuration logic, sheet 3 of 4

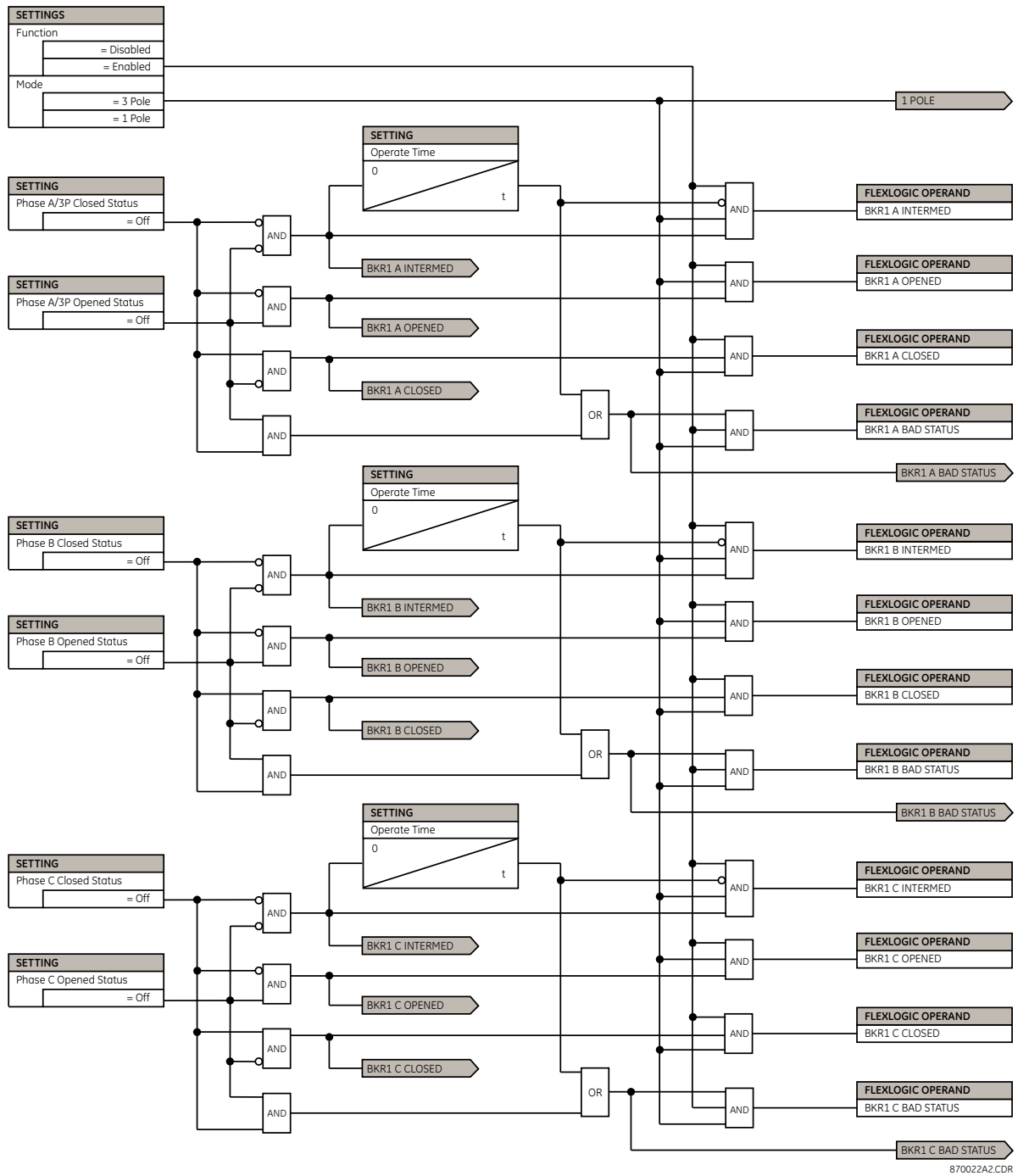
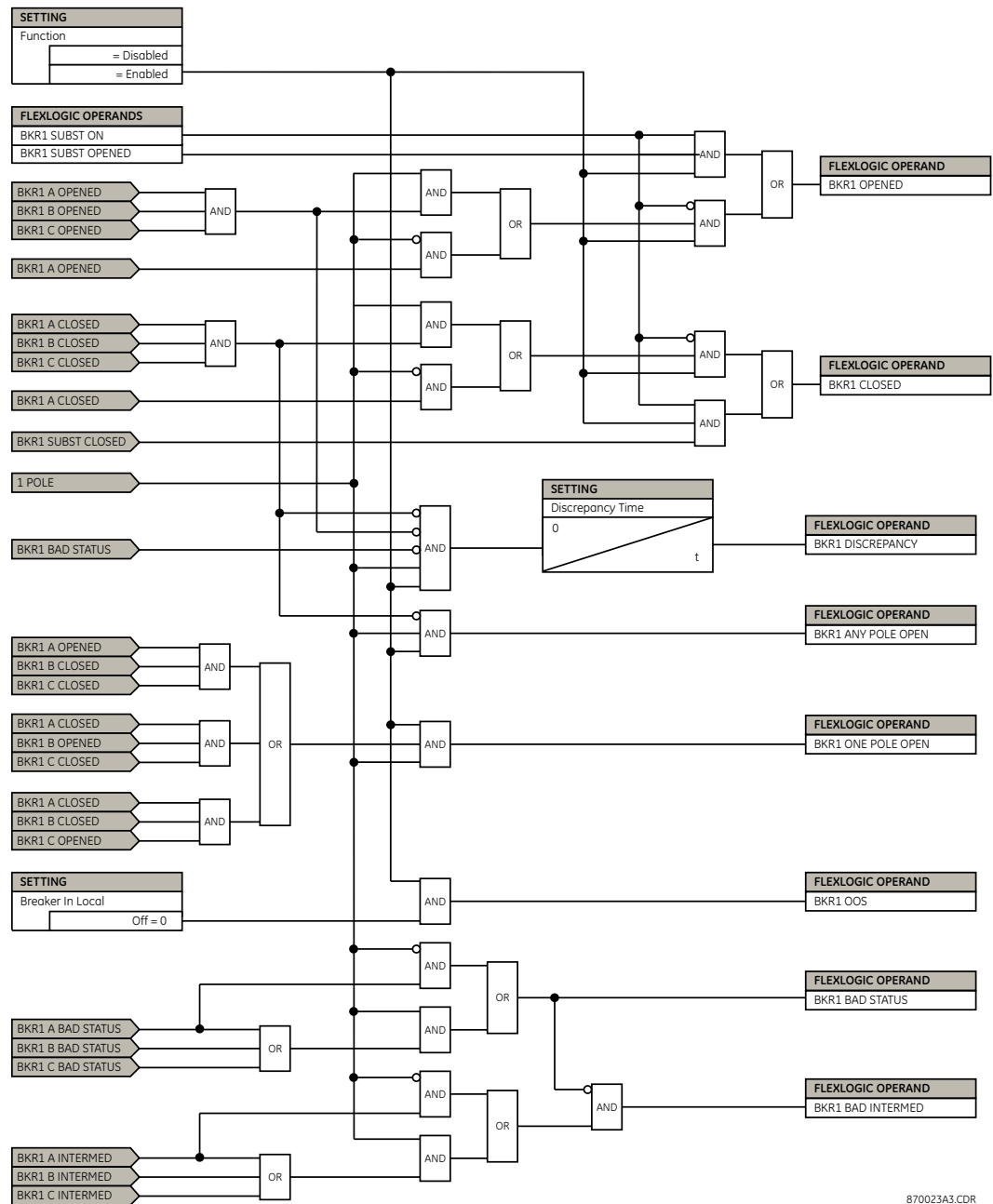


Figure 311: Breaker configuration logic, sheet 4 of 4



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Breaker flashover

The detection of breaker flashover is based on the following condition:

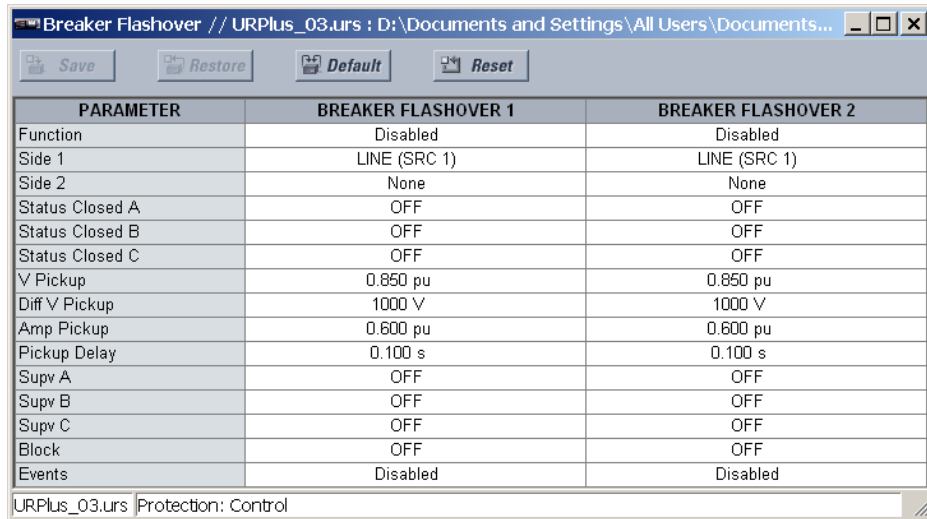
1. Breaker open
2. Voltage drop measured from either side of the breaker during the flashover period
3. Voltage difference drop
4. Measured flashover current through the breaker

Furthermore, the breaker flashover scheme is applicable for cases where either one or two sets of three-phase voltages are available across the breaker.

Breaker flashover settings

Select the **Settings > Protection > Control > Breaker Flashover** menu to open the breaker flashover configuration window.

Figure 312: Breaker flashover configuration settings



PARAMETER	BREAKER FLASHOVER 1	BREAKER FLASHOVER 2
Function	Disabled	Disabled
Side 1	LINE (SRC 1)	LINE (SRC 1)
Side 2	None	None
Status Closed A	OFF	OFF
Status Closed B	OFF	OFF
Status Closed C	OFF	OFF
V Pickup	0.850 pu	0.850 pu
Diff V Pickup	1000 V	1000 V
Amp Pickup	0.600 pu	0.600 pu
Pickup Delay	0.100 s	0.100 s
Supv A	OFF	OFF
Supv B	OFF	OFF
Supv C	OFF	OFF
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each breaker flashover element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the breaker flashover protection element.

Side 1

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting specifies a signal source used to provide three-phase voltages and three-phase currents from one side of the current breaker. The source is selected by this setting and must be configured with breaker phase voltages and currents, even if only three VTs are available across the breaker.

Side 2

Range: None, LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: varies with UR^{plus}-series model; see the EnerVista UR^{plus} Setup software

This setting specifies a signal source used to provide another set of three-phase voltages whenever six VTs are available across the breaker.

Status Closed A, Status Closed B, Status Closed C

Range: any FlexLogic operand or shared operand

Default: BKR1 CLOSED

These settings specify operands to indicate the open status of the breaker. A separate operand can be selected to detect individual breaker pole status and provide flashover detection. The recommended setting is 52a breaker contact or another operand defining the breaker poles open status.

Voltage Pickup

Range: 0.000 to 1.500 pu in steps of 0.001

Default: 0.850 pu

This setting specifies a pickup level for the phase voltages from both sides of the breaker. If six VTs are available, opening the breaker leads to two possible combinations – live voltages from only one side of the breaker, or live voltages from both sides of the breaker. Either case sets the scheme ready for flashover detection upon detection of voltage above the selected value. Set this value to 85 to 90% of the nominal voltage.

Voltage Difference Pickup

Range: 0 to 100000 volts in steps of 1

Default: 1000 volts

This setting specifies a pickup level for the phase voltage difference when two VTs per phase are available across the breaker. Set the pickup voltage difference below the monitored voltage difference when close or open breaker resistors are left in service. The setting is selected as primary volts difference between the sources.

Current Pickup

Range: 0.000 to 1.500 pu in steps of 0.001

Default: 0.600 pu

This setting specifies the normal load current that can flow through the breaker. Depending on the flashover protection application, the flashover current can vary from levels of the charging current when the line is de-energized (all line breakers open), to well above the maximum line (feeder) load (line/feeder connected to load).

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.100 seconds

This setting specifies the time delay to operate the breaker flashover element after a pickup condition is detected.

Supervision A, Supervision B, Supervision C

Range: any FlexLogic operand or shared operand

Default: OFF

These settings specify operands (per breaker pole) that supervise the operation of the element per phase. Supervision can be provided by operation of other protection elements, breaker failure, and close and trip commands. A six-cycle time delay applies after the selected operand resets.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the breaker flashover element.

Events

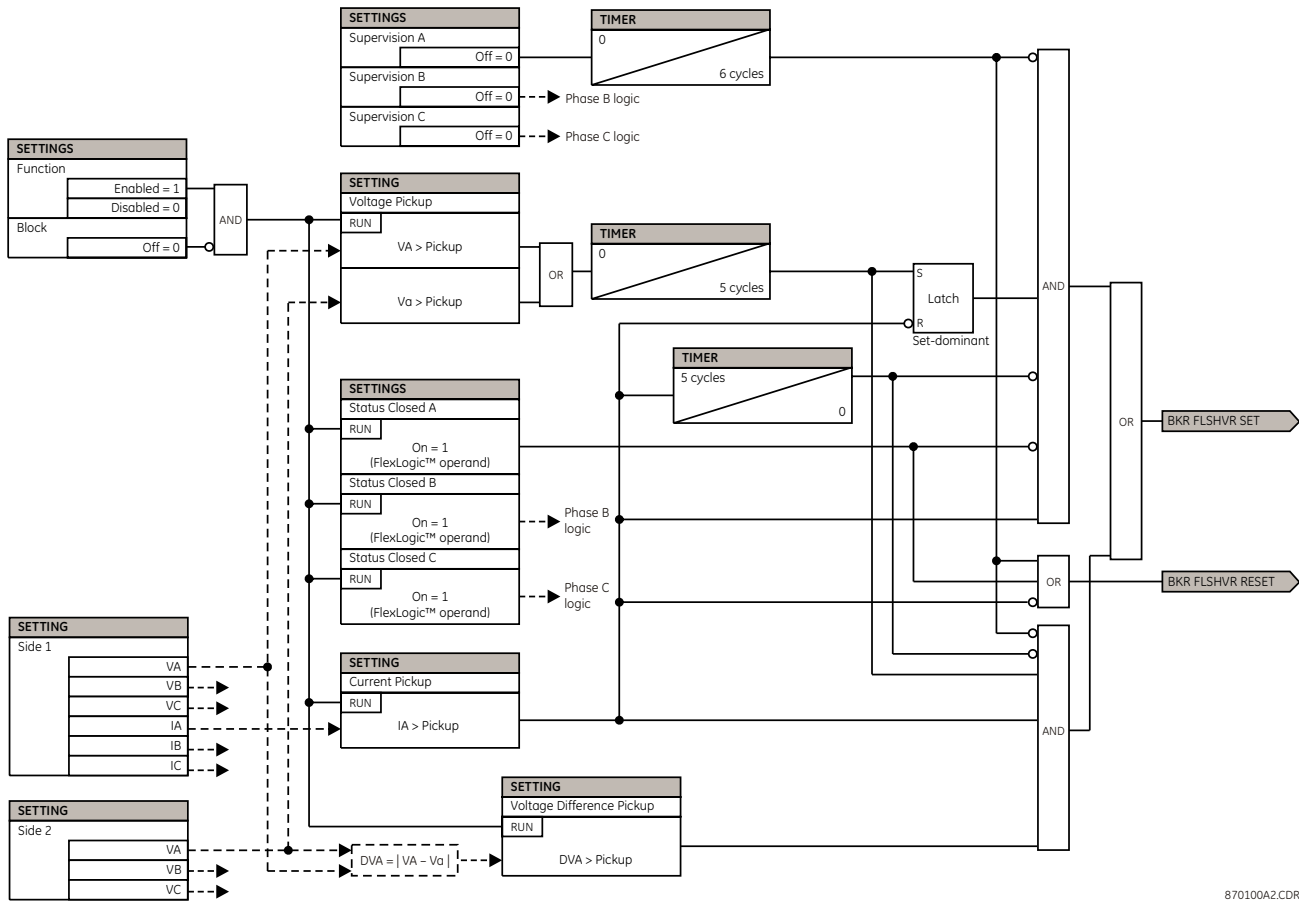
Range: Enabled, Disabled

Default: varies with UR^{PLUS}-series model; see the EnerVista UR^{PLUS} Setup software

This setting enables and disables the logging of breaker flashover events in the sequence of events recorder.

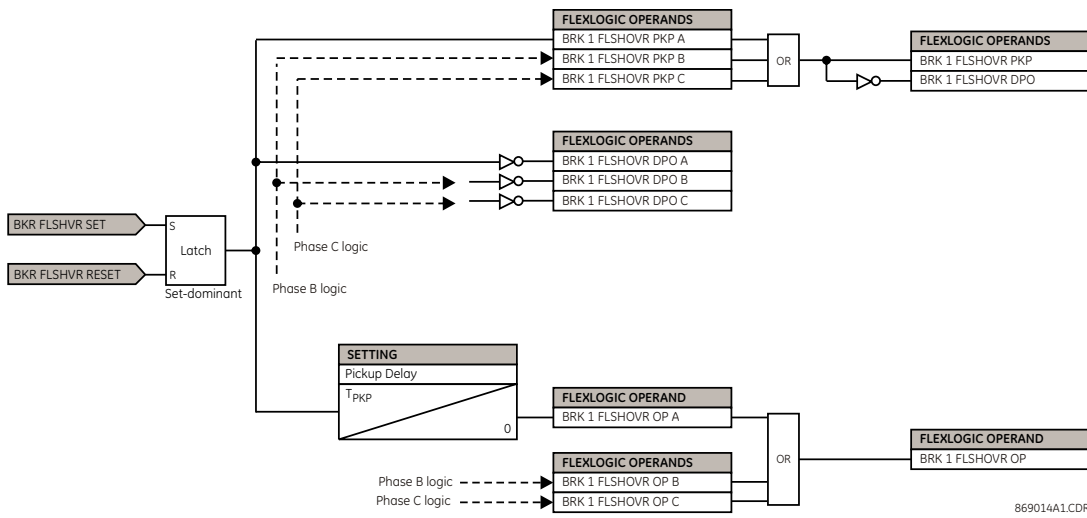
The figures show the logic for the breaker flashover element.

Figure 313: Breaker flashover logic, sheet 1 of 2



870100A2.CDR

Figure 314: Breaker flashover logic, sheet 2 of 2



869014A1.CDR

Three VT breaker flashover application

When only one set of VTs is available across the breaker, set the **Side 2** setting to “None.” To detect an open breaker condition in this application, the scheme checks if the per-phase voltages were recovered (picked up), the status of the breaker is open (contact input

indicating the breaker status is off), and no flashover current is flowing. A contact showing the breaker status must be provided to the relay. The voltage difference is not considered as a condition for open breaker in this part of the logic.

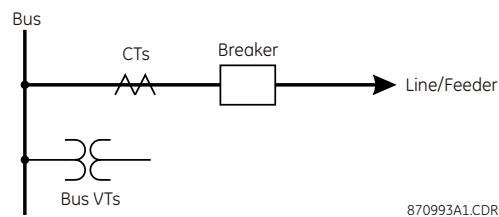


Voltages must be present prior to flashover conditions. If the three VTs are placed after the breaker on the line (or feeder), and the downstream breaker is open, the measured voltage is zero and the flashover element is not initiated.

The flashover detection resets if the current drops back to zero, the breaker closes, or the selected FlexLogic operand for supervision changes to high. Using supervision through the **Supervision A** through **Supervision C** settings is recommended by selecting a trip operand that does not allow the flashover element to pick up prior to the trip. The flashover detection can be used for external alarm, re-tripping the breaker, or energizing the lockout relay.

Consider the configuration shown.

Figure 315: Breaker flashover application example



The source 1 (SRC1) phase currents are feeder CTs and phase voltages are bus VTs, and contact input 1 is set as breaker 52a contact. The conditions prior to flashover detection are

1. 52a status = 0
2. VAg, VBg, or VCg is greater than the pickup setting
3. IA, IB, IC = 0; no current flows through the breaker
4. ΔVA is greater than pickup (not applicable in this scheme)

The conditions at flashover detection are

1. 52a status = 0
2. VAg, VBg, or VCg is lower than the pickup setting
3. IA, IB, or IC is greater than the pickup current flowing through the breaker
4. ΔVA is greater than pickup (not applicable in this scheme)

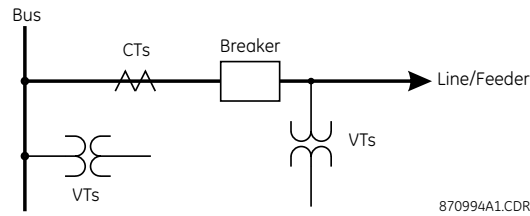
Six VT breaker flashover application

The per-phase voltage difference approaches zero when the breaker is closed. This is well below any typical minimum pickup voltage. Select the level of the **Voltage Difference Pickup** setting to be less than the voltage difference measured across the breaker when the close or open breaker resistors are left in service. Prior to flashover, the voltage difference is larger than the **Voltage Difference Pickup** setting. This applies to either the difference between two live voltages per phase or when the voltage from one side of the breaker has dropped to zero (line de-energized), at least one per-phase voltage is larger than the **Voltage Pickup** setting, and no current flows through the breaker poles. During breaker flashover, the per-phase voltages from both sides of the breaker drops below the pickup value defined by the **Voltage Pickup** setting, the voltage difference drops below the pickup setting, and flashover current is detected. These flashover conditions initiate FlexLogic pickup operands and start the **Pickup Delay** timer.

This application does not require detection of breaker status via a 52a contact, as it uses a voltage difference larger than the **Voltage Difference Pickup** setting. However, monitor the breaker contact to ensure scheme stability.

Consider the configuration shown.

Figure 316: Breaker flashover application example



The source 1 (SRC1) phase currents are CTs and phase voltages are bus VTs. The source 2 (SRC2) phase voltages are line VTs. Contact input 1 is set as the breaker 52a contact (optional).

The conditions prior to flashover detection are

1. ΔVA is greater than pickup
2. VAg , VBg , or VCg is greater than the pickup setting
3. IA , IB , $IC = 0$; no current flows through the breaker
4. 52a status = 0 (optional)

The conditions at flashover detection are

1. ΔVA is less than pickup
2. VAg , VBg , or VCg is lower than the pickup setting
3. IA , IB , or IC is greater than the pickup current flowing through the breaker
4. 52a status = 0 (optional)

Digital counters

There are eight identical digital counters in the D90^{Plus}. A digital counter counts the number of state transitions from logic 0 to logic 1. It counts operations, such as element pickup, changes of state of an external contact (for example, a breaker auxiliary switch), or pulses from a watt-hour meter.

Select the **Settings > Protection > Control > Digital Counters** menu to open the digital counters configuration window.

Figure 317: Digital counters configuration settings

PARAMETER	COUNTER 1	COUNTER 2
Function	Disabled	Disabled
Name	Counter 1	Counter 2
Units		
Preset	0	0
Compare	0	0
Up	OFF	OFF
Down	OFF	OFF
Block	OFF	OFF
Set To Preset	OFF	OFF
Reset	OFF	OFF
Freeze/Reset	OFF	OFF
Freeze/Count	OFF	OFF

The following settings are available for each digital counter.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the digital counter.

Name

Range: up to 12 alphanumeric characters

Default: Counter 1

An alphanumeric name can be assigned to a digital counter for diagnostic, setting, and event recording purposes. The "Counter 1" text in event records and FlexLogic operands are replaced by the text programmed in this setting.

Units

Range: up to 6 alphanumeric characters

Default: empty

This setting assigns a label to identify the unit of measure pertaining to the digital transitions to be counted. The units label appears in the corresponding actual values status.

Preset

Range: -2 147 483 648 to 2 147 483 647 in steps of 1

Default: 0

This setting specifies the count to a required preset value before counting operations begin, as in the case where a substitute relay is to be installed in place of an in-service relay, or while the counter is running.

Compare

Range: -2 147 483 648 to 2 147 483 647 in steps of 1

Default: 0

This setting specifies the value to which the accumulated count value is compared. Three FlexLogic output operands are provided to indicate if the present value is greater than the set value ([Counter 1 HI](#)), equal to the set value ([Counter 1 EQL](#)), or less than the set value ([Counter 1 LO](#)).

Up

Range: any FlexLogic operand

Default: Off

This setting selects the FlexLogic operand for incrementing the counter. If an enabled up input is received when the accumulated value is at the limit of 2 147 483 647 counts, the counter rolls over to -2 147 483 648 counts.

Down

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand for decrementing the counter. If an enabled down input is received when the accumulated value is at the limit of -2 147 483 648 counts, the counter rolls over to 2 147 483 647 counts.

Block

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand for blocking the counting operation. All counter operands are blocked upon assertion of this operand.

Set To Preset

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand used to set the count to the preset value and functions as follows:

- The counter is set to the preset value when the counter is enabled and the operand assigned to the **Set To Preset** setting is asserted (logic 1). When the counter is enabled and the operand assigned to the **Set To Preset** value is logic 0, the counter is set to 0.
- The counter is set to the preset value when the counter is running and operand assigned to the **Set To Preset** setting changes the state from 0 to 1. If the operand assigned to the **Set To Preset** setting changes from 1 to 0 while the counter is running, there is no effect on the count.
- The counter is set to the preset value when a reset or reset/freeze command is sent to the counter and the operand assigned to the **Set To Preset** setting is logic 1. When a reset or reset/freeze command is sent to the counter and the operand assigned to the **Set To Preset** setting is logic 0, the counter is set to 0.

Reset

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand for setting the count to either 0 or the preset value depending on the state of the operand assigned to the **Set To Preset** setting.

Freeze/Reset

Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and resetting the count to 0.

Freeze/Count

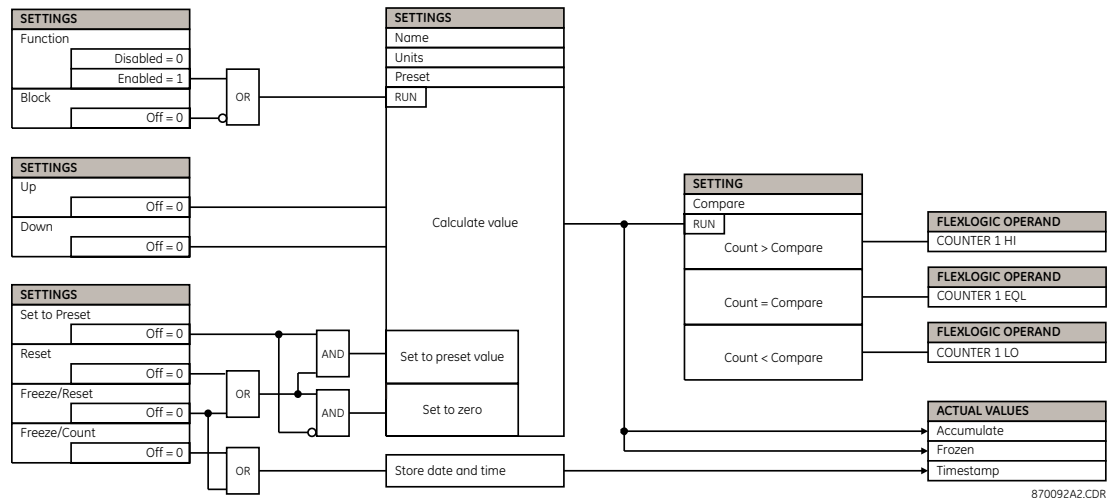
Range: any FlexLogic operand or shared operand

Default: OFF

This setting selects an operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and for continuing counting. The present accumulated value and captured frozen value with the associated date and time stamp are available as actual values. If control power is interrupted, the accumulated and frozen values are saved into non-volatile memory during the power down operation.

The figure shows the digital counter logic. The logic is identical for all digital counters.

Figure 318: Digital counter logic



FlexCurves

There are four user-programmable FlexCurves available with the D90^{Plus} system, labeled A, B, C, and D.

The curve shapes for the four FlexCurves are derived from the following equations:

$$T_{operate} = TDM \times \left(T_{flex} \text{ at } \frac{I}{I_{pickup}} \right), \text{ when } \frac{I}{I_{pickup}} \geq 1.00 \quad \text{Eq. 40}$$

$$T_{reset} = TDM \times \left(T_{flex} \text{ at } \frac{I}{I_{pickup}} \right), \text{ when } \frac{I}{I_{pickup}} \leq 0.98 \quad \text{Eq. 41}$$

where

$T_{operate}$ is the operate time in seconds

TDM is the multiplier setting

I is the input current

I_{pickup} is the value of the pickup current setting

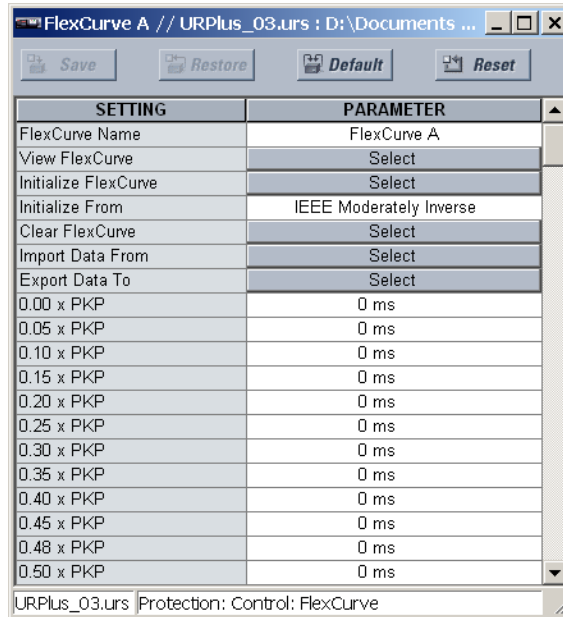
T_{flex} is the FlexCurve time in seconds

T_{reset} is the reset time in seconds

FlexCurve settings

Select the **Settings > Protection > Control > FlexCurves > FlexCurve A** menu to access the FlexCurve A settings. The same group of settings is available for FlexCurves B, C, and D.

Figure 319: FlexCurve configuration settings



The following settings are available for each custom FlexCurve.

FlexCurve Name

Range: up to 20 alphanumeric characters

Default: FlexCurve A

This setting specifies a user-defined name for the FlexCurve.

Initialize From

Range: IEEE Moderately Inverse, IEEE Very Inverse, IEEE Extremely Inverse, IEC Curve A, IEC Curve B, IEC Curve C, IEC Short Inverse, IAC Extreme Inv, IAC Very Inverse, IAC Inverse, IAC Short Inverse, I Squared T, Recloser Curve, FlexCurve A, FlexCurve B, FlexCurve C, FlexCurve D

Default: IEEE Moderately Inverse

This setting specifies a curve to use as a base for a custom FlexCurve. When the **Initialize FlexCurve** button is clicked, the pickup settings are populated with values specified by the curve selected in this setting.

0.00 x Pickup, 0.05 x Pickup, ..., 20.00 x Pickup

Range: 0 to 65535 ms in steps of 1

Default: 0 ms

These settings specify the time to reset and operate at the following pickup levels: 0.00 to 0.98 and 1.03 to 20.00. This data is converted into two continuous curves by linear interpolation between data points. To enter a custom FlexCurve, enter the reset or operate time for each selected pickup point.

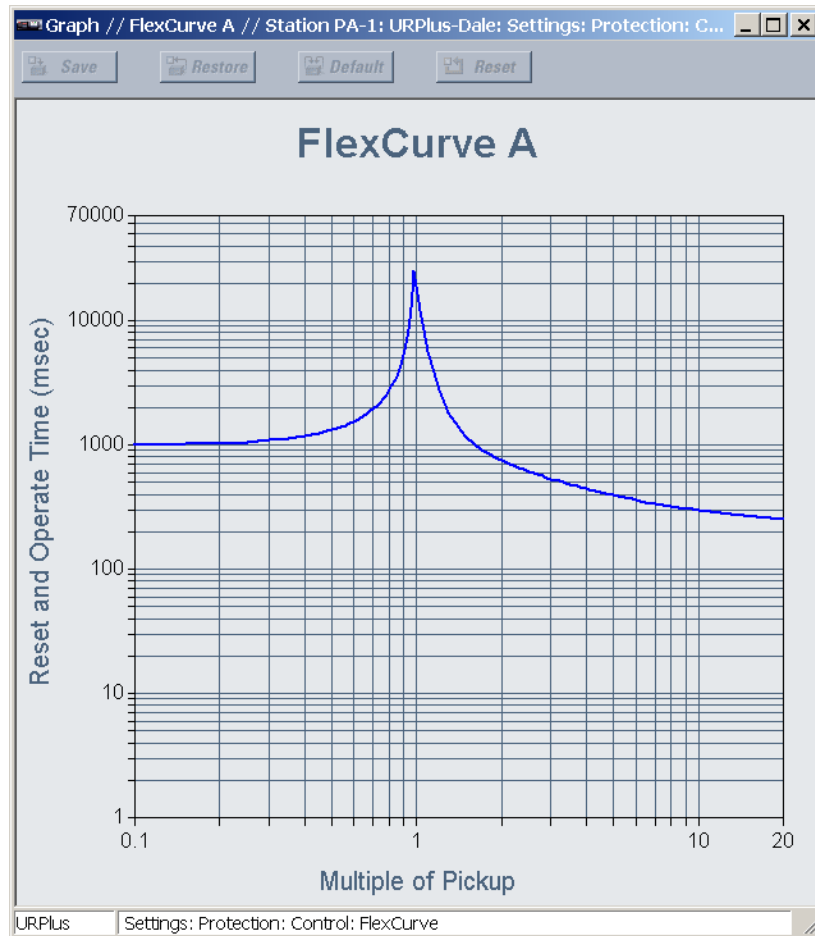


Take care when setting the two points that are close to the multiple of pickup of 1, that is, 0.98 pu and 1.03 pu. It is recommended to set the two times to a similar value, otherwise the linear approximation can result in undesired behavior for the operating quantity that is close to 1.00 pu.

FlexCurve software features

The EnerVista software allows for easy configuration and management of FlexCurves and their associated data points. Click the **View FlexCurve** button to graphically display the selected FlexCurve.

Figure 320: FlexCurve display example



Prospective FlexCurves can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Click the **Initialize FlexCurve** button to populate the pickup values with the points from the curve specified by the **Initialize From** setting. These values can then be edited to create a custom curve. Note that the pickup multiples start at zero (implying the reset time), operating time below pickup, and operating time above pickup. Click the **Clear FlexCurve** button to reset all pickup values to zero.

Curve data can be imported from comma-separated values (CSV) files by clicking the **Import Data From** button. Likewise, curve data can be saved in CSV format by clicking the **Export Data To** button. CSV is a delimited data format with fields separated by the comma character and records separated by new lines. See IETF RFC 4180 for additional details.

Recloser curve editing

Recloser curve selection is special in that recloser curves can be shaped into a composite curve with a minimum response time and a fixed time above specified pickup multiples. There are 41 recloser curve types supported. These definite operating times are useful to coordinate operating times, typically at higher currents and where upstream and downstream protective devices have different operating characteristics. The recloser curve configuration window shown as follows appears when the **Initialize From** setting is set to "Recloser Curve" and the **Initialize FlexCurve** button is clicked.

Figure 321: Recloser curve initialization

Multiplier: Scales (multiplies) the curve operating times

Adder: Adds the time specified in this field (in ms) to each curve operating time value.

Minimum Response Time (MRT): If enabled, the MRT setting defines the shortest operating time even if the curve suggests a shorter time at higher current multiples. A composite operating characteristic is effectively defined. For current multiples lower than the intersection point, the curve dictates the operating time; otherwise, the MRT does. An information message appears when attempting to apply an MRT shorter than the minimum curve time.

High Current Time: Allows the user to set a pickup multiple from which point onwards the operating time is fixed. This is normally only required at higher current levels. The HCT Ratio defines the high current pickup multiple; the HCT defines the operating time.

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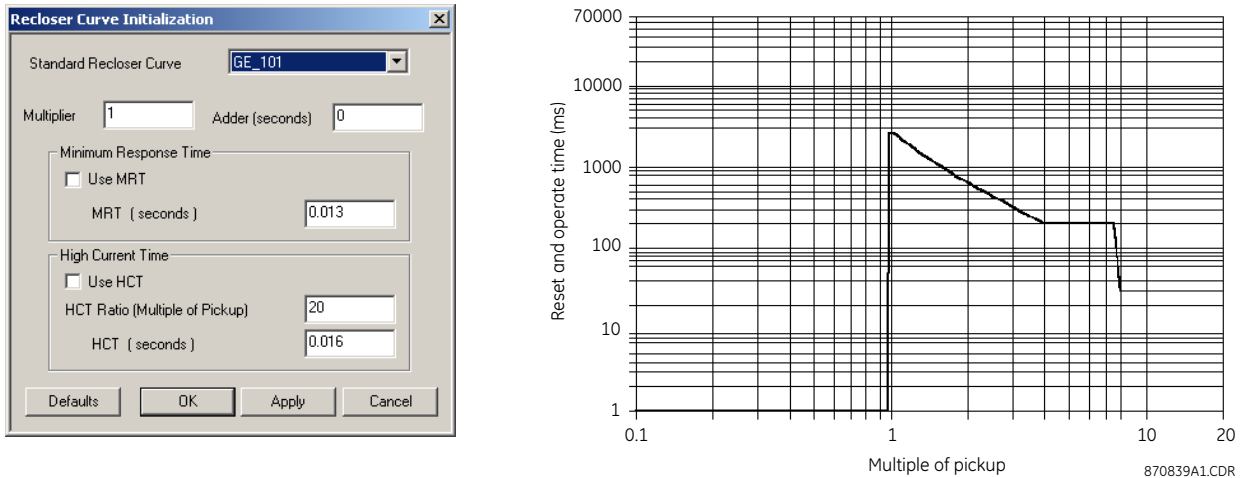


The multiplier and adder settings affect the curve portion of the characteristic and not the MRT and HCT settings. The HCT settings override the MRT settings for multiples of pickup greater than the HCT ratio.

Composite recloser curve example

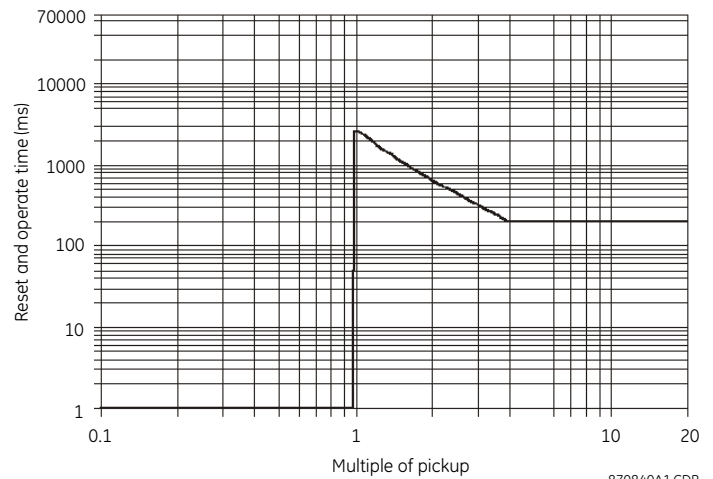
A composite curve can be created from the GE_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at eight times pickup with an operating time of 30 ms. At approximately four times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms (see figure).

Figure 322: Composite recloser curve with HCT disabled



With the HCT feature enabled, the operating time reduces to 30 ms for pickup multiples exceeding eight times pickup.

Figure 323: Composite recloser curve with HCT enabled



Configuring a composite curve with an increase in operating time at increased pickup multiples is not allowed. If this is attempted, the EnerVista UR^{PLUS} Setup software generates an error message and discards the proposed changes.

Protection inputs and outputs

Three groupings of protection inputs and outputs are defined: physical, shared, and virtual. Within these three groupings there are two types: analog and digital.

Protection virtual inputs

There are 64 virtual inputs that can be programmed individually to respond to input signals from the front panel interface and communications protocols. All virtual input operands are defaulted to off (logic 0) unless the appropriate input signal is received.

Select the **Settings > Protection > Protection Inputs/Outputs > Virtual Inputs** menu to access the protection virtual input configuration settings.

Figure 324: Protection virtual inputs configuration settings

PROT VIRT INPUT	FUNCTION	ID	TYPE	EVENTS
VIRT INPUT 1	Disabled	Virt Ip 1	Latched	Disabled
VIRT INPUT 2	Disabled	Virt Ip 2	Latched	Disabled
VIRT INPUT 3	Disabled	Virt Ip 3	Latched	Disabled
VIRT INPUT 4	Disabled	Virt Ip 4	Latched	Disabled
VIRT INPUT 5	Disabled	Virt Ip 5	Latched	Disabled
VIRT INPUT 6	Disabled	Virt Ip 6	Latched	Disabled
VIRT INPUT 7	Disabled	Virt Ip 7	Latched	Disabled
VIRT INPUT 8	Disabled	Virt Ip 8	Latched	Disabled
VIRT INPUT 9	Disabled	Virt Ip 9	Latched	Disabled
VIRT INPUT 10	Disabled	Virt Ip 10	Latched	Disabled
VIRT INPUT 11	Disabled	Virt Ip 11	Latched	Disabled
VIRT INPUT 12	Disabled	Virt Ip 12	Latched	Disabled
VIRT INPUT 13	Disabled	Virt Ip 13	Latched	Disabled
VIRT INPUT 14	Disabled	Virt Ip 14	Latched	Disabled
VIRT INPUT 15	Disabled	Virt Ip 15	Latched	Disabled
VIRT INPUT 16	Disabled	Virt Ip 16	Latched	Disabled

The following settings are available for each protection virtual input. The default values outlined are for virtual input 1.

Function

Range: Enabled, Disabled
 Default: Disabled

If this setting is “Disabled,” the virtual input is forced to off (logic 0) regardless of any attempt to alter the input. If set to “Enabled,” the input operates as shown on the logic diagram and generates output logic operands in response to received input signals and the applied settings.

ID

Range: up to 12 alphanumeric characters
 Default: Virt Ip 1

This setting specifies an identifier that can be assigned to each virtual input.

Type

Range: Self-Reset, Latched
 Default: Latched

There are two types of operation: self-reset and latched. If this setting is “Self-Reset,” the output operand is asserted (logic 1) for only one evaluation of the protection FlexLogic equations and then returns to 0 when the input signal transits from off to on. If set to “Latched,” the virtual input sets the state of the output operand to the same state as the most recent received input.



The self-reset operating mode generates an output operand for a single evaluation of FlexLogic equations. If the operand is to be used anywhere other than internally in an automation logic equation, it likely will have to be lengthened in time. A FlexLogic timer with a delayed reset can perform this function.

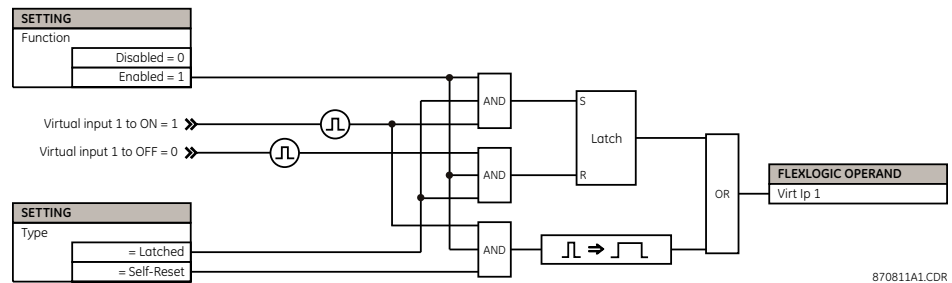
Events

Range: Enabled, Disabled
 Default: Disabled

When this setting is “Enabled,” every change in the protection virtual input state triggers an event in the sequence of events recorder.

The figure shows the protection virtual input logic. The logic is identical for all protection virtual inputs.

Figure 325: Protection virtual input logic



Protection virtual input actual values

Select the **Actual Values > Protection > Protection Inputs/Outputs > Virtual Inputs** menu to open the protection virtual input actual values window.

Figure 326: Protection virtual input actual values

PROT VIRTUAL INPUT	NAME	STATUS
VI 1	Virt Ip 1	Off
VI 2	Virt Ip 2	Off
VI 3	Virt Ip 3	Off
VI 4	Virt Ip 4	Off
VI 5	Virt Ip 5	Off
VI 6	Virt Ip 6	Off
VI 7	Virt Ip 7	Off
VI 8	Virt Ip 8	Off

The following actual values are available for all enabled protection virtual inputs.

Name

Range: up to 12 alphanumeric characters

This value displays the programmed **ID** for the corresponding protection virtual input.

Status

Range: On, Off

This value indicates the logic state of the virtual input.

Protection virtual outputs

There are 96 virtual outputs that can be assigned via FlexLogic. Virtual outputs are resolved in each pass through the evaluation of FlexLogic equations.

Select the **Settings > Protection > Protection Inputs/Outputs > Virtual Outputs** menu to access the protection virtual output configuration settings.

Figure 327: Protection virtual output settings

PROT VIRT OUTPUT	ID	EVENTS
VIRT OUTPUT 1	Virt Op 1	Disabled
VIRT OUTPUT 2	Virt Op 2	Disabled
VIRT OUTPUT 3	Virt Op 3	Disabled
VIRT OUTPUT 4	Virt Op 4	Disabled
VIRT OUTPUT 5	Virt Op 5	Disabled
VIRT OUTPUT 6	Virt Op 6	Disabled
VIRT OUTPUT 7	Virt Op 7	Disabled
VIRT OUTPUT 8	Virt Op 8	Disabled
VIRT OUTPUT 9	Virt Op 9	Disabled
VIRT OUTPUT 10	Virt Op 10	Disabled
VIRT OUTPUT 11	Virt Op 11	Disabled
VIRT OUTPUT 12	Virt Op 12	Disabled
VIRT OUTPUT 13	Virt Op 13	Disabled
VIRT OUTPUT 14	Virt Op 14	Disabled
VIRT OUTPUT 15	Virt Op 15	Disabled
VIRT OUTPUT 16	Virt Op 16	Disabled

The following settings are available for each protection virtual output. If not assigned, the virtual output is forced to off (logic 0).

ID

Range: up to 12 alphanumeric characters

Default: Virt Op 1

This setting specifies an identifier that can be assigned to each protection virtual output.

Events

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” every change in the protection virtual output state triggers an event in the sequence of events recorder.

Protection virtual output actual values

Select the **Actual Values > Protection > Protection Inputs/Outputs > Virtual Outputs** menu to open the protection virtual outputs actual values window.

Figure 328: Protection virtual output actual values

PROT VIRT OUTPUT	NAME	STATUS
VO 1	Virt Op 1	Off
VO 2	Virt Op 2	Off
VO 3	Virt Op 3	Off
VO 4	Virt Op 4	Off
VO 5	Virt Op 5	Off
VO 6	Virt Op 6	Off
VO 7	Virt Op 7	Off
VO 8	Virt Op 8	Off

The following actual values are available for all configured protection virtual outputs.

Name

Range: up to 12 alphanumeric characters

This value displays the programmed ID for the corresponding protection virtual output.

Status

Range: On, Off

This value indicates the logic state of the protection virtual output.

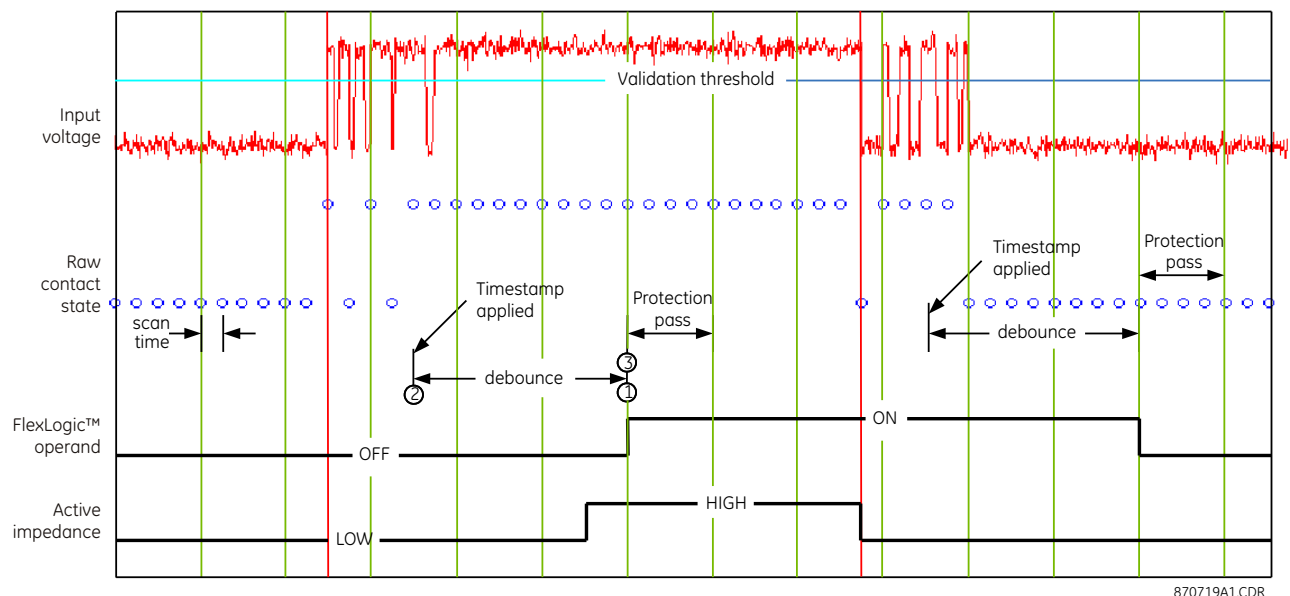
Contact input configuration

The D90^{Plus} can monitor the status of up to 115 field contacts. Each input can be wetted from the D90^{Plus} 48 volt auxiliary supply or from an external power supply. Each contact input has a dedicated delay timer for filtering of contact bouncing. The D90^{Plus} can also detect an oscillating input via the chatter feature. Each contact input has active impedance circuitry to provide security against false turn-on of an input due to excessive stray capacitance of field wiring.

A raw status is scanned synchronously for all contact inputs at the rate of 0.25 ms, as shown in the following figure. A new contact input state must be maintained for a user-programmable debounce time for the D90^{Plus} to validate the new contact state. The debounce time is set at 2.0 ms in the figure. As such, the eighth sample validates the change of state (mark 1 in the figure). Once validated (de-bounced), the contact input asserts a corresponding FlexLogic operand and logs an event (if event logging is enabled).

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the event recorder (mark 2 in the figure).

Figure 329: Contact input debouncing mechanism and time-stamping



Protection elements, as well as FlexLogic equations and timers, are executed 16 times in a power system cycle. The protection pass duration is controlled by the frequency tracking mechanism. The FlexLogic operand reflecting the debounced state of the contact is updated at the protection pass following the validation (mark 3 in the figure). The update is performed at the beginning of the protection pass so all protection functions and protection FlexLogic equations are fed with the updated states of the contact inputs.

The FlexLogic operand response time to the contact input change is equal to the debounce time setting plus a maximum of one protection pass (depending on system frequency if frequency tracking is enabled). If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass (that is, by the entire duration of the protection pass). If the change occurs just prior to a protection pass, the

state is recognized immediately. Statistically, a delay of half the protection pass is expected. Owing to the 0.25 ms scan rate, the time resolution for the input contact is less than 1 ms.

For example, 16 protection passes per cycle on a 60 Hz system correspond to a protection pass every 1.04 ms. With a contact debounce time setting of 3.0 ms, the FlexLogic operand assert time limits are: $3.0 + 0.0 = 3.0$ ms and $3.0 + 1.04 = 4.04$ ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1 ms accuracy using the time of the first scan corresponding to the new state. Therefore, the time stamp reflects a change in the DC voltage across the contact input terminals that was not accidental as it was subsequently validated using the debounce timer. Keep in mind that the associated FlexLogic operand is asserted/de-asserted later, after validating the change. The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the OFF-ON and ON-OFF transitions.

The active impedance feature controls the input impedance presented to the system according to the current state of the input. When the contact input circuitry initially detects a voltage increase, it draws 10 mA of current. If the state change is due to a transient coupled through the stray capacitance of the field wiring, then the high current sink charges the capacitance causing the transient to rapidly decay. If voltage increase is due to a state change of the field contact, then the increased current has no impact on the input voltage, and the state change is validated. Once the input has been declared to be on, the input circuitry reduces the current drawn to 1 mA to minimize the power dissipated by the input.



The contact input update time is 1 ms. However, depending on where the contact input status change is triggered within a one millisecond window, the worst-case contact input recognition time is 2 ms.

Contact input and output default assignment

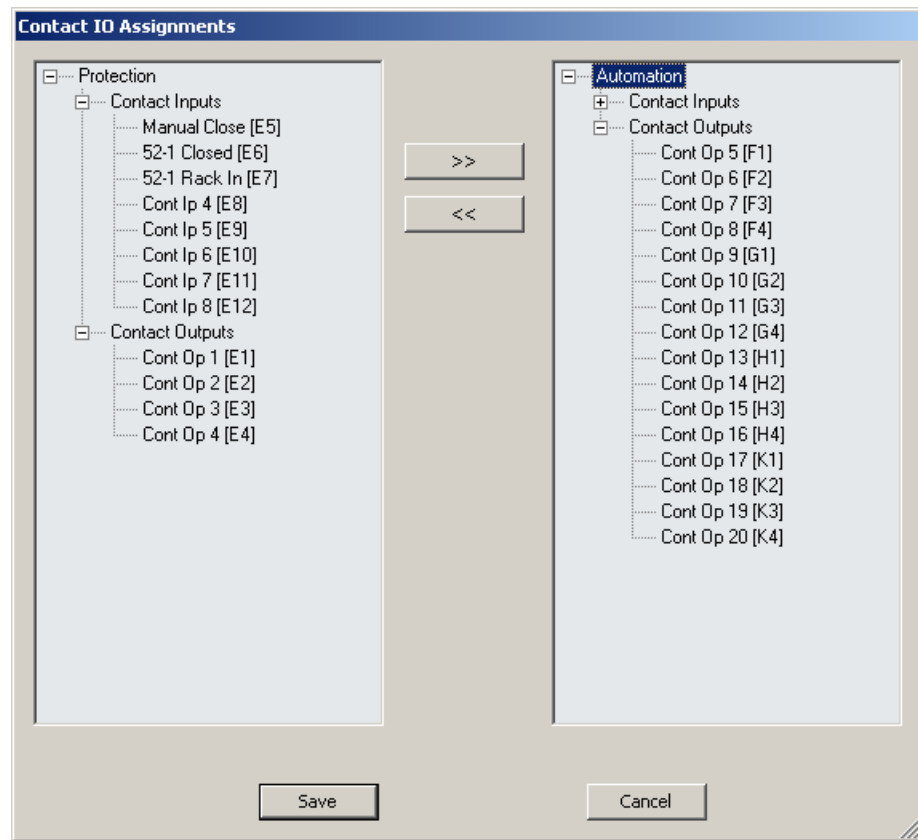
When a new settings file is created, the available contacts are assigned automatically to the protection or automation functions according to the following convention:

- First I/O module → protection
- All subsequent I/O modules → automation

For example, if a D90^{PLUS} is configured with contact input/output cards in slots E, F, and G, then the inputs and outputs associated with slot E are assigned to protection and the inputs and outputs associated with slots F and G are assigned to automation.

These default assignments can be changed to match the requirements of the application. This is done by right-clicking the setting filename and choosing the **Manage Settings File > I/O Assignments** item. The following window displays.

Figure 330: Contact input and output assignments



All available contact inputs and outputs can be reassigned using the >> and << buttons.

Contact input settings

When the input detects a voltage decrease, the input circuitry draws 10 mA of current. If the voltage decrease is due to a state change then the voltage quickly decreases, speeding up the recognition of the reset of the field contact.

Select the **Settings > Protection > Protection Inputs/Outputs > Contact Inputs > Contact Inputs** menu to access the contact input configuration settings.

Figure 331: Contact input configuration settings

CONTACT INPUT	ID	DEBOUNCE TIME	NOMINAL VOLTAGE	EVENTS
E5	BKR1 52a	2.00 ms	125 V	Enabled
E6	BKR2 52a	2.00 ms	125 V	Enabled
E7	Cont Ip 3	2.00 ms	125 V	Enabled
E8	Cont Ip 4	2.00 ms	125 V	Enabled
E9	Cont Ip 5	2.00 ms	125 V	Enabled
E10	Cont Ip 6	2.00 ms	125 V	Enabled
E11	Cont Ip 7	2.00 ms	125 V	Enabled
E12	Cont Ip 8	2.00 ms	125 V	Enabled

URPlus_03.urs Protection: Protection Inputs/Outputs: Contact Inputs

The contact inputs menu contains configuration settings for each contact input. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then displays settings for only those inputs. The following settings are available for each contact input.

ID

Range: up to 12 alphanumeric characters
Default: Cont Ip 1

An alphanumeric ID can be assigned to a contact input for diagnostic, setting, and event recording purposes. The “CONTACT IP 1” text in event records and FlexLogic operands are replaced by the text programmed in this setting.

Debounce Time

Range: 1.5 to 16.0 ms in steps of 0.25
Default: 2.0 ms

This setting defines the time required for the contact to overcome contact bouncing conditions. As this time differs for different contact types and manufacturers, program it as a maximum contact debounce time (per manufacturer specifications) plus additional margin to ensure proper operation.

Nominal Voltage

Range: 24 to 250 volts in steps of 1
Default: 125 volts

This setting specifies the range required to validate a closed contact input. This range is fixed at 70 to 130% of this setting value, with an absolute minimum of 20 volts and an absolute maximum of 285 volts.

Table 21: Nominal voltage setting for typical battery voltages

Nominal voltage	Validation threshold
24 V	20 V
48 V	33.6 V
125 V	87.5 V
250 V	175 V

Events

Range: Enabled, Disabled
Default: Disabled

If this setting is “Enabled,” every change in the contact input state triggers an event in the event recorder.

Contact input chatter detection

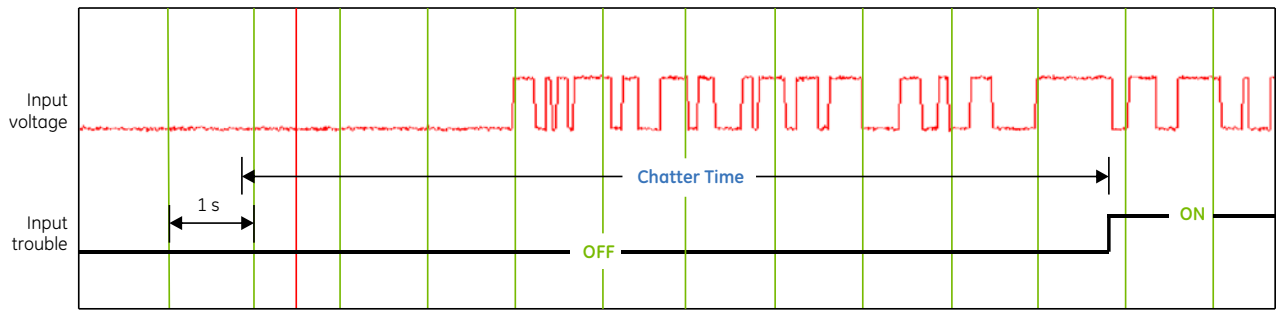
The D90^{Plus} has a chatter detection feature. When enabled, the IED monitors the number of state changes that occur within a set duration. If this value exceeds a set value, then a trouble condition is declared for the input and the **CONTACT INPUT TROUBLE** operand asserts.

The input trouble alarm impacts relay functionality as follows:

- FlexLogic operands: operand state is blocked
- DNP 3.0 communications: reporting of the input is blocked
- IEC 60870-5-104 communications: reporting of the input is blocked
- IEC 61850 GSSE and IEC 61850 GOOSE: reporting of the input is blocked
- Sequence of events recorder: reporting of the input is blocked

The trouble condition resets if the input undergoes no state changes for a duration equal to twice the chatter time setting.

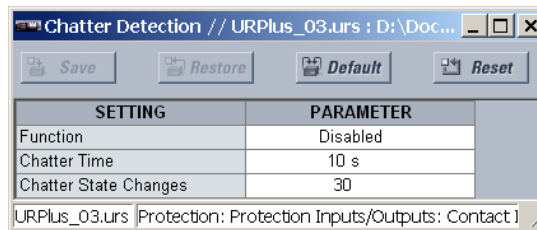
Figure 332: Chatter detection example



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Select the **Settings > Protection > Protection Inputs/Outputs > Contact Inputs > Chatter Detection** menu to access the contact input chatter detection settings.

Figure 333: Contact input chatter detection configuration



The following settings are applied to all available protection and automation contact inputs.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the chatter detection feature.

Chatter Time

Range: 1 to 100 seconds in steps of 1

Default: 10 seconds

This setting specifies the time window that the relay contacts are monitored for contact input state changes.

Chatter State Changes

Range: 10 to 100 in steps of 1

Default: 30

This setting specifies the number of state changes that must occur in the time window defined by the **Chatter Time** setting before issuing the trouble operand.

Since chatter detection is a hardware diagnostic, a trouble indication is logged regardless of the **Events** setting being enabled or disabled for a particular input.

Protection contact input actual values

Select the **Actual Values > Protection > Protection Inputs/Outputs > Contact Inputs** menu to open the protection contact input actual values window.

Figure 334: Protection contact input actual values

CONTACT INPUT	NAME	STATUS
E5	BKR1 52a	Off
E6	BKR2 52a	Off
E7	Cont Ip 3	Off
E8	Cont Ip 4	Off
E9	Cont Ip 5	Off
E10	Cont Ip 6	Off
E11	Cont Ip 7	Off
E12	Cont Ip 8	Off

The following actual values are available for all protection contact inputs.

Name

Range: up to 12 alphanumeric characters

This value displays the programmed ID for the corresponding protection contact input.

Status

Range: On, Off

This value indicates the logic state of the protection contact input.

Contact outputs

Upon startup of the unit, the main processor determines from an assessment of the modules installed in the chassis which contact outputs are available and presents the settings for only these outputs.

Select the **Settings > Protection > Protection Inputs/Outputs > Contact Outputs** menu to access the contact output configuration settings.

Figure 335: Protection contact output configuration settings

CONTACT OUTPUT	ID	OPERATE	SEAL-IN	VOLTAGE THRESHOLD	EVENTS
E1	BKR1 TR COIL	BKR1 TRIP CMD 3-POLE	BKR1 TR COIL IO _n (E1)	20	Enabled
E2	BKR1 CL COIL	BKR1 CLOSE CMD	BKR1 CL COIL IO _n (E2)	20	Enabled
E3	BKR2 TR COIL	BKR2 TRIP CMD 3-POLE	BKR2 TR COIL IO _n (E3)	20	Enabled
E4	BKR2 CL COIL	BKR2 CLOSE CMD	BKR2 CL COIL IO _n (E4)	20	Enabled

The following settings are available for all contact outputs.

ID

Range: up to 12 alphanumeric characters

Default: Cont Op 1

This setting specifies an alphanumeric identifier for the contact output.

Operate

Range: any FlexLogic operand or shared operand

Default: as shown above

This setting selects an operand (virtual output, element state, contact input, or virtual input) that operates the contact output when asserted.

Seal-In

Range: any FlexLogic operand or shared operand

Default: as shown above

This setting selects an operand (virtual output, element state, contact input, or virtual input) that seals-in the contact output when asserted.

Voltage Threshold

Range: 20 to 250 volts in steps of 1

Default: 20

This setting specifies the level at which the Contact Op 1 VOn and Contact Op 1 VOff operands function. It is only shown for contact outputs that have monitoring.

Events

Range: Enabled, Disabled

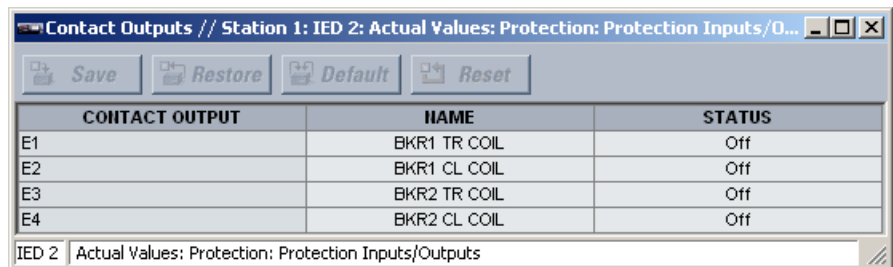
Default: Enabled

If this setting is "Enabled," every change in the contact output state triggers an event in the sequence of events recorder.

Protection contact output actual values

Select the **Actual Values > Protection > Protection Inputs/Outputs > Contact Outputs** item to open the protection contact output actual values window.

Figure 336: Protection contact output actual values



CONTACT OUTPUT	NAME	STATUS
E1	BKR1 TR COIL	Off
E2	BKR1 CL COIL	Off
E3	BKR2 TR COIL	Off
E4	BKR2 CL COIL	Off

The following actual values are available for all protection contact outputs.

Name

Range: up to 12 alphanumeric characters

This value displays the programmed **ID** for the corresponding protection contact output.

Status

Range: On, Off, VOn, VOff, IOn, IOff

This value indicates the logic state of the protection contact output.

Direct inputs

These settings specify how the direct input information is processed. Select the **Protection > Protection Inputs/Outputs > Direct Inputs** menu to open the direct inputs configuration window.

Figure 337: Direct inputs configuration settings

SETTING	CHANNEL 1	CHANNEL 2
Direct Input 1 Device ID	0	0
Direct Input 1 Bit Number	0	0
Direct Input 1 Default State	Off	Off
Direct Input 1 Events	Disabled	Disabled
Direct Input 2 Device ID	0	0
Direct Input 2 Bit Number	0	0
Direct Input 2 Default State	Off	Off
Direct Input 2 Events	Disabled	Disabled
Direct Input 3 Device ID	0	0
Direct Input 3 Bit Number	0	0
Direct Input 3 Default State	Off	Off
Direct Input 3 Events	Disabled	Disabled

The following settings are available all direct inputs. The settings outlined are for direct input 1.

Direct Input 1 Device ID

Range: 0 to 16 in steps of 1

Default: 0

This setting represents the source of the direct input. The specified direct input is driven by the device identified here.

Direct Input 1 Bit Number

Range: 0 to 96 in steps of 1

Default: 0

This setting specifies the bit number to extract the state for this direct input. The corresponding direct input is driven by the bit identified here. This setting also corresponds to the direct output number of the sending device.

Direct Input 1 Default State

Range: On, Off, Latest/On, Latest/Off

Default: Off

This setting represents the state of the direct input when the associated direct device is offline. The following choices are available:

- A value of "On" defaults the input to logic 1
- A value of "Off" defaults the input to logic 0
- A value of "Latest/On" freezes the input in case of lost communications. If the latest state is not known (such as after relay power-up but before the first communication exchange), the input defaults to logic 1. When communication resumes, the input becomes fully operational.
- A value of "Latest/Off" freezes the input in case of lost communications. If the latest state is not known (such as after relay power-up but before the first communication exchange), the input defaults to logic 0. When communication resumes, the input becomes fully operational.

Direct Input 1 Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of direct input events in the sequence of events recorder.

Direct input states

Select the **Actual Values > Protection > Protection Inputs/Outputs > Direct Inputs** menu to open the direct input states window.

Figure 338: Direct inputs states

PARAMETER	CHANNEL 1	CHANNEL 2
Direct Input 1 State	0	0
Direct Input 2 State	0	0
Direct Input 3 State	0	0
Direct Input 4 State	0	0
Direct Input 5 State	0	0
Direct Input 6 State	0	0
Direct Input 7 State	0	0
Direct Input 8 State	0	0

The following actual values are available for all direct inputs, where input 1 is used as the example.

Direct Input 1 State

Range: 0, 1

This value displays the current state of the direct input. A value of "0" indicates off and a value of "1" indicates on.

Direct device states

Select the **Actual Values > Protection > Protection Inputs/Outputs > Direct Devices** menu to open the direct device states window.

Figure 339: Direct device states

PARAMETER	CHANNEL 1	CHANNEL 2
Direct Device 1 State	0	0
Direct Device 2 State	0	0
Direct Device 3 State	0	0
Direct Device 4 State	0	0
Direct Device 5 State	0	0
Direct Device 6 State	0	0
Direct Device 7 State	0	0
Direct Device 8 State	0	0

The following actual values are available for all direct devices. The actual values outlined are for direct device 1.

Direct Device 1 State

Range: Offline, Online

This value displays the current state of the direct device.

Direct outputs

These settings specify how the direct output information is processed. Select the **Settings > Protection Inputs/Outputs > Direct Outputs** menu to open the direct outputs configuration window.

Figure 340: Direct output configuration settings

SETTING	CHANNEL 1	CHANNEL 2
Direct Output 1 Operand	OFF	OFF
Direct Output 1 Events	Disabled	Disabled
Direct Output 2 Operand	OFF	OFF
Direct Output 2 Events	Disabled	Disabled
Direct Output 3 Operand	OFF	OFF
Direct Output 3 Events	Disabled	Disabled

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The following settings are available for all direct outputs. The default values outlined are for direct output 1.

Direct Input 1 Operand

Range: any FlexLogic operand

Default: Off

This setting specifies the FlexLogic operand that determines the state of the direct output.

Direct Input 1 Events

Range: Enabled, Disabled

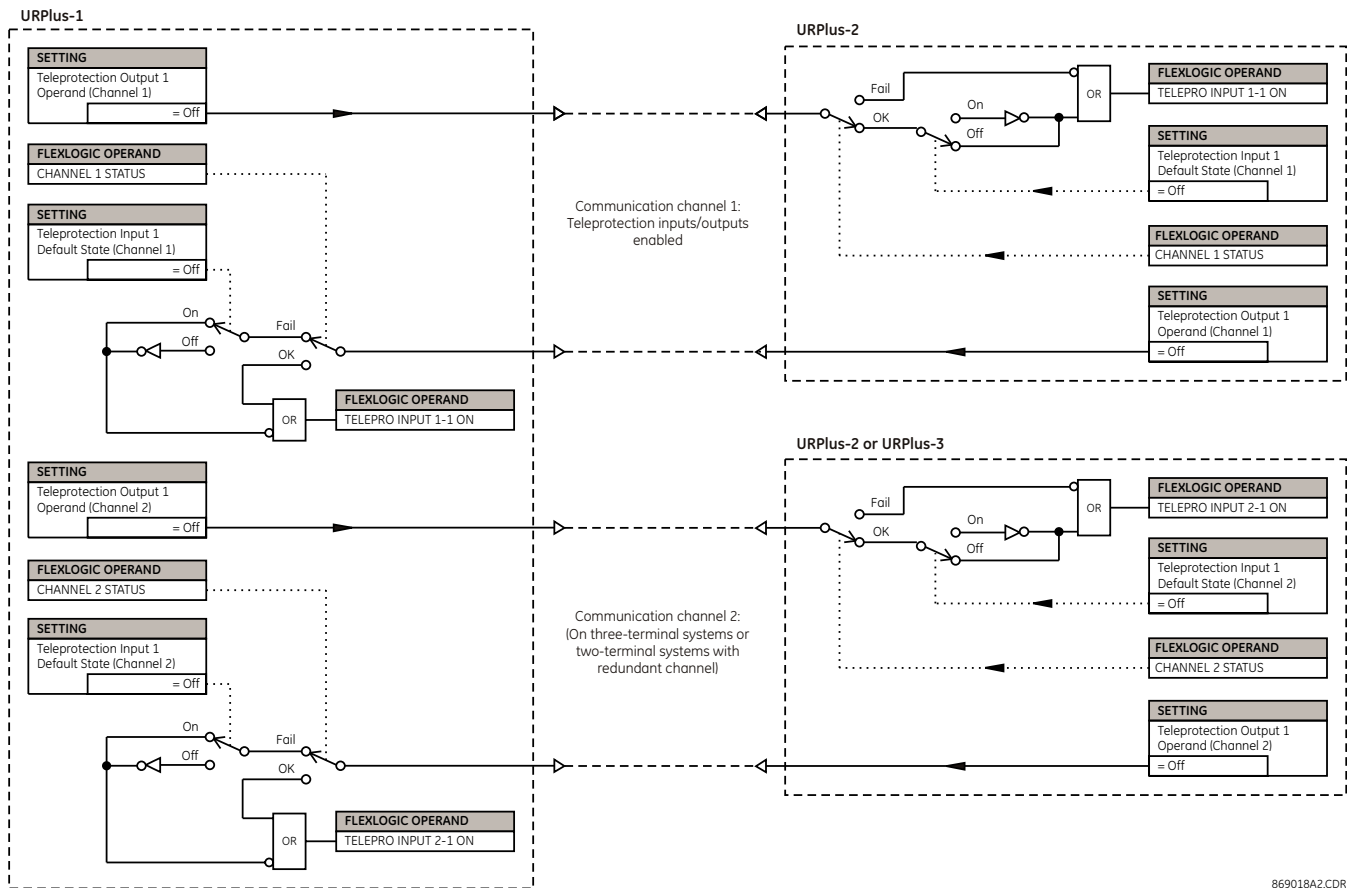
Default: Disabled

This setting enables and disables the logging of direct output events in the sequence of events recorder.

Teleprotection inputs and outputs

The D90^{Plus} provides 16 teleprotection inputs on communication channel 1 (numbered 1-1 through 1-16) and 16 teleprotection inputs on communication channel 2 (on two-terminals two-channel and three-terminal systems only, numbered 2-1 through 2-16). The remote relay connected to channels 1 and 2 of the local relay is programmed by assigning FlexLogic operands to be sent via the selected communication channel. This allows the user to create distributed protection and control schemes via dedicated communication channels. Some examples are directional comparison pilot schemes and direct transfer tripping. Note that failures of communication channels affect teleprotection functionality. The teleprotection function must be enabled to utilize the inputs.

Figure 341: Teleprotection inputs and outputs processing



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Teleprotection input settings

Select the **Settings > Protection > Protection Inputs/Outputs > Teleprotection > Teleprotection Inputs** menu to open the teleprotection inputs configuration window.

Figure 342: Teleprotection inputs configuration settings

SETTING	CHANNEL 1	CHANNEL 2
Teleprotection Input 1 Default States	Off	Off
Teleprotection Input 2 Default States	Off	Off
Teleprotection Input 3 Default States	Off	Off
Teleprotection Input 4 Default States	Off	Off
Teleprotection Input 5 Default States	Off	Off
Teleprotection Input 6 Default States	Off	Off
Teleprotection Input 7 Default States	Off	Off
Teleprotection Input 8 Default States	Off	Off
Teleprotection Input 9 Default States	Off	Off
Teleprotection Input 10 Default States	Off	Off
Teleprotection Input 11 Default States	Off	Off
Teleprotection Input 12 Default States	Off	Off
Teleprotection Input 13 Default States	Off	Off
Teleprotection Input 14 Default States	Off	Off
Teleprotection Input 15 Default States	Off	Off
Teleprotection Input 16 Default States	Off	Off

The following setting is available for all 16 teleprotection inputs on channels 1 and 2.

Teleprotection Input 1 Default States

Range: Off, On, Latest/Off, Latest/On
Default: Off

Programming this setting to “On” defaults the input to logic 1 when the channel fails. A value of “Off” defaults the input to logic 0 when the channel fails.

The “Latest/On” and “Latest/Off” values freeze the input in case of lost communication. If the latest state is not known, such as after relay power-up but before the first communication exchange, then the input defaults to logic 1 for “Latest/On” and logic 0 for “Latest/Off.”

Teleprotection output settings

Select the **Settings > Protection > Protection Inputs/Outputs > Teleprotection > Teleprotection Outputs** menu to open the teleprotection outputs configuration window.

Figure 343: Teleprotection outputs configuration settings

SETTING	CHANNEL 1	CHANNEL 2
Teleprotection Output 1 Operands	OFF	OFF
Teleprotection Output 2 Operands	OFF	OFF
Teleprotection Output 3 Operands	OFF	OFF
Teleprotection Output 4 Operands	OFF	OFF
Teleprotection Output 5 Operands	OFF	OFF
Teleprotection Output 6 Operands	OFF	OFF
Teleprotection Output 7 Operands	OFF	OFF
Teleprotection Output 8 Operands	OFF	OFF
Teleprotection Output 9 Operands	OFF	OFF
Teleprotection Output 10 Operands	OFF	OFF
Teleprotection Output 11 Operands	OFF	OFF
Teleprotection Output 12 Operands	OFF	OFF
Teleprotection Output 13 Operands	OFF	OFF
Teleprotection Output 14 Operands	OFF	OFF
Teleprotection Output 15 Operands	OFF	OFF
Teleprotection Output 16 Operands	OFF	OFF

The following setting is available for all 16 teleprotection inputs on channels 1 and 2.

Teleprotection Output 1 Operands

Range: any FlexLogic operand
Default: Off

Processing of the teleprotection inputs and outputs is dependent on the number of communication channels and terminals. On two-terminal two-channel systems, they are processed continuously on each channel and mapped separately per channel. Therefore, to achieve redundancy, the user must assign the same operand on both channels (teleprotection outputs at the sending end or corresponding teleprotection inputs at the receiving end). On three-terminal two-channel systems, redundancy is achieved by programming signal re-transmittal in the case of channel failure between any pair of UR^{PLUS}-series devices.

Teleprotection input actual values

Select the **Actual Values > Protection > Protection Inputs/Outputs > Teleprotection Inputs** menu to open the teleprotection inputs states window.

Figure 344: Teleprotection input states

PARAMETER	CHANNEL 1	CHANNEL 2
Teleprotection Input 1 State	0	0
Teleprotection Input 2 State	0	0
Teleprotection Input 3 State	0	0
Teleprotection Input 4 State	0	0
Teleprotection Input 5 State	0	0
Teleprotection Input 6 State	0	0
Teleprotection Input 7 State	0	0
Teleprotection Input 8 State	0	0
Teleprotection Input 9 State	0	0
Teleprotection Input 10 State	0	0
Teleprotection Input 11 State	0	0
Teleprotection Input 12 State	0	0
Teleprotection Input 13 State	0	0
Teleprotection Input 14 State	0	0
Teleprotection Input 15 State	0	0
Teleprotection Input 16 State	0	0

The following actual value is available for all 16 teleprotection inputs on channels 1 and 2.

Teleprotection Input 1 State

Range: Off, On, Latest/On, Latest/Off

This actual value displays the state of the teleprotection input on channels 1 and 2.

The “Latest/On” and “Latest/Off” values freeze the input in case of lost communication. If the latest state is not known, such as after relay power-up but before the first communication exchange, then the input defaults to logic 1 for “Latest/On” and logic 0 for “Latest/Off.”

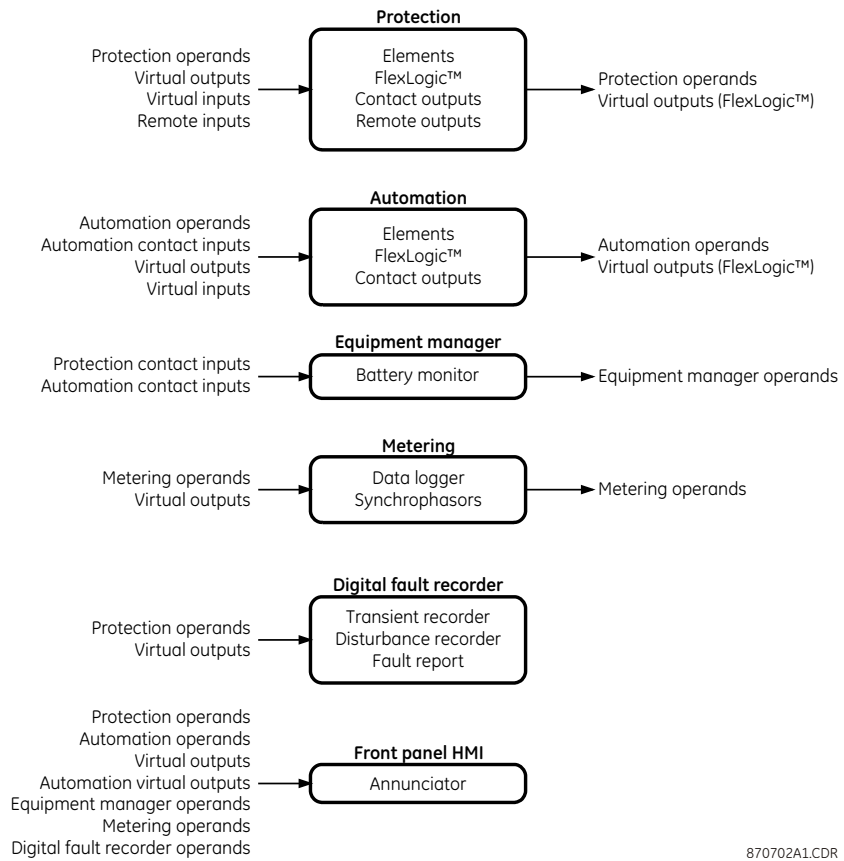
Using shared operands in protection

The EnerVista UR^{Plus} Setup software groups the D90^{Plus} system into the following eight primary functions. Each function has its own settings and each generates its own outputs in the form of operands.

- Communications
- Protection
- Automation
- Digital fault recorder (DFR)
- Metering
- Equipment manager
- Self-tests
- Front panel interface (HMI)

It is often desirable for an output from an element within one function to be available to an element within another function. For example, it can be useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available to each function, as shown.

Figure 345: Default operand list by function



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The content of each operand list depends on the order code.

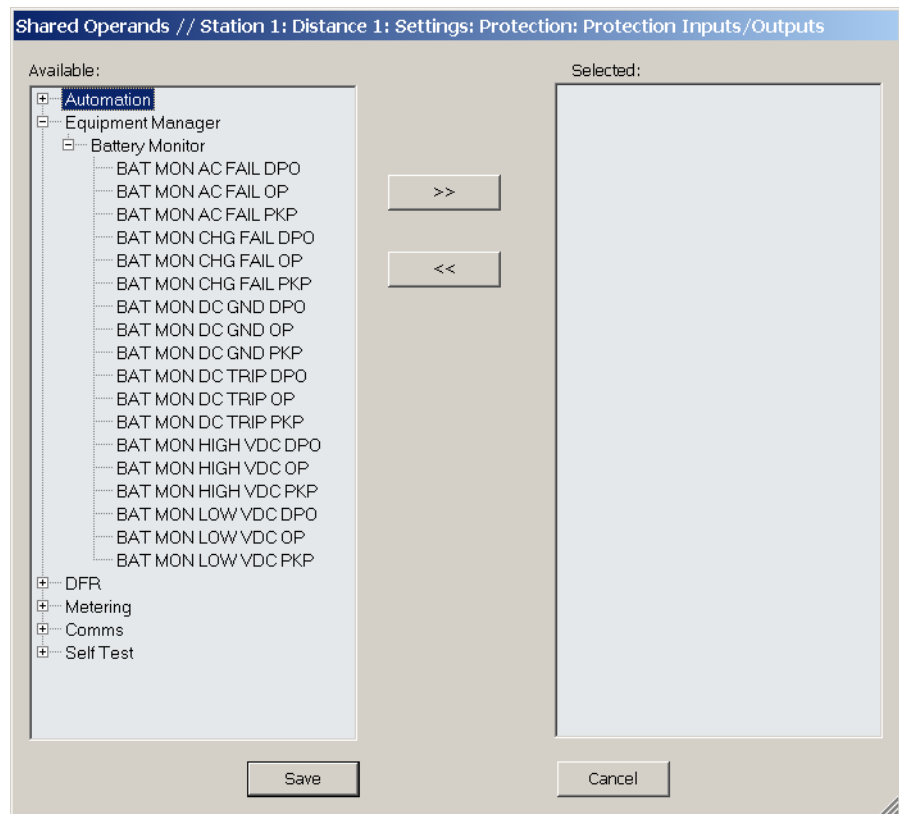
The shared operands functionality expands upon this system. An output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals then can be assigned as inputs to other functions.

For example, assume that the **GND TOC1 OP** protection operand is required as a signal within the automation function. This operand then is assigned as a shared operand and subsequently becomes available to the automation function. A total of 64 operands can be assigned as shared operands within each function.

Shared protection operands

Select the **Settings > Protection > Protection Inputs/Outputs > Shared Operands** menu to select the shared protection FlexLogic operands.

Figure 346: Shared operands configuration window

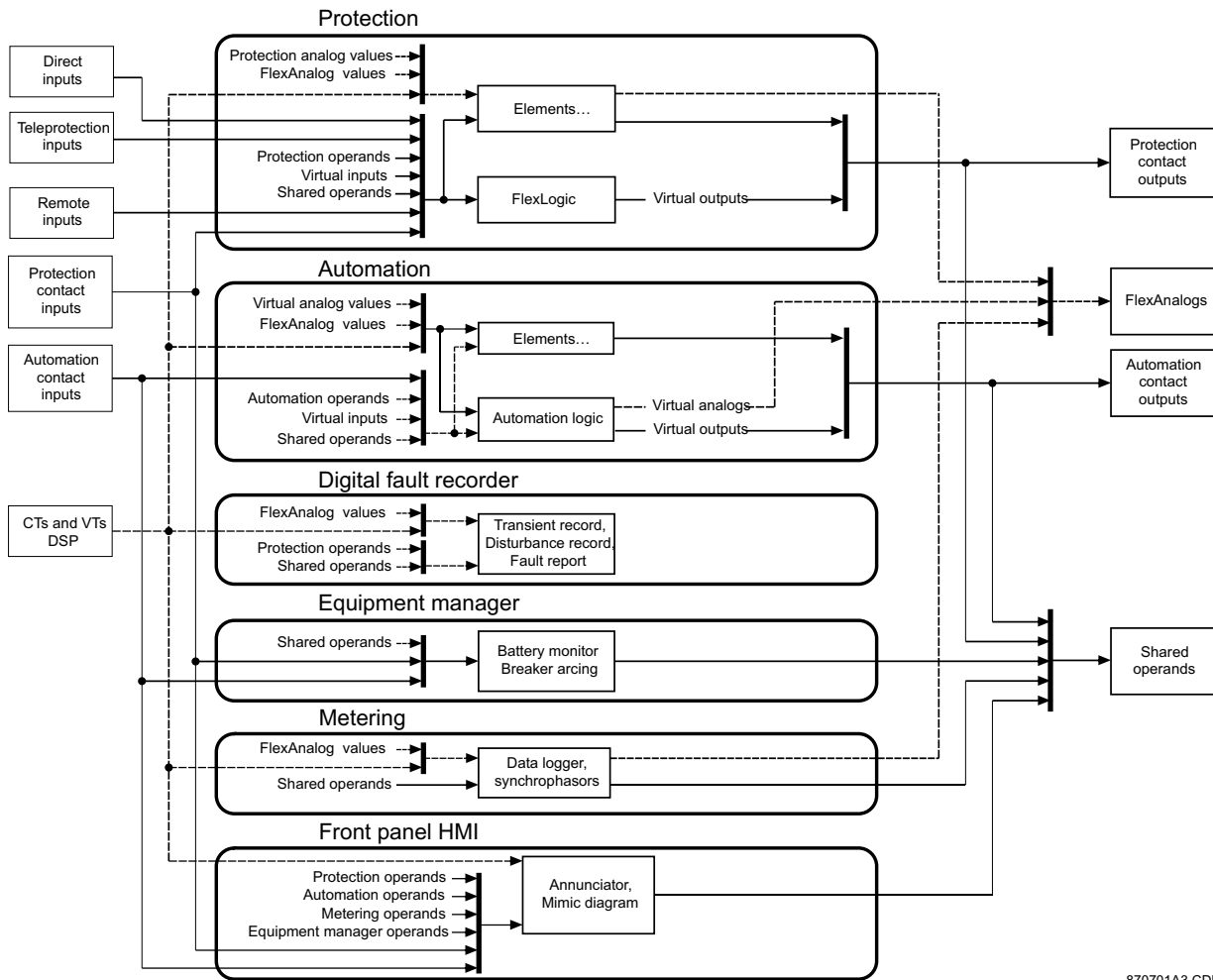


The left side of this screen displays all D90^{Plus} operands that are available to the protection function as shared operands. Select any operands from the other five primary features by clicking the >> button. Operands can be de-assigned as shared operands by clicking the << button.

Protection FlexLogic

The arrangement of internal digital logic in the D90^{Plus} combines fixed and user-programmable parameters. The logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through FlexLogic. In general, the system receives analog and digital inputs that it uses to produce analog and digital outputs. The major sub-systems of a generic UR^{Plus}-series device involved in this process are shown here.

Figure 347: UR^{Plus}-series architecture overview



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The states of all digital signals used in the D90^{Plus} are represented by flags (or FlexLogic operands, which are described later in this section). A logic 1 state is represented by a set flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in a FlexLogic equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is desired, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic is required, it is implemented via FlexLogic. For example, to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the phase time overcurrent element, the two control input states are programmed in a FlexLogic equation. This equation ANDs the two control inputs to produce a virtual output, which is then selected when programming the phase time overcurrent to be used as a blocking input. Virtual outputs can only be created by FlexLogic equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. FlexLogic minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed FlexLogic).

FlexLogic allows users to customize the relay through a series of equations that consist of operators and operands. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a virtual output. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

A FlexLogic equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a timer. Each equation defines the combinations of parameters to be used to set a virtual output flag. Evaluation of an equation results in either a logic 1 state (=ON, flag set) or logic 0 state (=OFF, flag not set). Each equation is evaluated at least four times every power system cycle.

Some types of operands are present in the relay in multiple instances (for example, contact and remote inputs). These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are tabulated as follows.

Table 22: Protection FlexLogic operand types

Type	State	Example	Characteristics (input is logic 1 or "on" if...)
Contact input	On	CONT IP1 ON	Voltage is presently applied to the input (external contact closed)
	Off	CONT IP1 OFF	Voltage is presently not applied to the input (external contact open)
Contact output	Voltage on	CONT OP1 VON	Voltage exists across the contact
	Voltage off	CONT OP1 VOFF	Voltage does not exist across the contact
	Current on	CONT OP1 ION	Current is flowing through the contact
	Current off	CONT OP1 IOFF	Current is not flowing through the contact
Digital counter	Greater than	COUNTER 1 HI	The number of pulses counted is above the set number
	Equal to	COUNTER 1 EQL	The number of pulses counted is equal to the set number
	Less than	COUNTER 1 LO	The number of pulses counted is below the set number
Direct input	On	DIRECT INPUT 1 ON	The direct input is presently in the ON state
Element (analog)	Pickup	PHASE TOC1 PKP	The tested parameter is presently above the pickup setting of an element that responds to rising values or below the pickup setting of an element that responds to falling values
	Dropout	PHASE TOC1 DPO	This operand is the logical inverse of the pickup operand
	Operate	PHASE TOC1 OP	The tested parameter has been above/below the pickup setting of the element for the programmed delay time, or has been at logic 1 and is now at logic 0 but the reset timer has not finished timing
	Block	PHASE TOC1 BLK	The output of the comparator is set to the block function

Type	State	Example	Characteristics (input is logic 1 or "on" if...)
Element (digital)	Pickup	DIG ELEM 1 PKP	The output operand is at logic 1
	Dropout	DIG ELEM 1 DPO	This operand is the logical inverse of the pickup operand
	Operate	DIG ELEM 1 OP	The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing
Fixed	On	ON	Logic 1
	Off	OFF	Logic 0
Remote input	On	REMOTE IN 1 ON	The remote input is presently in the on state
Virtual input	On	VIRT IP 1 ON	The virtual input is presently in the on state
Virtual output	On	VIRT OP 1 ON	The virtual output is presently in the on state

Protection FlexLogic gates and operators

The table summarizes characteristics of logic gates used in protection FlexLogic equations.

Table 23: Protection FlexLogic gate characteristics

Gate	Inputs	Output is logic 1 if...
NOT	1	the input is logic 0
OR	2 to 16	any input is logic 1
AND	2 to 16	all inputs are logic 1
NOR	2 to 16	all inputs are logic 0
NAND	2 to 16	any input is logic 0
XOR	2	only one input is logic 1

The following operators are available for use in protection FlexLogic equations.

Table 24: Protection FlexLogic operators

Type	Syntax	Description	Operation
Editor	INSERT	Insert a parameter in the equation list	---
	DELETE	Delete a parameter from an equation list	---
End	END	The first END operator signifies the last entry in the FlexLogic equation	---
One shots	POSITIVE ONE SHOT	One shot that corresponds to a positive-going edge	A <i>one shot</i> refers to a single input gate that generates a pulse in response to an edge on the input. The output from a one shot is true (positive) for only one pass through the FlexLogic equation. There are a maximum of 64 one shots.
	NEGATIVE ONE SHOT	One shot that corresponds to a negative-going edge	
	DUAL ONE SHOT	One shot that responds to both the positive and negative-going edges	

Type	Syntax	Description	Operation
Logic gates	NOT	A logical NOT gate	Operates on the previous parameter
	AND(<i>n</i>)	An <i>n</i> -input AND gate, <i>n</i> = 1 to 16	Operates on the previous <i>n</i> parameters
	OR(<i>n</i>)	An <i>n</i> -input OR gate, <i>n</i> = 1 to 16	Operates on the previous <i>n</i> parameters
	NOR(<i>n</i>)	An <i>n</i> -input NOR gate, <i>n</i> = 1 to 16	Operates on the previous <i>n</i> parameters
	NAND(<i>n</i>)	An <i>n</i> -input NAND gate, <i>n</i> = 1 to 16	Operates on the previous <i>n</i> parameters
	XOR(2)	A two-input exclusive OR gate	Operates on the previous 2 parameters
	LATCH(S,R)	Latch (set, reset), reset-dominant	Operates on the previous 2 parameters. The parameter preceding LATCH(S,R) is the reset input. The parameter preceding the reset input is the set input.
Timers	TIMER <i>n</i>	Timer set with the settings programmed for FlexLogic timer <i>n</i> , where <i>n</i> = 1 to 32	The timer is started by the preceding parameter. The output of the timer is TIMER #.
Assign outputs	VIRT OP <i>n</i>	Assigns the previous FlexLogic parameter to virtual output <i>n</i> , where <i>n</i> = 1 to 96	The virtual output is set by the preceding parameter

FlexLogic rules

When forming a protection FlexLogic equation, the sequence in the linear array of parameters must follow these general rules.

1. Logic operands must precede the logic operator that uses the operands as inputs.
2. Logic operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.
3. Assigning the output of a logic operator to a virtual output terminates the equation.
4. A timer operator (for example **TIMER 1**) or virtual output assignment (for example, = **Virt Op 1**) can be used only once. If this rule is broken, a syntax error is declared.

Protection FlexLogic equation editor

A protection FlexLogic equation can contain up to 512 entries, including the **END** operator. If a disabled element is selected as a FlexLogic entry, the associated state flag is never asserted (set to logic 1).

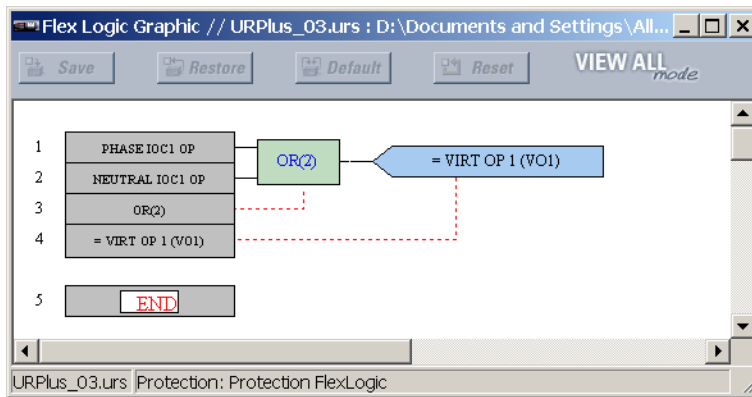
Select the **Settings > Protection > Protection FlexLogic > FlexLogic Equation Editor** menu to open the protection FlexLogic equation editor window.

Figure 348: Protection FlexLogic configuration settings

FLEXLOGIC ENTRY	TYPE	SYNTAX	COMMENTS
View Graphic	View	View	
FlexLogic Entry 1	Protection Element	PHASE IOC1 OP	
FlexLogic Entry 2	Protection Element	NEUTRAL IOC1 OP	
FlexLogic Entry 3	OR	2 Input	
FlexLogic Entry 4	Assign Virtual Output	= Virt Op 1 (VO1)	
FlexLogic Entry 5	End Of List		
FlexLogic Entry 6	End Of List		

A graphical representation of the protection FlexLogic can be displayed by clicking the **View** button at the top of the equation.

Figure 349: Typical protection FlexLogic display



Protection FlexLogic timers

There are 32 identical protection FlexLogic timers available. These timers can be used as operators in FlexLogic equations.

Select the **Settings > Protection > Protection FlexLogic > FlexLogic Timers** menu to open the protection FlexLogic timers configuration window.

Figure 350: Protection FlexLogic timers configuration settings

PROTECTION TIMER	PICKUP DELAY	DROPOUT DELAY
PROT TIMER 1	0 ms	0 ms
PROT TIMER 2	0 ms	0 ms
PROT TIMER 3	0 ms	0 ms
PROT TIMER 4	0 ms	0 ms
PROT TIMER 5	0 ms	0 ms

The following settings are available for each protection FlexLogic timer.

Pickup Delay

Range: 0 to 3600000000 ms in steps of 1

Default: 0

This setting specifies the time delay to pickup. If a pickup delay is not required, set this value to "0."

Dropout Delay

Range: 0 to 3600000000 ms in steps of 1

Default: 0

This setting specifies the time delay to dropout. If a dropout delay is not required, set this value to "0."

Non-volatile latches

The non-volatile latches provide a permanent logical flag that is stored safely and does not reset upon reboot after the relay is powered down. Typical applications include sustaining operator commands or permanently blocking relay functions, such as autoreclose, until a deliberate interface action resets the latch. There are 16 non-volatile latches available for use in protection schemes.

Select the **Settings > Protection > Protection FlexLogic > Non-Volatile Latches** menu to open the non-volatile latches configuration window.

Figure 351: Non-volatile latches configuration settings

PROTECTION LATCH	FUNCTION	TYPE	SET	RESET	EVENTS
PROT LATCH 1	Disabled	Reset Dominant	OFF	OFF	Disabled
PROT LATCH 2	Disabled	Reset Dominant	OFF	OFF	Disabled
PROT LATCH 3	Disabled	Reset Dominant	OFF	OFF	Disabled
PROT LATCH 4	Disabled	Reset Dominant	OFF	OFF	Disabled
PROT LATCH 5	Disabled	Reset Dominant	OFF	OFF	Disabled

The following settings are available for each latch.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the corresponding protection non-volatile latch.

Type

Range: Reset Dominant, Set Dominant

Default: Reset Dominant

This setting selects the non-volatile latch as set-dominant or reset-dominant.

Set

Range: any FlexLogic operand or shared operand

Default: OFF

If the operand assigned to this setting is asserted, the non-volatile latch is set.

Reset

Range: any FlexLogic operand or shared operand

Default: OFF

If the operand assigned to this setting is asserted, the non-volatile latch is reset.

Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of non-volatile latch events in the sequence of events recorder.

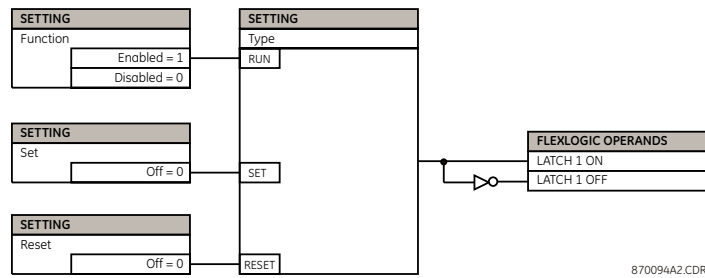
The following table summarizes the operation of non-volatile latches.

Table 25: Non-volatile latch operation table

Type	Latch operation			
	Set	Reset	On	Off
Reset-dominant	ON	OFF	ON	OFF
	OFF	OFF	Previous state	Previous state
	ON	ON	OFF	ON
	OFF	ON	OFF	ON
Set-dominant	ON	OFF	ON	OFF
	ON	ON	ON	OFF
	OFF	OFF	Previous state	Previous state
	OFF	ON	OFF	ON

The figure shows the logic diagram for protection non-volatile latches.

Figure 352: Non-volatile latch logic



Protection FlexElements

A FlexElement is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference between any two analog actual values of the same type. The effective operating signal can be treated as a signed number or an absolute value. The output from a FlexElement can also be used for further logic processing. The number of FlexElements dedicated is 16.

The element can be programmed to respond either to a signal level or to a rate-of-change (delta) over a pre-defined period of time. The output operand is asserted when the operating signal is higher than a threshold or lower than a user-specified threshold.

Select the **Settings > Protection > Protection FlexLogic > FlexElements** menu to open the protection FlexElements configuration window.

Figure 353: Protection FlexElements configuration settings

PARAMETER	FLEXELEMENTS 1	FLEXELEMENTS 2
Function	Disabled	Disabled
Name	FxE 1	FxE 2
Input Plus	OFF	OFF
Input Minus	OFF	OFF
Input Mode	SIGNED	SIGNED
Compare Mode	LEVEL	LEVEL
Direction Type	OVER	OVER
Pickup	1.000 pu	1.000 pu
Hysteresis	3.0 %	3.0 %
DeltaT Units	Milliseconds	Milliseconds
DeltaT	20	20
Pickup Delay	0.000 s	0.000 s
Reset Delay	0.000 s	0.000 s
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each protection FlexElement.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the corresponding FlexElement.

Name

Range: up to 6 alphanumeric characters

Default: FxE 1

An alphanumeric identifier can be assigned to a FlexElement for diagnostic, setting, and event recording purposes. The default "FxE 1" text that appears in event records and logic operands are replaced by the text programmed in this setting.

Input Plus

Range: any analog actual value parameter or OFF

Default: OFF

This setting specifies the first (non-inverted) input to the FlexElement. A value of zero is assumed as the input if this setting is "OFF." For proper operation of the element, at least one input must be selected. Otherwise, the element does not assert its output operands.

Input Minus

Range: any analog actual value parameter or OFF

Default: OFF

This setting specifies the second (inverted) input to the FlexElement. A value of zero is assumed as the input if this setting is set to "OFF." For proper operation of the element at least one input must be selected. Otherwise, the element does not assert its output operands. Use this input to invert the signal if needed for convenience, or to make the element respond to a differential signal such as for a top-bottom oil temperature differential alarm. The element does not operate if the two input signals are of different types (for example if one tries to use active power and phase angle to build the effective operating signal).

Input Mode

Range: Signed, Absolute

Default: Signed

If this setting value is "Signed," then the FlexElement responds directly to the differential signal. If this setting value is "Absolute," then the FlexElement responds to the absolute value of the differential signal. Sample applications for the absolute input mode include monitoring the angular difference between two phasors with a symmetrical limit angle in both directions, monitoring power regardless of its direction, or monitoring a trend regardless of whether the signal increases or decreases.

Compare Mode

Range: Level, Delta

Default: Level

This setting specifies how the element responds to its operating signal. If this setting value is "Level," the element responds directly to its operating signal (as defined by the **Input Plus**, **Input Minus**, and **Input Mode** settings). If this setting value is "Delta," the element responds to the rate of change of its operating signal (as defined by the **Delta T** and **Delta T Units** settings).

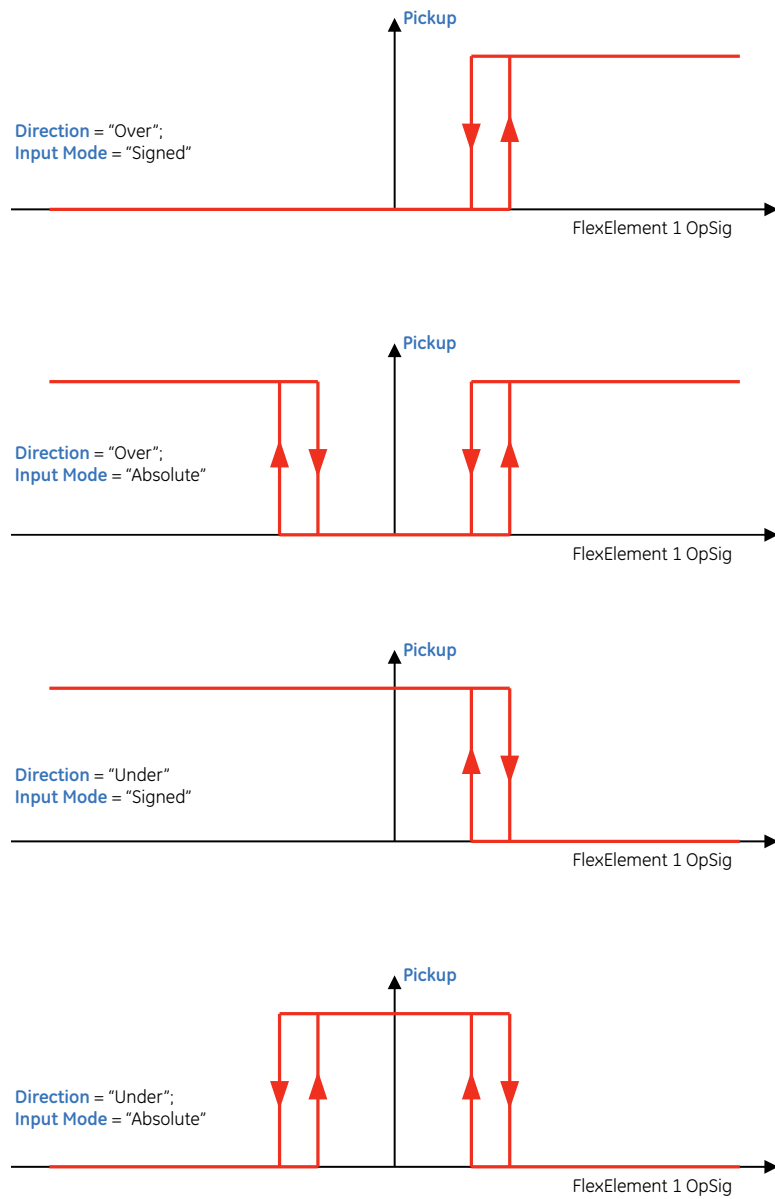
Direction Type

Range: Over, Under

Default: Over

This setting enables the relay to respond to either high or low values of the operating signal.

Figure 354: Relationship of input mode and direction settings



Pickup

Range: -90.000 to 90.000 pu in steps of 0.001

Default: 1.000 pu

This setting specifies the operating threshold for the effective operating signal of the FlexElement. If the **Direction Type** setting is "Over," the element picks up when the operating signal exceeds the value specified here. If the **Direction Type** setting is "Under," the element picks up when the operating signal falls below the value specified here.

This setting is entered in per-unit values using the following definitions of the base units.

Table 26: Protection FlexElement pickup per-unit base units

Element	Base unit
Frequency	1 Hz
Power factor	1.00

Element	Base unit
Source current	Maximum nominal primary RMS value of the +IN and -IN inputs
Source power	Maximum value of the product of the voltage and current base values for the +IN and -IN inputs
Source voltage	Maximum nominal primary RMS value of the +IN and -IN inputs

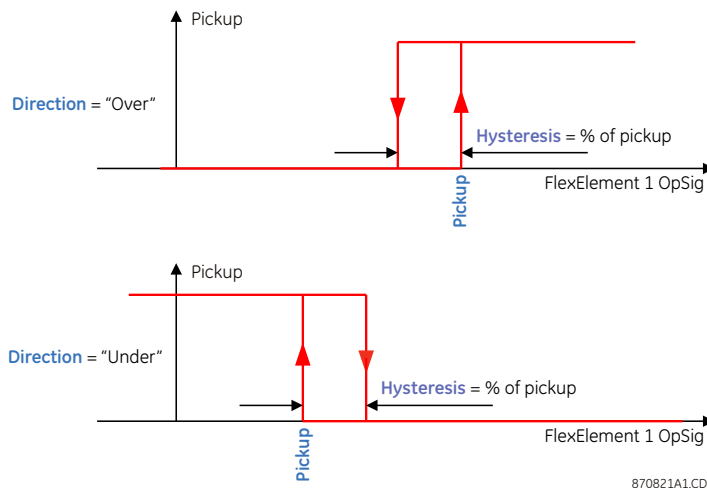
Hysteresis

Range: 0.1 to 50.0% in steps of 0.1

Default: 3.0%

This setting controls the element pickup and dropout relation by specifying the width of the hysteresis loop as a percentage of the pickup value. Both the operating signal and the pickup threshold can be negative, facilitating applications such as reverse power alarm protection. The FlexElement can be programmed to work with all analog actual values measured by the relay.

Figure 355: Direction, pickup, and hysteresis relation



Delta T Units

Range: milliseconds, seconds, minutes

Default: milliseconds

This setting specifies the time unit for the **Delta T** setting. It is applicable only in the delta comparison mode.

Delta T

Range: 20 to 86400 in steps of 1

Default: 20

This setting specifies duration of the time interval for the rate of change mode of operation. It is applicable only in the delta comparison mode.

Pickup Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies the pickup delay of the FlexElement.

Reset Delay

Range: 0.000 to 65.535 seconds in steps of 0.001

Default: 0.000 seconds

This setting specifies the reset delay of the FlexElement.

Block

Range: any FlexLogic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting blocks operation of the FlexElement.

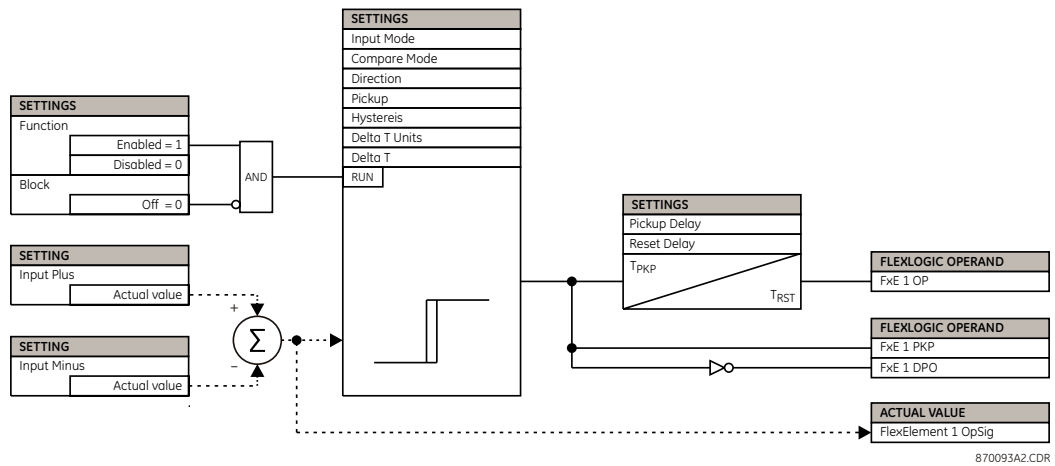
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of FlexElement events in the sequence of events recorder.

The figure shows the logic diagram for FlexElements.

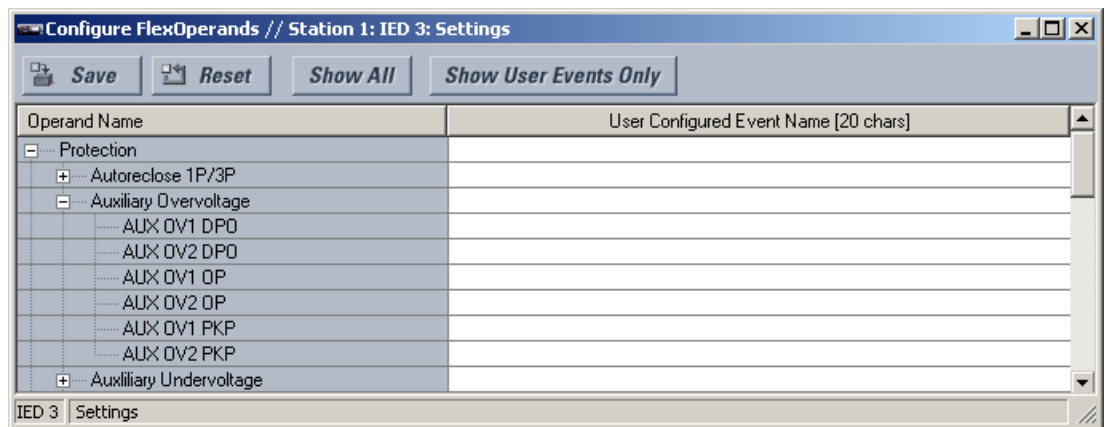
Figure 356: Protection FlexElements logic



Customizing the protection FlexLogic operands

Select the **Settings > Configure FlexOperands** menu to open the user-configurable operands window.

Figure 357: User-configurable protection FlexLogic operands window



The left side of this screen displays all operands that are currently available to the D90^{PLUS}. The protection FlexLogic operands are displayed by expanding the **Protection** entry. Each operand can be renamed with a user-specified value to provide additional information or match specific applications.

User Configured Event Name

Range: up to 20 alphanumeric characters

Default: ---

Each available protection FlexLogic operand can be renamed to a user-specified value. This feature allows users to rename operands to allow for clearer identification or to match specific applications. The new operand name appears in protection and automation logic, in settings that take operands as their value, and in event reports.

Protection FlexLogic operands

The following protection FlexLogic operands are available for the D90^{PLUS}. They are listed alphabetically by operand syntax. The definitions reflect the default operand names. Some operands can be renamed within their settings window, including the names of breakers, contact inputs, virtual inputs, and virtual outputs. All operands can also be assigned user-defined names through the **Settings > Configure FlexOperands** menu.

Autoreclose operands

AR 1-P RIP	Asserted when a single-pole autoreclose is in progress.
AR 3-P/1 RIP	Asserted when a three-pole autoreclose is in progress via dead time 1.
AR 3-P/2 RIP	Asserted when a three-pole autoreclose is in progress via dead time 2.
AR 3-P/3 RIP	Asserted when a three-pole autoreclose is in progress via dead time 3.
AR 3-P/4 RIP	Asserted when a three-pole autoreclose is in progress via dead time 4.
AR BKR1 BLK	Asserted when reclosure of breaker 1 is blocked.
AR BKR2 BLK	Asserted when reclosure of breaker 2 is blocked.
AR CLOSE BKR1.....	Asserted when a close breaker 1 signal is issued.
AR CLOSE BKR2.....	Asserted when a close breaker 2 signal is issued.
AR DISABLED	Asserted when the autoreclose element is disabled.
AR ENABLED	Asserted when the autoreclose element is enabled.
AR FORCE 3-P TRIP	Asserted when a trip is forced to a three-phase trip.
AR INCOMPLETE SEQ.....	Asserted when the incomplete sequence timer times out.
AR LO	Asserted when the autoreclose element is in the lockout state.
AR RESET.....	Asserted when the autoreclose element has been reset manually or by the reset timer.
AR RIP	Asserted when the autoreclose element is in the reclose-in-progress state.
AR SHOT CNT > 0.....	Asserted when the first close breaker signal has been issued.
AR SHOT CNT = 1.....	Asserted when the shot count is equal to 1.
AR SHOT CNT = 2.....	Asserted when the shot count is equal to 2.
AR SHOT CNT = 3.....	Asserted when the shot count is equal to 3.
AR SHOT CNT = 4.....	Asserted when the shot count is equal to 4.
AR ZONE 1 EXTENT.....	Asserted when the zone 1 distance function is set to the extended over-reach value.

Auxiliary overvoltage operands

AUX OV1 DPO	Asserted when the auxiliary overvoltage element drops out.
AUX OV1 OP.....	Asserted when the auxiliary overvoltage element operates.
AUX OV1 PKP.....	Asserted when the auxiliary overvoltage element picks up.

Auxiliary undervoltage operands

AUX UV1 DPO..... Asserted when the auxiliary undervoltage element drops out.
 AUX UV1 OP Asserted when the auxiliary undervoltage element operates.
 AUX UV1 PKP..... Asserted when the auxiliary undervoltage element picks up.

Breaker configuration operands

BKR1 ANY POLE OPEN Asserted when at least one pole of breaker 1 is open.
 BKR1 BAD STATE Asserted when the normally open and normally closed breaker indications disagree.
 BKR1 CLOSE CMD..... Asserted when close command is executed on breaker 1.
 BKR1 CLOSED..... Asserted when breaker 1 is closed.
 BKR1 DISCREPANCY..... Asserted when the three poles of the breaker disagree (that is, when they are not all opened or all closed).
 BKR1 INTERMED..... Asserted when the breaker is in transition between the opened and closed states.
 BKR1 ONE POLE OPEN..... Asserted when only one pole of breaker 1 is open.
 BKR1 OPEN CMD Asserted when an open command has been executed on breaker 1.
 BKR1 OPENED..... Asserted when breaker 1 is opened.
 BKR1 SUBST CLOSED..... Asserted when the status of breaker 1 has been substituted with a closed indication.
 BKR1 SUBST ON..... Asserted when breaker status substitution is enabled.
 BKR1 SUBST OPENED..... Asserted when the status of the breaker has been substituted with an opened indication.
 BKR1 TRIP CMD A..... Asserted when a close command is executed on pole A of breaker 1.
 BKR1 TRIP CMD B..... Asserted when a close command is executed on pole B of breaker 1.
 BKR1 TRIP CMD C..... Asserted when a close command is executed on pole C of breaker 1.
 BKR1A BAD STATE..... Asserted when the normally open and normally closed breaker indications disagree for pole A of breaker 1.
 BKR1A CLOSED..... Asserted when breaker 1 pole A is closed.
 BKR1A INTERMED..... Asserted when breaker 1 pole A is in transition between the opened and closed states.
 BKR1A OPENED..... Asserted when breaker 1 pole A is opened.
 BKR1B BAD STATE..... Asserted when the normally open and normally closed breaker indications disagree for pole B of breaker 1.
 BKR1B CLOSED..... Asserted when breaker 1 pole B is closed.
 BKR1B INTERMED..... Asserted when breaker 1 pole B is in transition between the opened and closed states.
 BKR1B OPENED..... Asserted when breaker 1 pole B is opened.
 BKR1C BAD STATE..... Asserted when the normally open and normally closed breaker indications disagree for pole C of breaker 1.
 BKR1C CLOSED..... Asserted when breaker 1 pole C is closed.
 BKR1C INTERMED..... Asserted when breaker 1 pole C is in transition between the opened and closed states.
 BKR1C OPENED..... Asserted when breaker 1 pole C is opened.
 BKR2..... The operands listed above are also available for breaker 2.

Breaker failure operands

BKR FAIL 1 RETRIP..... Asserted upon a breaker failure 1 three-pole trip.

BKR FAIL 1 RETRIPA.....	Asserted when breaker failure 1 re-trips on phase A (single-pole schemes only).
BKR FAIL 1 RETRIPB.....	Asserted when breaker failure 1 re-trips on phase B (single-pole schemes only).
BKR FAIL 1 RETRIPC.....	Asserted when breaker failure 1 re-trips on phase C (single-pole schemes only).
BKR FAIL 1 T1 OP.....	Asserted when the breaker failure 1 timer 1 operates.
BKR FAIL 1 T2 OP.....	Asserted when the breaker failure 1 timer 2 operates.
BKR FAIL 1 T3 OP.....	Asserted when the breaker failure 1 timer 3 operates.
BKR FAIL 1 TRIP OP.....	Asserted when breaker failure 1 trip has operated.
BKR FAIL 2	The same set of operands listed above are available for the breaker failure 2 element.

Breaker flashover operands

BKR 1 FLSHOVR DPO.....	Asserted when breaker 1 flashover drops out.
BKR 1 FLSHOVR DPO A.....	Asserted when breaker 1 flashover drops out for phase A.
BKR 1 FLSHOVR DPO B.....	Asserted when breaker 1 flashover drops out for phase B.
BKR 1 FLSHOVR DPO C.....	Asserted when breaker 1 flashover drops out for phase C.
BKR 1 FLSHOVR OP.....	Asserted when breaker 1 flashover operates.
BKR 1 FLSHOVR OP A.....	Asserted when breaker 1 flashover operates for phase A.
BKR 1 FLSHOVR OP B.....	Asserted when breaker 1 flashover operates for phase B.
BKR 1 FLSHOVR OP C.....	Asserted when breaker 1 flashover operates for phase C.
BKR 1 FLSHOVR PKP.....	Asserted when breaker 1 flashover picks up.
BKR 1 FLSHOVR PKP A.....	Asserted when breaker 1 flashover picks up for phase A.
BKR 1 FLSHOVR PKP B.....	Asserted when breaker 1 flashover picks up for phase B.
BKR 1 FLSHOVR PKP C.....	Asserted when breaker 1 flashover picks up for phase C.
BKR 2 FLSHOVR.....	The operands listed above are available for the breaker flashover 2 element.

Protection contact input operands

CONTACT IP 1 ON.....	Asserted when the field contact connected to contact input 1 is closed.
CONTACT IP 1 OFF.....	Asserted when the field contact connected to contact input 1 is opened.
CONTACT IP 1 TROUBLE OP.....	Asserted when there is an internal or external problem with contact input 1.
CONTACT IP 1 TROUBLE DPO.....	Asserted when there are no problems with contact input 1.
CONTACT IP 2 to 40.....	The operands listed above are available for the contact inputs 2 through 40.

Digital counter operands

COUNTER 1 EQL.....	Asserted when the output of digital counter 1 is equal to the comparison value.
COUNTER 1 HI.....	Asserted when the output of digital counter 1 is greater than the comparison value.
COUNTER 1 LO.....	Asserted when the output of digital counter 1 is less than the comparison value.
COUNTER 2 to 8.....	The operands listed above are also available for digital counters 2 through 8.

Directional comparison unblocking scheme operands

DCUB OP.....	Asserted when the directional comparison unblocking scheme operates.
--------------	--

DCUB TRIP A	Asserted when the directional comparison unblocking scheme operates to trip phase A.
DCUB TRIP B	Asserted when the directional comparison unblocking scheme operates to trip phase B.
DCUB TRIP C	Asserted when the directional comparison unblocking scheme operates to trip phase C.
DCUB TRIP 3P	Asserted when the directional comparison unblocking scheme operates to trip all three phases.
DCUB TX1	Asserted when the directional comparison unblocking scheme asserts transmit bit 1.
DCUB TX2	Asserted when the directional comparison unblocking scheme asserts transmit bit 2.
DCUB TX3	Asserted when the directional comparison unblocking scheme asserts transmit bit 3.
DCUB TX4	Asserted when the directional comparison unblocking scheme asserts transmit bit 4.

Directional comparison blocking scheme operands

DIR BLOCK OP	Asserted when the directional blocking scheme operates.
DIR BLOCK TRIP A	Asserted when the directional blocking scheme operates to trip phase A.
DIR BLOCK TRIP B	Asserted when the directional blocking scheme operates to trip phase B.
DIR BLOCK TRIP C	Asserted when the directional blocking scheme operates to trip phase C.
DIR BLOCK TRIP 3P	Asserted when the directional blocking scheme operates to trip all three phases.
DIR BLOCK TX INIT	Asserted when the directional blocking signal is initiated.
DIR BLOCK TX1 STOP	Asserted when the directional blocking scheme de-asserts transmit bit 1.
DIR BLOCK TX2 STOP	Asserted when the directional blocking scheme de-asserts transmit bit 2.
DIR BLOCK TX3 STOP	Asserted when the directional blocking scheme de-asserts transmit bit 3.
DIR BLOCK TX4 STOP	Asserted when the directional blocking scheme de-asserts transmit bit 4.

Direct underreaching transfer trip operands

DUTT OP	Asserted when the direct underreaching transfer trip scheme operates.
DUTT TRIP A	Asserted when the direct underreaching transfer trip scheme operates to trip phase A.
DUTT TRIP B	Asserted when the direct underreaching transfer trip scheme operates to trip phase B.
DUTT TRIP C	Asserted when the direct underreaching transfer trip scheme operates to trip phase C.
DUTT TRIP 3P	Asserted when the direct underreaching transfer trip scheme operates to trip all three phases.
DUTT TX1	Asserted when the direct underreaching transfer trip scheme asserts transmit bit 1.
DUTT TX2	Asserted when the direct underreaching transfer trip scheme asserts transmit bit 2.

- DUTT TX3 Asserted when the direct underreaching transfer trip scheme asserts transmit bit 3.
- DUTT TX4 Asserted when the direct underreaching transfer trip scheme asserts transmit bit 4.

FlexMatrix operands

- FLXMAT 1 DPO Asserted when FlexMatrix 1 drops out.
- FLXMAT 1 OP Asserted when FlexMatrix 1 operates.
- FLXMAT 1 PKP Asserted when FlexMatrix 1 picks up.
- FLXMAT 2 to 8 The operands listed above are also available for FlexMatrix elements 2 through 8.

FlexElement operands

- FXE 1 DPO Asserted when protection FlexElement 1 drops out.
- FXE 1 OP Asserted when protection FlexElement 1 operates.
- FXE 1 PKP Asserted when protection FlexElement 1 picks up.
- FXE 2 to 16 The operands listed above are also available for protection FlexElements 2 through 16.

Ground distance operands

- GND DIST Z1 DPO A Asserted when ground distance zone 1 phase A drops out.
- GND DIST Z1 DPO B Asserted when ground distance zone 1 phase B drops out.
- GND DIST Z1 DPO C Asserted when ground distance zone 1 phase C drops out.
- GND DIST Z1 OP Asserted when ground distance zone 1 operates.
- GND DIST Z1 OP A Asserted when ground distance zone 1 phase A operates.
- GND DIST Z1 OP B Asserted when ground distance zone 1 phase B operates.
- GND DIST Z1 OP C Asserted when ground distance zone 1 phase C operates.
- GND DIST Z1 PKP Asserted when ground distance zone 1 picks up.
- GND DIST Z1 PKP A Asserted when ground distance zone 1 phase A picks up.
- GND DIST Z1 PKP B Asserted when ground distance zone 1 phase B picks up.
- GND DIST Z1 PKP C Asserted when ground distance zone 1 phase C picks up.
- GND DIST Z1 SUPN IN Asserted when ground distance zone 1 neutral is supervising.
- GND DIST Z2 DIR SUPN Asserted when ground distance zone 2 directional is supervising. This operand is only available for zone 2.
- GND DIST Z2 to Z5 The operands listed above are also available for ground distance elements 2 through 5.

Ground instantaneous overcurrent operands

- GROUND IOC1 DPO Asserted when ground instantaneous overcurrent 1 drops out.
- GROUND IOC1 OP Asserted when ground instantaneous overcurrent 1 operates.
- GROUND IOC1 PKP Asserted when ground instantaneous overcurrent 1 picks up.
- GROUND IOC2 to 12 The operands listed above are also available for ground instantaneous overcurrent elements 2 through 12.

Ground time overcurrent operands

- GROUND TOC1 DPO Asserted when ground time overcurrent 1 drops out.
- GROUND TOC1 OP Asserted when ground time overcurrent 1 operates.
- GROUND TOC1 PKP Asserted when ground time overcurrent 1 picks up.
- GROUND TOC2 to 6 The operands listed above are also available for ground time overcurrent elements 2 through 6.

Hybrid permissive overreaching transfer trip (hybrid POTT) operands

- HYBRID POTT OP Asserted when the hybrid permissive overreaching transfer trip scheme operates.

HYBRID POTT TRIP A	Asserted when the hybrid permissive overreaching transfer trip scheme operates to trip phase A.
HYBRID POTT TRIP B	Asserted when the hybrid permissive overreaching transfer trip scheme operates to trip phase B.
HYBRID POTT TRIP C	Asserted when the hybrid permissive overreaching transfer trip scheme operates to trip phase C.
HYBRID POTT TRIP 3P	Asserted when the hybrid permissive overreaching transfer trip scheme operates to trip all three phases.
HYBRID POTT TX1	Asserted when the hybrid permissive overreaching transfer trip scheme asserts transmit bit 1.
HYBRID POTT TX2	Asserted when the hybrid permissive overreaching transfer trip scheme asserts transmit bit 2.
HYBRID POTT TX3	Asserted when the hybrid permissive overreaching transfer trip scheme asserts transmit bit 3.
HYBRID POTT TX4	Asserted when the hybrid permissive overreaching transfer trip scheme asserts transmit bit 4.

Non-volatile latch operands

LATCH 1 OFF	Asserted when non-volatile latch 1 is off (logic 0).
LATCH 1 ON	Asserted when non-volatile latch 1 is on (logic 1).
LATCH 2 to 16	The operands listed above are also available for non-volatile latches 2 to 16.

Line pickup operands

LINE PICKUP DPO	Asserted when the line pickup element drops out.
LINE PICKUP I<A	Asserted when the line pickup element detects phase A current less than 5% of nominal.
LINE PICKUP I<B	Asserted when the line pickup element detects phase B current less than 5% of nominal.
LINE PICKUP I<C	Asserted when the line pickup element detects phase C current less than 5% of nominal.
LINE PICKUP LEO PKP	Asserted when the line pickup element line end open feature picks up.
LINE PICKUP OP	Asserted when the line pickup element operates.
LINE PICKUP PKP	Asserted when the line pickup element picks up.
LINE PICKUP RCL TRIP	Asserted when the line pickup element operates from overreaching zone 2 when reclosing the line (zone 1 extension functionality).
LINE PICKUP UV PKP	Asserted when the line pickup undervoltage protection picks up.

Load encroachment operands

LOAD ENCRO DPO	Asserted when the load encroachment element picks up.
LOAD ENCRO OP	Asserted when the load encroachment element operates.
LOAD ENCRO PKP	Asserted when the load encroachment element drops out.

Negative-sequence directional overcurrent operands

NEG SEQ DIR OC1 FWD	Asserted when the negative-sequence directional overcurrent 1 element forward mode operates.
NEG SEQ DIR OC1 REV	Asserted when the negative-sequence directional overcurrent 1 element reverse mode operates.
NEG SEQ DIR OC2 FWD	Asserted when the negative-sequence directional overcurrent 2 element forward mode operates.

NEG SEQ DIR OC2 REV Asserted when the negative-sequence directional overcurrent 2 element reverse mode operates.

Negative-sequence instantaneous overcurrent operands

NEG SEQ IOC1 DPO Asserted when the negative-sequence instantaneous overcurrent 1 element drops out.

NEG SEQ IOC1 OP Asserted when the negative-sequence instantaneous overcurrent 1 element operates.

NEG SEQ IOC1 PKP Asserted when the negative-sequence instantaneous overcurrent 1 element picks up.

NEG SEQ IOC2 The operands listed above are also available for negative-sequence instantaneous overcurrent 2.

Negative-sequence overvoltage operands

NEG SEQ OV DPO Asserted when the negative-sequence overvoltage element drops out.

NEG SEQ OV OP Asserted when the negative-sequence overvoltage element operates.

NEG SEQ OV PKP Asserted when the negative-sequence overvoltage element picks up.

Negative-sequence time overcurrent operands

NEG SEQ TOC1 DPO Asserted when the negative-sequence time overcurrent 1 element drops out.

NEG SEQ TOC1 OP Asserted when the negative-sequence time overcurrent 1 element operates.

NEG SEQ TOC1 PKP Asserted when the negative-sequence time overcurrent 1 element picks up.

NEG SEQ TOC2 The operands listed above are also available for negative-sequence time overcurrent 2.

Neutral instantaneous overcurrent operands

NEUTRAL IOC1 DPO Asserted when the neutral instantaneous overcurrent 1 element drops out.

NEUTRAL IOC1 OP Asserted when the neutral instantaneous overcurrent 1 element operates.

NEUTRAL IOC1 PKP Asserted when the neutral instantaneous overcurrent 1 element picks up.

NEUTRAL IOC2 to 12 The operands listed above are also available for neutral instantaneous overcurrent 2 through 12.

Neutral overvoltage operands

NEUTRAL OV1 DPO Asserted when the neutral overvoltage 1 element drops out.

NEUTRAL OV1 OP Asserted when the neutral overvoltage 1 element operates.

NEUTRAL OV1 PKP Asserted when the neutral overvoltage 1 element picks up.

NEUTRAL OV2 to 3 The operands listed above are also available for neutral overvoltage 2 and 3.

Neutral time overcurrent operands

NEUTRAL TOC1 DPO Asserted when the neutral time overcurrent 1 element drops out.

NEUTRAL TOC1 OP Asserted when the neutral time overcurrent 1 element operates.

NEUTRAL TOC1 PKP Asserted when the neutral time overcurrent 1 element picks up.

NEUTRAL TOC 2 to 6 The operands listed above are also available for neutral time overcurrent 2 through 6.

Neutral directional overcurrent operands

NTRL DIR OC1 FWD Asserted when the neutral directional overcurrent 1 element forward mode operates.
 NTRL DIR OC1 REV Asserted when the neutral directional overcurrent 1 element reverse mode operates.
 NTRL DIR OC2 FWD Asserted when the neutral directional overcurrent 2 element forward mode operates.
 NTRL DIR OC2 REV Asserted when the neutral directional overcurrent 2 element reverse mode operates.

Open pole detector operands

OPEN POLE BKR Φ A OPEN Asserted when an open pole condition is detected on phase A, based on breaker auxiliary contacts.
 OPEN POLE BKR Φ B OPEN Asserted when an open pole condition is detected on phase B, based on breaker auxiliary contacts.
 OPEN POLE BKR Φ C OPEN Asserted when an open pole condition is detected on phase C, based on breaker auxiliary contacts.
 OPEN POLE BLK AB Asserted when the blocking signal for the AB phase distance elements is established.
 OPEN POLE BLK BC Asserted when the blocking signal for the BC phase distance elements is established.
 OPEN POLE BLK CA Asserted when the blocking signal for the CA phase distance elements is established.
 OPEN POLE BLK N Asserted when the blocking signal for the neutral, ground, and negative-sequence overcurrent elements is established.
 OPEN POLE OP Asserted when the open pole detector operates.
 OPEN POLE OP Φ A Asserted when an open pole condition is detected in phase A.
 OPEN POLE OP Φ B Asserted when an open pole condition is detected in phase B.
 OPEN POLE OP Φ C Asserted when an open pole condition is detected in phase C.
 OPEN POLE REM OP Φ A Asserted when a remote open pole condition is detected in phase A.
 OPEN POLE REM OP Φ B Asserted when a remote open pole condition is detected in phase B.
 OPEN POLE REM OP Φ C Asserted when a remote open pole condition is detected in phase C.

Phase directional overcurrent operands

PH DIR1 BLK Asserted when the phase directional overcurrent 1 element is blocked.
 PH DIR1 BLK A Asserted when the phase directional overcurrent 1 element is blocked in phase A.
 PH DIR1 BLK B Asserted when the phase directional overcurrent 1 element is blocked in phase B.
 PH DIR1 BLK C Asserted when the phase directional overcurrent 1 element is blocked in phase C.
 PH DIR 2 Same set of operands as shown above for the phase directional overcurrent 2 element.

Phase distance operands

PH DIST Z1 DPO AB Asserted when phase distance zone 1 phase AB drops out.
 PH DIST Z1 DPO BC Asserted when phase distance zone 1 phase BC drops out.

PH DIST Z1 DPO CA.....	Asserted when phase distance zone 1 phase CA drops out.
PH DIST Z1 OP	Asserted when phase distance zone 1 operates.
PH DIST Z1 OP AB	Asserted when phase distance zone 1 phase AB operates.
PH DIST Z1 OP BC	Asserted when phase distance zone 1 phase BC operates.
PH DIST Z1 OP CA	Asserted when phase distance zone 1 phase CA operates.
PH DIST Z1 PKP	Asserted when phase distance zone 1 picks up.
PH DIST Z1 PKP AB	Asserted when phase distance zone 1 phase AB picks up.
PH DIST Z1 PKP BC	Asserted when phase distance zone 1 phase BC picks up.
PH DIST Z1 PKP CA	Asserted when phase distance zone 1 phase CA picks up.
PH DIST Z1 SUPN IAB	Asserted when phase distance zone 1 phase AB instantaneous overcurrent is supervising.
PH DIST Z1 SUPN IBC	Asserted when phase distance zone 1 phase BC instantaneous overcurrent is supervising.
PH DIST Z1 SUPN ICA	Asserted when phase distance zone 1 phase CA instantaneous overcurrent is supervising.
PH DIST Z2 to Z5.....	Same set of operands as shown above for phase distance zones 2 through 5.

Phase instantaneous overcurrent operands

PHASE IOC1 DPO.....	Asserted when at least one phase of the phase instantaneous overcurrent 1 element drops out.
PHASE IOC1 DPO A.....	Asserted when phase A of the phase instantaneous overcurrent 1 element drops out.
PHASE IOC1 DPO B.....	Asserted when phase B of the phase instantaneous overcurrent 1 element drops out.
PHASE IOC1 DPO C.....	Asserted when phase C of the phase instantaneous overcurrent 1 element drops out.
PHASE IOC1 OP	Asserted when at least one phase of the phase instantaneous overcurrent 1 element operates.
PHASE IOC1 OP A.....	Asserted when phase A of the phase instantaneous overcurrent 1 element operates.
PHASE IOC1 OP B.....	Asserted when phase B of the phase instantaneous overcurrent 1 element operates.
PHASE IOC1 OP C.....	Asserted when phase C of the phase instantaneous overcurrent 1 element operates.
PHASE IOC1 PKP	Asserted when at least one phase of the phase instantaneous overcurrent 1 element picks up.
PHASE IOC1 PKP A.....	Asserted when phase A of the phase instantaneous overcurrent 1 element picks up.
PHASE IOC1 PKP B.....	Asserted when phase B of the phase instantaneous overcurrent 1 element picks up.
PHASE IOC1 PKP C.....	Asserted when phase C of the phase instantaneous overcurrent 1 element picks up.
PHASE IOC2 to 12.....	Same set of operands as shown above for the phase instantaneous overcurrent elements 2 through 12.

Phase overvoltage operands

PHASE OV1 DPO	Asserted when at least one phase of the phase overvoltage 1 element drops out.
PHASE OV1 DPO A.....	Asserted when phase A of the phase overvoltage 1 element drops out.

PHASE OV1 DPO B.....	Asserted when phase B of the phase overvoltage 1 element drops out.
PHASE OV1 DPO C.....	Asserted when phase C of the phase overvoltage 1 element drops out.
PHASE OV1 OP.....	Asserted when at least one phase of the phase overvoltage 1 element operates.
PHASE OV1 OP A.....	Asserted when phase A of the phase overvoltage 1 element operates.
PHASE OV1 OP B.....	Asserted when phase B of the phase overvoltage 1 element operates.
PHASE OV1 OP C.....	Asserted when phase C of the phase overvoltage 1 element operates.
PHASE OV1 PKP.....	Asserted when at least one phase of the phase overvoltage 1 element picks up.
PHASE OV1 PKP A.....	Asserted when phase A of the phase overvoltage 1 element picks up.
PHASE OV1 PKP B.....	Asserted when phase B of the phase overvoltage 1 element picks up.
PHASE OV1 PKP C.....	Asserted when phase C of the phase overvoltage 1 element picks up.
PHASE OV2.....	Same set of operands as shown above for the phase overvoltage 2 element.

Phase select operands

PHASE SELECT 3P.....	Asserted when a three-phase symmetrical fault is detected.
PHASE SELECT AB.....	Asserted when a phase A to B fault is detected.
PHASE SELECT ABG.....	Asserted when a phase A to B to ground fault is detected.
PHASE SELECT AG.....	Asserted when a phase A to ground fault is detected.
PHASE SELECT BC.....	Asserted when a phase B to C fault is detected.
PHASE SELECT BCG.....	Asserted when a phase B to C to ground fault is detected.
PHASE SELECT BG.....	Asserted when a phase B to ground fault is detected.
PHASE SELECT CA.....	Asserted when a phase C to A fault is detected.
PHASE SELECT CAG.....	Asserted when a phase C to A to ground fault is detected.
PHASE SELECT CG.....	Asserted when a phase C to ground fault is detected.
PHASE SELECT MULTI-P.....	Asserted when a multi-phase fault is detected.
PHASE SELECT SLG.....	Asserted when a single line to ground fault is detected.
PHASE SELECT VOID.....	Asserted when the fault type cannot be detected.

Phase time overcurrent operands

PHASE TOC1 DPO.....	Asserted when at least one phase of the phase time overcurrent 1 element drops out.
PHASE TOC1 DPO A.....	Asserted when phase A of the phase time overcurrent 1 element drops out.
PHASE TOC1 DPO B.....	Asserted when phase B of the phase time overcurrent 1 element drops out.
PHASE TOC1 DPO C.....	Asserted when phase C of the phase time overcurrent 1 element drops out.
PHASE TOC1 OP.....	Asserted when at least one phase of the phase time overcurrent 1 element operates.
PHASE TOC1 OP A.....	Asserted when phase A of the phase time overcurrent 1 element operates.

PHASE TOC1 OP B.....	Asserted when phase B of the phase time overcurrent 1 element operates.
PHASE TOC1 OP C.....	Asserted when phase C of the phase time overcurrent 1 element operates.
PHASE TOC1 PKP.....	Asserted when at least one phase of the phase time overcurrent 1 element picks up.
PHASE TOC1 PKP A.....	Asserted when phase A of the phase time overcurrent 1 element picks up.
PHASE TOC1 PKP B.....	Asserted when phase B of the phase time overcurrent 1 element picks up.
PHASE TOC1 PKP C.....	Asserted when phase C of the phase time overcurrent 1 element picks up.
PHASE TOC2 to 6.....	Same set of operands as shown above for the phase time overcurrent elements 2 through 6.

Phase undervoltage operands

PHASE UV1 DPO.....	Asserted when at least one phase of the phase undervoltage 1 element drops out.
PHASE UV1 DPO A.....	Asserted when phase A of the phase undervoltage 1 element drops out.
PHASE UV1 DPO B.....	Asserted when phase B of the phase undervoltage 1 element drops out.
PHASE UV1 DPO C.....	Asserted when phase C of the phase undervoltage 1 element drops out.
PHASE UV1 OP.....	Asserted when at least one phase of the phase undervoltage 1 element operates.
PHASE UV1 OP A.....	Asserted when phase A of the phase undervoltage 1 element operates.
PHASE UV1 OP B.....	Asserted when phase B of the phase undervoltage 1 element operates.
PHASE UV1 OP C.....	Asserted when phase C of the phase undervoltage 1 element operates.
PHASE UV1 PKP.....	Asserted when at least one phase of the phase undervoltage 1 element picks up.
PHASE UV1 PKP A.....	Asserted when phase A of the phase undervoltage 1 element picks up.
PHASE UV1 PKP B.....	Asserted when phase B of the phase undervoltage 1 element picks up.
PHASE UV1 PKP C.....	Asserted when phase C of the phase undervoltage 1 element picks up.
PHASE UV2.....	Same set of operands as shown above for the phase undervoltage 2 element.

Permissive overreach transfer trip (POTT scheme) operands

POTT OP.....	Asserted when the permissive over-reaching transfer trip scheme operates.
POTT TRIP 3P.....	Asserted when the permissive over-reaching transfer trip scheme operates to trip all three phases.
POTT TRIP A.....	Asserted when the permissive over-reaching transfer trip scheme operates to trip phase A.
POTT TRIP B.....	Asserted when the permissive over-reaching transfer trip scheme operates to trip phase B.

POTT TRIP C	Asserted when the permissive over-reaching transfer trip scheme operates to trip phase C.
POTT TX	Asserted when the permissive signal is sent.
POTT TX1	Asserted when the permissive over-reaching transfer trip scheme asserts transit bit number 1.
POTT TX2	Asserted when the permissive over-reaching transfer trip scheme asserts transit bit number 2.
POTT TX3	Asserted when the permissive over-reaching transfer trip scheme asserts transit bit number 3.
POTT TX4	Asserted when the permissive over-reaching transfer trip scheme asserts transit bit number 4.

Power swing detection operands

POWER SWING 50DD	Asserted when the power swing detection element detects a disturbance other than a power swing.
POWER SWING BLOCK	Asserted when the power swing detection blocking element operates.
POWER SWING INCOMING	Asserted when an unstable power swing is detected (incoming locus).
POWER SWING INNER	Asserted when the positive-sequence impedance is in the inner characteristic.
POWER SWING MIDDLE	Asserted when the positive-sequence impedance is in the middle characteristic.
POWER SWING OUTER	Asserted when the positive-sequence impedance is in the outer characteristic.
POWER SWING OUTGOING	Asserted when an unstable power swing is detected (outgoing locus).
POWER SWING TMR1 PKP	Asserted when power swing timer 1 picks up.
POWER SWING TMR2 PKP	Asserted when power swing timer 2 picks up.
POWER SWING TMR3 PKP	Asserted when power swing timer 3 picks up.
POWER SWING TMR4 PKP	Asserted when power swing timer 4 picks up.
POWER SWING UN/BLOCK	Asserted when the out-of-step tripping function operates.

Permissive underreach transfer trip (PUTT scheme) operands

PUTT OP	Asserted when power permissive under-reaching transfer trip scheme operates.
PUTT TRIP 3P	Asserted when power permissive under-reaching transfer trip scheme operates to trip all three phases.
PUTT TRIP A	Asserted when power permissive under-reaching transfer trip scheme operates to trip phase A.
PUTT TRIP B	Asserted when power permissive under-reaching transfer trip scheme operates to trip phase B.
PUTT TRIP C	Asserted when power permissive under-reaching transfer trip scheme operates to trip phase C.
PUTT TX1	Asserted when power permissive under-reaching transfer trip scheme asserts transit bit number 1.
PUTT TX2	Asserted when power permissive under-reaching transfer trip scheme asserts transit bit number 2.
PUTT TX3	Asserted when power permissive under-reaching transfer trip scheme asserts transit bit number 3.
PUTT TX4	Asserted when power permissive under-reaching transfer trip scheme asserts transit bit number 4.

Setting group operands

- SETTING GROUP ACT 1..... Asserted when setting group 1 is active.
- SETTING GROUP ACT 2..... Asserted when setting group 2 is active.
- SETTING GROUP ACT 3..... Asserted when setting group 3 is active.
- SETTING GROUP ACT 4..... Asserted when setting group 4 is active.
- SETTING GROUP ACT 5..... Asserted when setting group 5 is active.
- SETTING GROUP ACT 6..... Asserted when setting group 6 is active.

Disturbance detector operands

- SRC1 50DD OP Asserted when the disturbance detector for source 1 operates.
- SRC2 50DD OP Asserted when the disturbance detector for source 2 operates.
- SRC3 50DD OP Asserted when the disturbance detector for source 3 operates.

Voltage transformer fuse failure (VTFF) operands

- SRC1 VTFF DPO..... Asserted when the VT fuse failure detector for source 1 drops out.
- SRC1 VTFF OP Asserted when the VT fuse failure detector for source 1 operates.
- SRC1 VTFF VOL LOSS..... Asserted when the VT fuse failure detector for source 1 loses voltage signals (V_2 is less than 15% and V_1 is less than 5% of nominal).
- SRC2 to SRC3..... The set of operands shown above are available VT fuse failure elements for sources 2 through 3.

Trip output operands

- TRIP 1-POLE..... Asserted when a single-pole trip-and-reclose operation is initiated.
- TRIP 3-POLE..... Asserted upon a trip for all three breaker poles.
- TRIP AR INIT 3-POLE..... Asserted when a three-pole reclose is initiated.
- TRIP FORCE 3-POLE Asserted when a three-pole trip must be initiated.
- TRIP PHASE A..... Asserted upon a breaker pole A trip, initiate phase A breaker fail and reclose.
- TRIP PHASE B..... Asserted upon a breaker pole B trip, initiate phase A breaker fail and reclose.
- TRIP PHASE C..... Asserted upon a breaker pole C trip, initiate phase A breaker fail and reclose.

Protection FlexAnalog parameters

The following protection FlexAnalog parameters (analog operands) are available for the D90^{Plus}. They are listed alphabetically by operand syntax. The definitions reflect the programmed source and element names, where applicable.

Setting group analog operand

- Active Setting Group The currently active setting group

Digital counter analog operands

- Digital Counter 1 Value..... Actual value of digital counter 1
- Digital Counter 2 Value..... Actual value of digital counter 2
- Digital Counter 3 Value..... Actual value of digital counter 3
- Digital Counter 4 Value..... Actual value of digital counter 4
- Digital Counter 5 Value..... Actual value of digital counter 5

Digital Counter 6 Value Actual value of digital counter 6
Digital Counter 7 Value Actual value of digital counter 7
Digital Counter 8 Value Actual value of digital counter 8

FlexElement analog operands

FlexElement 1 Value Metered value for FlexElement 1
FlexElement 2 Value Metered value for FlexElement 2
FlexElement 3 Value Metered value for FlexElement 3
FlexElement 4 Value Metered value for FlexElement 4
FlexElement 5 Value Metered value for FlexElement 5
FlexElement 6 Value Metered value for FlexElement 6
FlexElement 7 Value Metered value for FlexElement 7
FlexElement 8 Value Metered value for FlexElement 8
FlexElement 9 Value Metered value for FlexElement 9
FlexElement 10 Value Metered value for FlexElement 10
FlexElement 11 Value Metered value for FlexElement 11
FlexElement 12 Value Metered value for FlexElement 12
FlexElement 13 Value Metered value for FlexElement 13
FlexElement 14 Value Metered value for FlexElement 14
FlexElement 15 Value Metered value for FlexElement 15
FlexElement 16 Value Metered value for FlexElement 16

D90^{Plus} Line Distance Protection System

Chapter 8: Automation

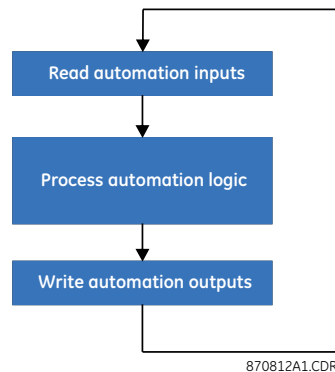
This section outlines how to program the D90^{Plus} automation features.

Automation controller overview

The D90^{Plus} automation controller allows custom automation schemes. The controller can access both digital and analog inputs and outputs. Operations carried out on digital inputs and outputs are referred to as logical operations, whereas operations carried out on analog inputs and outputs are referred to as math operations. Digital inputs and outputs include physical inputs and outputs residing locally in the D90^{Plus}, remote inputs and outputs originating in external devices, and outputs generated by internal, hard-coded functions. The results of processing inputs and outputs are stored locally in the form of virtual inputs and outputs. These can, in turn, be assigned to drive contact outputs, annunciator indications, or be used as inputs to internal, hard-coded functions. They are also available via communications to external devices or master programs.

All inputs are read at the beginning of the automation scan, then the logic is processed. After logic processing, the outputs are written. The D90^{Plus} automation scan rate is 50 ms. A total of 4096 lines can be programmed in the automation controller.

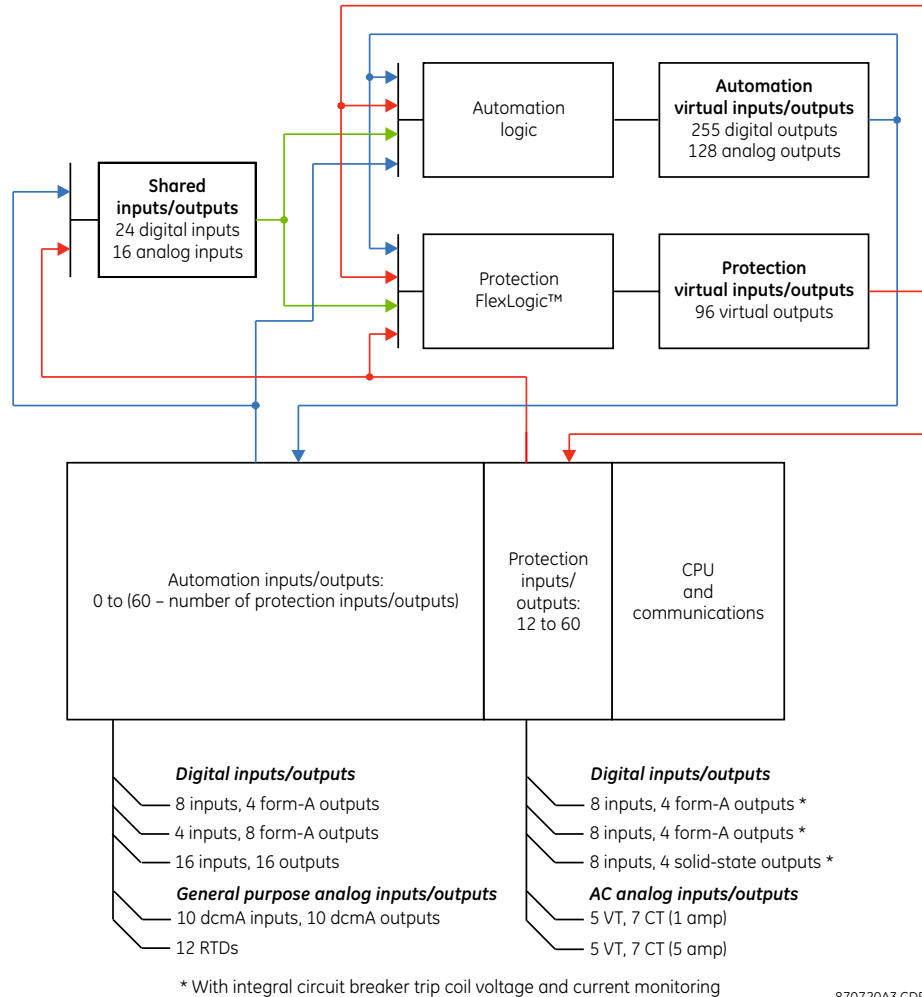
Figure 358: Automation scan



Input and output structure

The figure shows the input and output structure of the D90^{Plus}. Three groupings of inputs and outputs are defined (physical, shared, and virtual), with digital and analog types within each grouping.

Figure 359: Input and output structure



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The digital inputs and outputs have the following characteristics:

- Physical inputs and outputs — The D90^{Plus} can accommodate a maximum of five input and output modules. One module is reserved for protection, allowing up to four modules to be dedicated to automation, for a maximum of 48 points.
- Shared inputs and outputs — These are internal registers that are accessible to both the protection and automation functions. This allows protection physical inputs to be passed to the automation function and *vice-versa*.
- Virtual inputs and outputs — A total of 96 points are available in the controller for storage of the intermediate or final results of logic processing (defined as virtual digital outputs).

The analog inputs and outputs have the following characteristics:

- Physical inputs — These are derived from analog input cards designed to measure process variables produced by transducers.
- Shared inputs and outputs — These are internal registers that are accessible to both the protection and automation functions. This allows protection physical inputs to be

passed to the automation function and *vice-versa*. The D90^{PLUS} can store a total of 64 shared operands. This allows the automation function access to a large variety of analog measurements resident in the protection functions.

- Virtual inputs and outputs — A total of 64 points are available in the controller for storage of the intermediate or final results of math processing (defined as virtual analog outputs).

Breakers

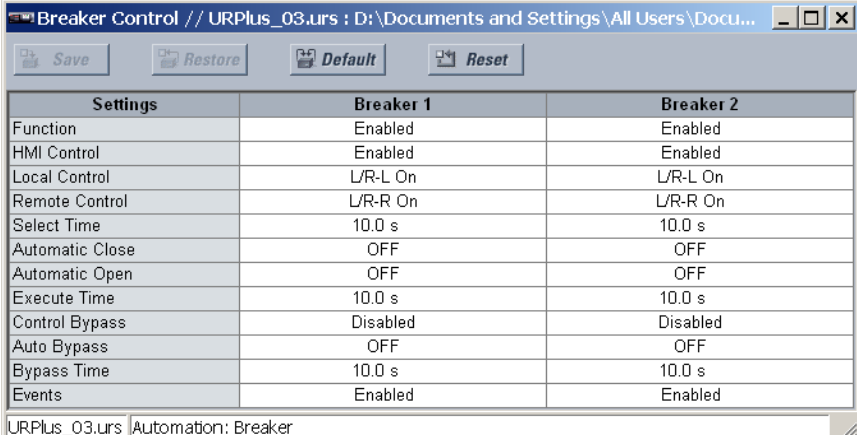
This section describes the breaker control and breaker interlocking features for each of the six available breakers.

Breaker control

The breaker control element contains the auxiliary logic for control of circuit breakers required for SCADA and for the front panel interface. The control function incorporates select-before-operate. Selection is required before a control action is permitted. Selecting a device inhibits service to other clients. Selection is also inhibited if an operation is in progress. The logic permits interlocking to be bypassed if required.

Select the **Settings > Automation > Breaker > Breaker Control** menu to open the breaker control configuration window.

Figure 360: Breaker control configuration settings window



Settings	Breaker 1	Breaker 2
Function	Enabled	Enabled
HMI Control	Enabled	Enabled
Local Control	L/R-L On	L/R-L On
Remote Control	L/R-R On	L/R-R On
Select Time	10.0 s	10.0 s
Automatic Close	OFF	OFF
Automatic Open	OFF	OFF
Execute Time	10.0 s	10.0 s
Control Bypass	Disabled	Disabled
Auto Bypass	OFF	OFF
Bypass Time	10.0 s	10.0 s
Events	Enabled	Enabled

The following settings are available for each breaker.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables or disables breaker control.

HMI Control

Range: Enabled, Disabled

Default: Enabled

This setting enables breaker control through the front panel interface and populates the front panel display with breaker control soft-keys.

Local Control

Range: any automation logic operand or shared operand

Default: L/R-L On

When the operand assigned to this setting is asserted, control is enabled from the front panel interface. This setting normally is assigned to the local status of a local/remote switch. If continuous local control is required, this setting can be programmed as "On."

Remote Control

Range: any automation logic operand or shared operand

Default: L/R-R On

When the operand assigned to this setting is asserted, control is enabled from SCADA. This setting is normally assigned to the remote status of a local/remote switch. If continuous remote control is required, this setting can be programmed as "On."

Select Time

Range: 0.00 to 30.00 seconds in steps of 0.01

Default: 10.00 seconds

This setting specifies the maximum permissible time from selection of the breaker and a control action.

Automatic Close

Range: any automation logic operand or shared operand

Default: OFF

This setting is used to close the device from an automatic control scheme.

Automatic Open

Range: any automation logic operand or shared operand

Default: OFF

This setting is used to open the device from an automatic control scheme.

Execute Time

Range: 0.0 to 10.0 seconds in steps of 0.1

Default: 10.0 seconds

This setting specifies the duration of the open and close commands used to control the breaker.

Control Bypass

Range: Enabled, Disabled

Default: Disabled

When enabled, this setting allows the interlocking to be bypassed from local or remote control.

NOTICE

Non-interlocked control can result in equipment damage.

Automation Bypass

Range: any automation logic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, interlocking is bypassed.

NOTICE

Non-interlocked control can result in equipment damage.

Bypass Time

Range: 0.0 to 30.0 seconds in steps of 0.1

Default: 10.0 seconds

This setting specifies the time window during which non-interlocked control can occur once bypass has been selected.

The following figures provide the breaker control logic.

Figure 361: Breaker control logic, sheet 1 of 3

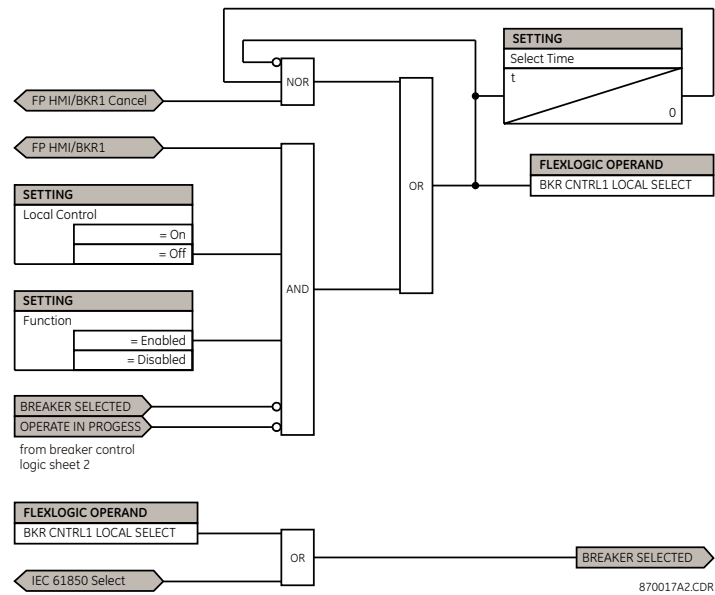


Figure 362: Breaker control logic, sheet 2 of 3

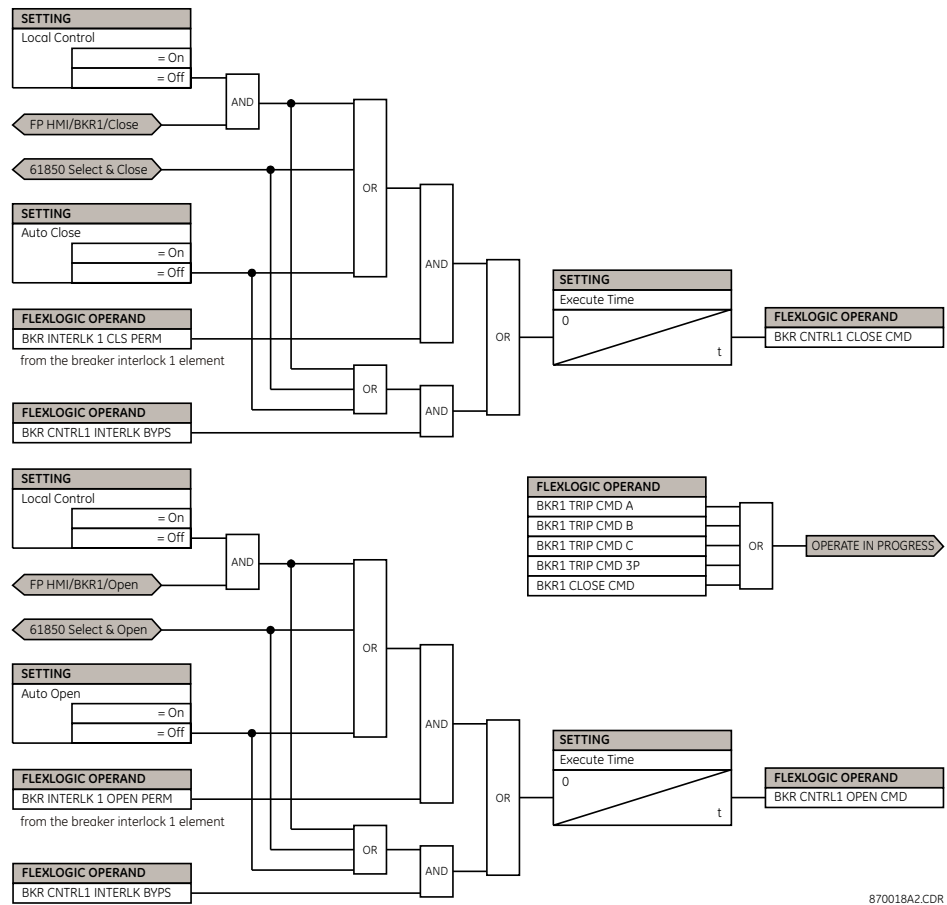
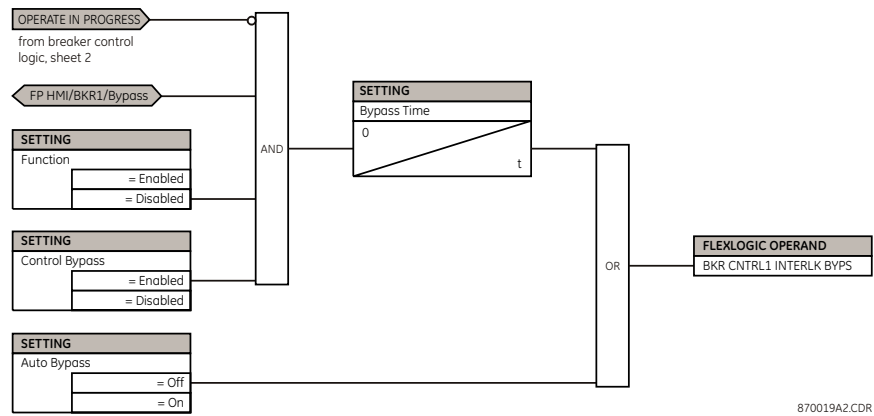


Figure 363: Breaker control logic, sheet 3 of 3



Breaker interlocking

The breaker interlocking element contains the auxiliary logic for interlocking of circuit breakers. Up to three inputs can be assigned for interlocking the open and close controls. An input is also available for supervision by a synchrocheck element. The breaker can also be tagged through the front panel interface or through SCADA. Opening and closing of a tagged device is inhibited in logic.

Select the **Settings > Automation > Breaker > Breaker Interlocking** menu to open the breaker interlocking configuration window.

Figure 364: Breaker interlocking configuration settings

Settings	Breaker 1	Breaker 2
Function	Disabled	Disabled
Tagging	Disabled	Disabled
Status Supervision	Disabled	Disabled
Close Interlock 1	OFF	OFF
Close Interlock 2	OFF	OFF
Close Interlock 3	OFF	OFF
Synchrocheck Permissive	OFF	OFF
Open Interlock 1	OFF	OFF
Open Interlock 2	OFF	OFF
Open Interlock 3	OFF	OFF
Events	Enabled	Enabled

The following settings are available for each breaker interlocking element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the breaker position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Tagging

Range: Enabled, Disabled

Default: Disabled

When enabled, tagging control is enabled and a TAG/UNTAG soft-key displays on the front panel interface. When a breaker is tagged both local and remote control of the device is inhibited.

Status Supervision

Range: Enabled, Disabled

Default: Disabled

When enabled, control of the breaker is supervised by its breaker status. An open command cannot be sent to a breaker that currently indicates open, and a close command cannot be sent to a breaker that indicates closed.

Close Interlock 1, Close Interlock 2, Close Interlock 3

Range: any automation logic operand or shared operand

Default: OFF

Closing of the device is inhibited if any of the operands assigned to these settings are asserted.

Synchrocheck Permissive

Range: any automation logic operand or shared operand

Default: SYNC 1 SYNC OP

This setting is used to supervise closing of the breaker by a synchrocheck element. If synchrocheck is not required, make this setting "ON."

Open Interlock 1, Open Interlock 2, Open Interlock 3

Range: any automation logic operand or shared operand

Default: Off

Opening of the device is inhibited if any of the operands assigned to these settings are asserted.

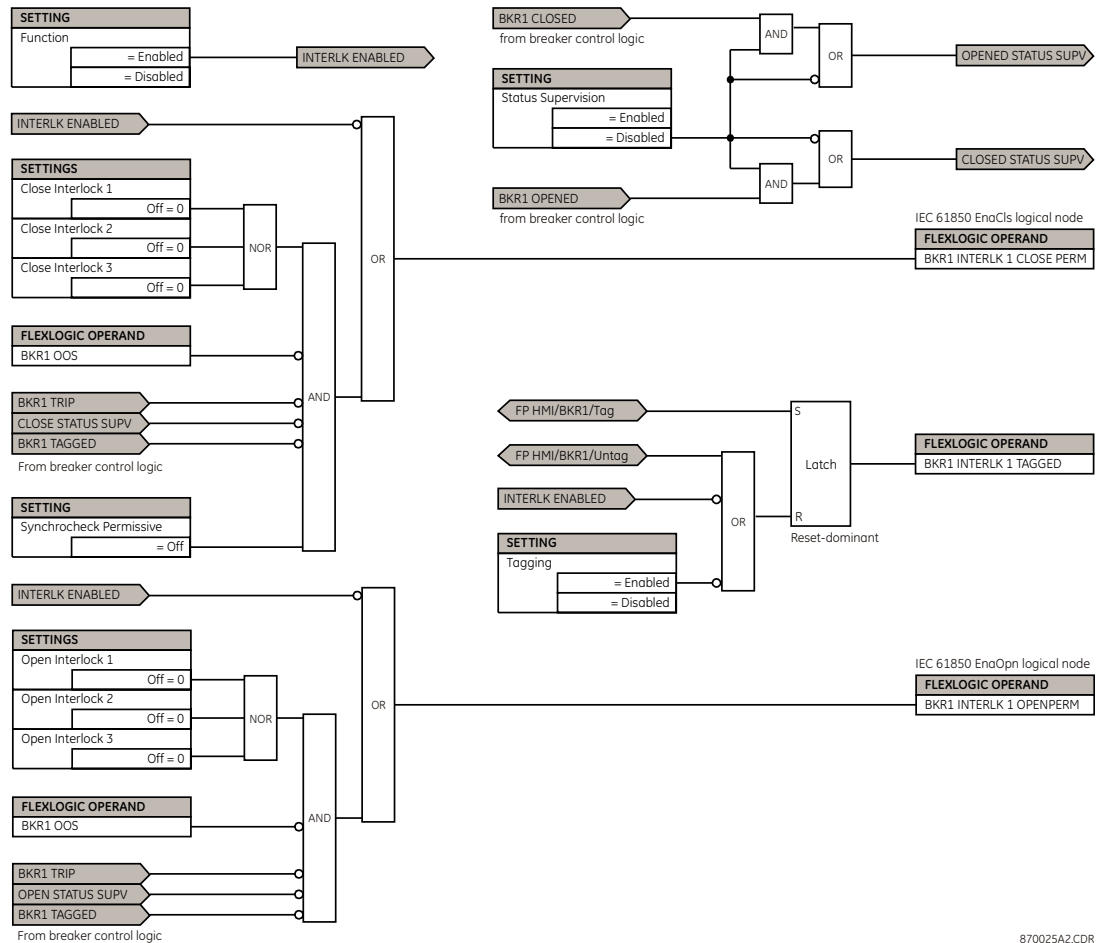
Events

Range: Enabled, Disabled
 Default: Enabled

The setting enables or disables the logging of breaker interlocking events in the sequence of events recorder.

The figure shows the breaker interlocking logic.

Figure 365: Breaker interlocking logic



Disconnects

The disconnect element contains the auxiliary logic for status and serves as the interface for opening and closing of the disconnect from protection and automation functions. The logic also permits a manual substitution of the position indication. There are 6 disconnect elements available in the D90^{PLUS}.

Disconnect configuration

Select the **Settings > Automation > Disconnects > Disconnect Configuration** menu to open the disconnect control configuration window.

Figure 366: Disconnect configuration settings

SETTING	PARAMETER
[DISCONNECT 1] Function	Enabled
[DISCONNECT 1] Long Name	Disconnect 1
[DISCONNECT 1] Short Name	DSC1
[DISCONNECT 1] Substitution	Disabled
[DISCONNECT 1] Block Close Command	OFF
[DISCONNECT 1] Block Open Command	OFF
[DISCONNECT 1] Disc Local Input	OFF
[DISCONNECT 1] Indication Mode	3-Pole
[DISCONNECT 1] Phase A/3P Closed Status	DSC1 89a On(F5)
[DISCONNECT 1] Phase A/3P Opened Status	DSC1 89a Off(F5)
[DISCONNECT 1] Phase B Closed Status	OFF
[DISCONNECT 1] Phase B Opened Status	OFF
[DISCONNECT 1] Phase C Closed Status	OFF
[DISCONNECT 1] Phase C Opened Status	OFF
[DISCONNECT 1] Operate Time	0.070 s
[DISCONNECT 1] Discrepancy Time	0.070 s
[DISCONNECT 1] Reset Counter	OFF
[DISCONNECT 1] Events	Enabled

The following settings are available for each disconnect.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables the disconnect position indications and control logic. If disabled, all outputs and front panel indications are switched off.

Long Name

Range: up to 12 alphanumeric characters

Default: DISCONNECT 1

This setting identifies the primary device for control confirmations on the front panel interface and in the event record.

Short Name

Range: up to 6 alphanumeric characters

Default: DSC1

This setting identifies the primary device soft-keys and indications on the front panel interface.

Substitution

Range: Enabled, Disabled

Default: Disabled

If this setting is "Enabled," the position indication of the disconnect can be substituted with a manually entered value.

Block Close Command

Range: any automation logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting prevents the disconnect from closing.

Block Open Command

Range: any automation logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting prevents the disconnect from opening.

Disconnect Local Input

Range: any automation logic operand or shared operand

Default: OFF

Closing or opening of the disconnect through the disconnect interlock element is inhibited if the operand assigned to this setting is asserted.

Indication Mode

Range: 3-Pole, 1-Pole

Default: 3-Pole

If the "3-Pole" value is selected, the disconnect indications are derived from a single status input (or pair of status inputs). If the "1-Pole" value is selected, the disconnect indications are derived from three status inputs (or pairs of status inputs).

Phase A/3P Closed Status

Range: any automation logic operand or shared operand

Default: Off

The operand assigned to this setting is used to derive the three-pole or phase A circuit disconnect position indication from a normally-opened (52a) status input.

Phase A/3P Opened Status

Range: any automation logic operand or shared operand

Default: DSC2 89a On(K10)

The operand assigned to this setting is used to derive the three-pole or phase A circuit disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal.

Phase B Closed Status

Range: any automation logic operand or shared operand

Default: DSC2 89a Off(K10)

The operand assigned to this setting is used to derive the phase B disconnect position indication from a normally-opened (52a) status input. This setting is not required if the **Indication Mode** is "1-Pole."

Phase B Opened Status

Range: any automation logic operand or shared operand

Default: Off

The operand assigned to this setting is used to derive the phase B disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This setting is not required if the **Indication Mode** is "1-Pole."

Phase C Opened Status

Range: any automation logic operand or shared operand

Default: Off

The operand assigned to this setting is used to derive the phase C disconnect position indication from a normally-opened (52a) status input. This setting is not required if the **Indication Mode** is "1-Pole."

Phase C Closed Status

Range: any automation logic operand or shared operand

Default: Off

The operand assigned to this setting is used to derive the phase C disconnect position indication from a normally-closed (52b) status input. If unavailable, the closed status input can be inverted to provide this signal. This setting is not required if the **Indication Mode** is "1-Pole."

Operate Time

Range: 0.000 to 2.000 seconds in steps of 0.001
 Default: 0.070 seconds

This setting specifies a timer that is asserted when both the normally open and normally closed disconnect indications are reset. When the timer expires, a bad status is indicated for the disconnect. Set the time to be equal to the normal operating time for the disconnect.

Discrepancy Time

Range: 0.000 to 2.000 seconds in steps of 0.001
 Default: 0.070 seconds

This setting specifies a timer that is asserted when the three disconnect poles are not all opened or not all closed. Set the time to be greater than the longest expected time for which the three disconnect poles disagree.

Reset Counter

Range: any automation logic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting resets the disconnect operation counters.

Events

Range: Enabled, Disabled
 Default: Enabled

This setting enables and disables the logging of circuit disconnect events in the sequence of events recorder.

The figures show the disconnect 1 configuration logic. The logic is identical for each available disconnect.

Figure 367: Disconnect logic, sheet 1 of 4

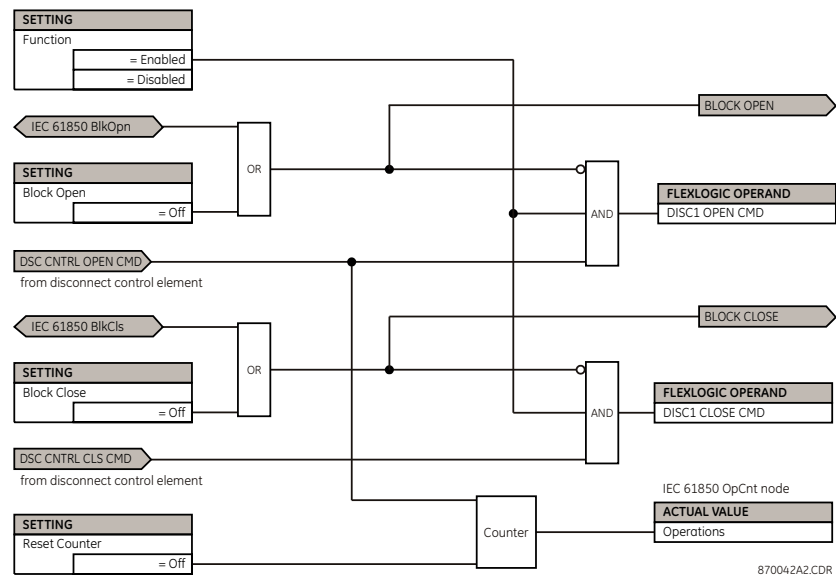


Figure 368: Disconnect logic, sheet 2 of 4

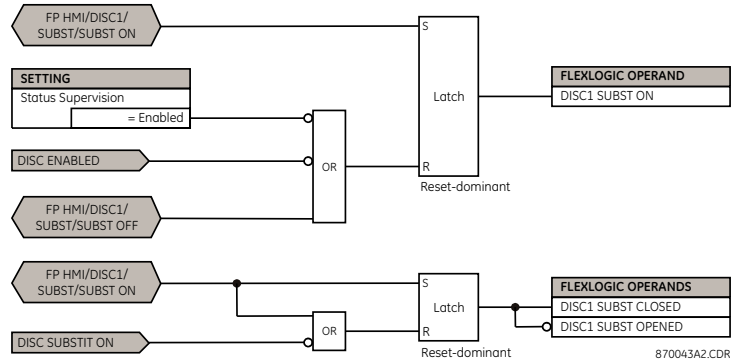


Figure 369: Disconnect logic, sheet 3 of 4

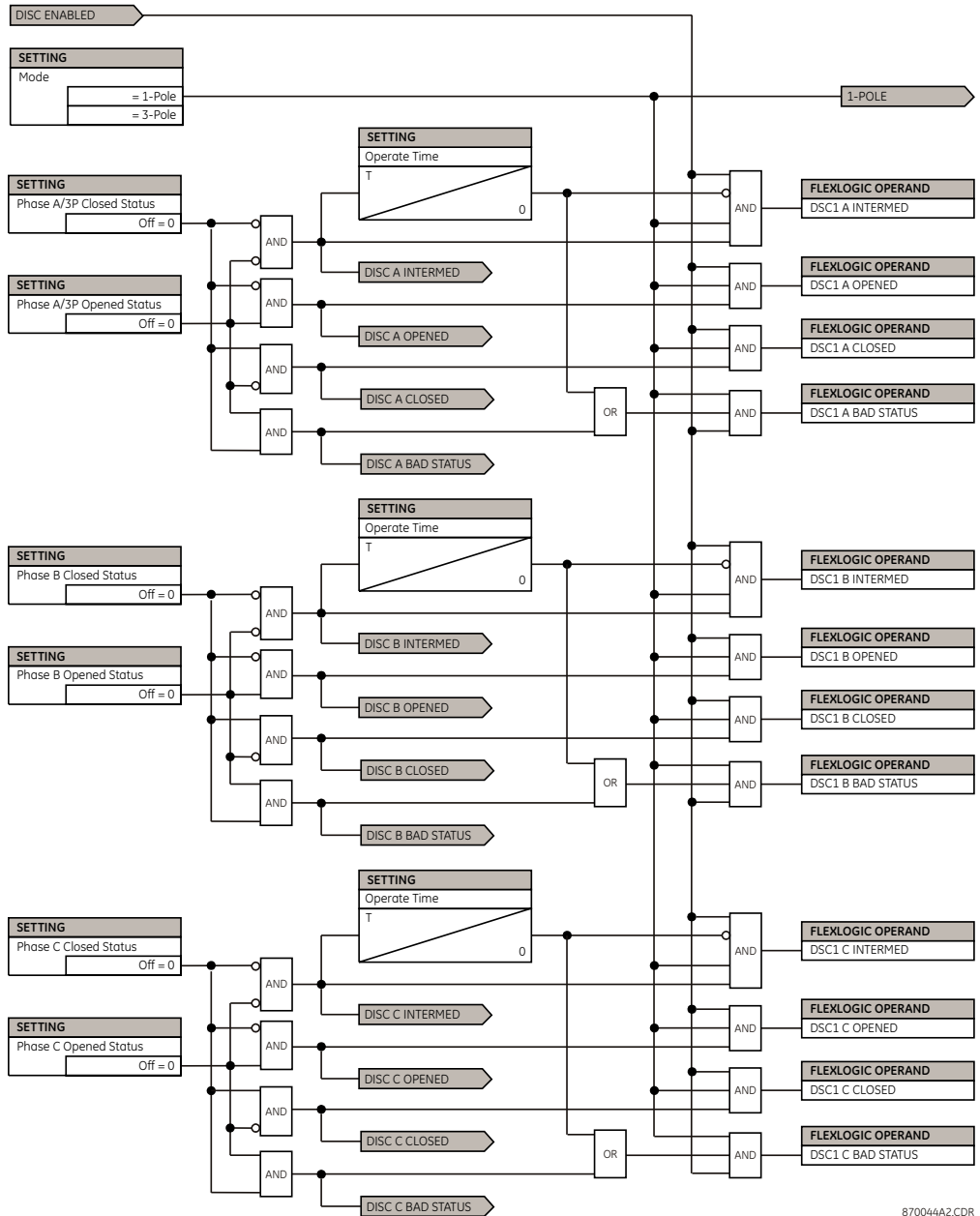
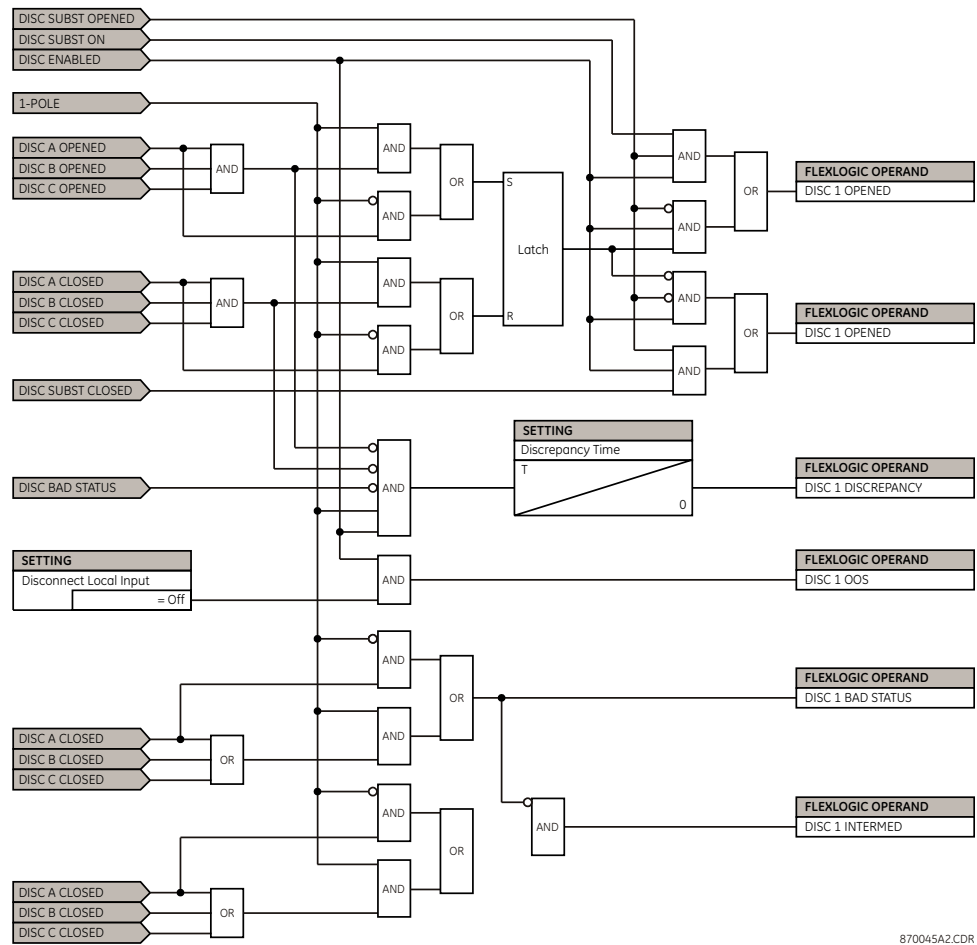


Figure 370: Disconnect logic, sheet 4 of 4



Disconnect control

The disconnect control element contains the auxiliary logic for control of circuit breakers required for SCADA and the front panel interface. The control function incorporates select-before-operate functionality. Selection is required before a control action is permitted. Selecting a device inhibits service to other clients. Selection is also inhibited if an operation is in-progress. The logic permits interlocking to be bypassed if required.

Select the **Settings > Automation > Disconnects > Disconnect Control** menu to open the disconnect control configuration window.

Figure 371: Disconnect control configuration settings

SETTING	PARAMETER
[DISCONNECT 1] Function	Enabled
[DISCONNECT 1] Pushbutton Control	Enabled
[DISCONNECT 1] Local Control	L/R-L On
[DISCONNECT 1] Remote Control	L/R-R On
[DISCONNECT 1] Select Time	10.0 s
[DISCONNECT 1] Automatic Close	OFF
[DISCONNECT 1] Automatic Open	OFF
[DISCONNECT 1] Execute Time	10.0 s
[DISCONNECT 1] Control Bypass	Disabled
[DISCONNECT 1] Automatic Bypass	OFF
[DISCONNECT 1] Bypass Time	10.0 s
[DISCONNECT 1] Events	Enabled

The following settings are available for each disconnect.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the disconnect control feature.

Pushbutton Control

Range: Enabled, Disabled

Default: Enabled

This setting enables control of the device via the front panel and populates the front panel interface with control soft-keys.

Local Control

Range: any automation logic operand or shared operand

Default: L/R-L On

When the operand assigned to this setting is asserted, control is permitted from the front panel interface. This setting is normally assigned to the local status of a local/remote switch. If continuous local control is required, this input can be switched to on.

Remote Control

Range: any automation logic operand or shared operand

Default: L/R-R On

When the operand assigned to this setting is asserted, remote control is permitted from SCADA. This setting normally is assigned to the remote status of a local/remote switch. If continuous remote control is required, this input can be switched to on.

Select Time

Range: 0.0 to 30.0 seconds in steps of 0.1

Default: 10.0 seconds

This setting specifies the maximum permissible time from selection of the disconnect and a control action.

Automatic Close

Range: any automation logic operand or shared operand

Default: OFF

The operand assigned to this setting is used to close the device from an automatic control scheme.

Automatic Open

Range: any automation logic operand or shared operand
 Default: OFF

The operand assigned to this setting is used to open the device from an automatic control scheme.

Execute Time

Range: 0.0 to 10.0 seconds in steps of 0.1
 Default: 10.0 seconds

This setting specifies the duration of the open and close commands used to control the disconnect.

Control Bypass

Range: Enabled, Disabled
 Default: Disabled

When enabled, this setting allows the interlocking to be bypassed from local or remote control.

NOTICE

Non-interlocked control can result in equipment damage.

Automatic Bypass

Range: any automation logic operand or shared operand
 Default: OFF

When the operand assigned to this setting is asserted, interlocking is bypassed.

NOTICE

Non-interlocked control can result in equipment damage.

Bypass Time

Range: 0.0 to 30.0 seconds in steps of 0.1
 Default: 10.0 seconds

This setting specifies the time window during which non-interlocked control can occur once bypass has been selected.

Events

Range: Enabled, Disabled
 Default: Enabled

This setting enables and disables the logging of disconnect control events in the sequence of events recorder.

The figures show the disconnect control logic. The logic is identical for all available disconnects.

Figure 372: Disconnect control logic, sheet 1 of 3

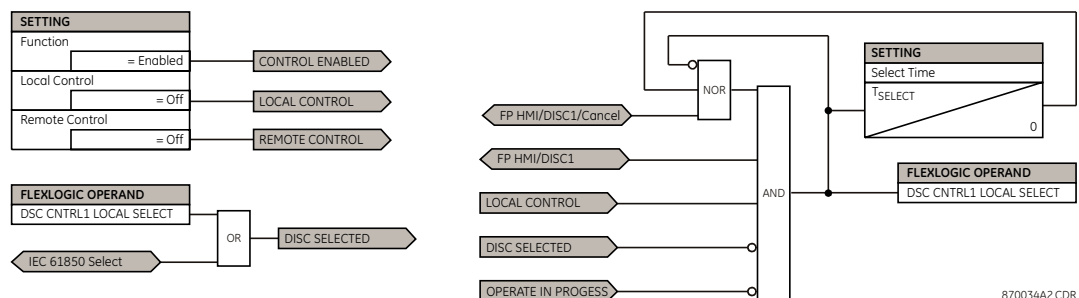


Figure 373: Disconnect control logic, sheet 2 of 3

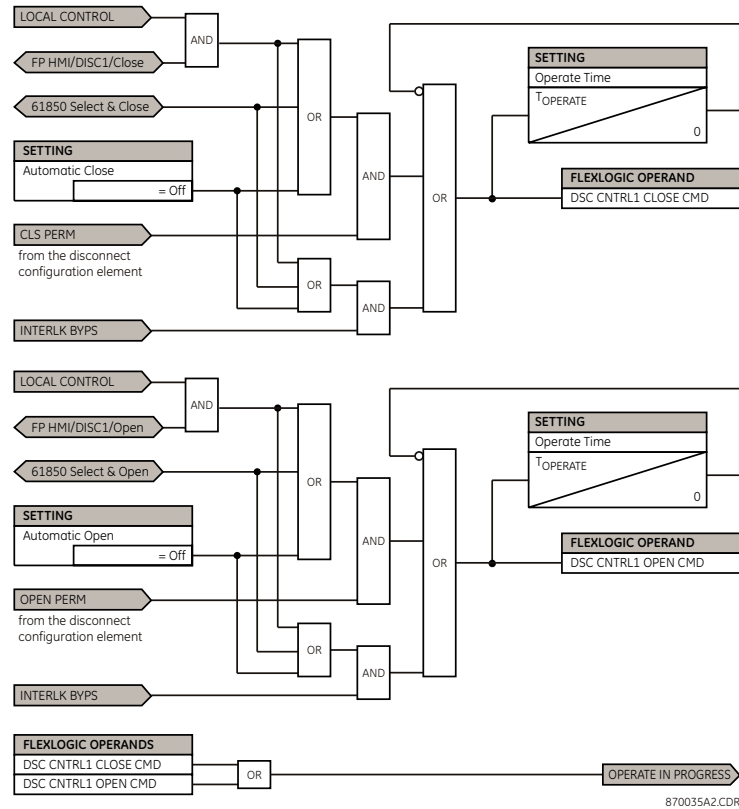
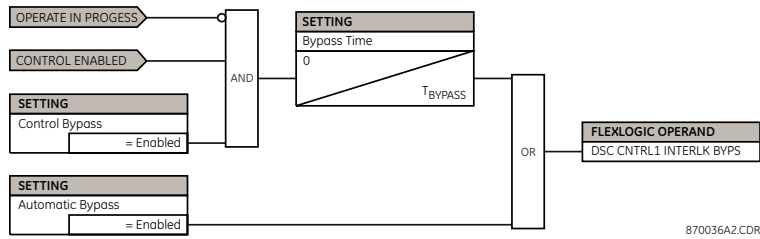


Figure 374: Disconnect control logic, sheet 3 of 3



Disconnect interlocking

The disconnect interlocking element contains the auxiliary logic for interlocking of disconnects. Up to three inputs can be assigned for interlocking the open and close controls. An input is also available for supervision by a synchrocheck element. The disconnect can also be tagged through the front panel interface or through SCADA. Opening and closing of a tagged device is inhibited in logic.

Select the **Settings > Automation > Disconnects > Disconnect Interlocking** menu to open the disconnect control configuration window.

Figure 375: Disconnect interlocking configuration settings

SETTING	PARAMETER
[DISCONNECT 1] Function	Disabled
[DISCONNECT 1] Tagging	Disabled
[DISCONNECT 1] Status Supervision	Disabled
[DISCONNECT 1] Close Interlock 1	OFF
[DISCONNECT 1] Close Interlock 2	OFF
[DISCONNECT 1] Close Interlock 3	OFF
[DISCONNECT 1] Open Interlock 1	OFF
[DISCONNECT 1] Open Interlock 2	OFF
[DISCONNECT 1] Open Interlock 3	OFF
[DISCONNECT 1] Events	Enabled

The following settings are available for each disconnect.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the disconnect position indications and control logic. If “Disabled,” all outputs and front panel indications are switched off.

Tagging

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” tagging control is enabled and a TAG/UNTAG soft-key is populated on the front panel interface. When a disconnect is tagged, both local and remote control of the device is inhibited.

Status Supervision

Range: Enabled, Disabled

Default: Disabled

When this setting is “Enabled,” control of the disconnect is supervised by its disconnect status. An open command cannot be sent to a disconnect that currently indicates open, and a close command cannot be sent to a disconnect that indicates closed.

Close Interlock 1, Close Interlock 2, Close Interlock 3

Range: any automation logic operand or shared operand

Default: OFF

If any of the operands assigned to these settings are asserted, closing of the device is inhibited.

Open Interlock 1, Open Interlock 2, Open Interlock 3

Range: any automation logic operand or shared operand

Default: OFF

If any of the operands assigned to these settings are asserted, opening of the device is inhibited.

Events

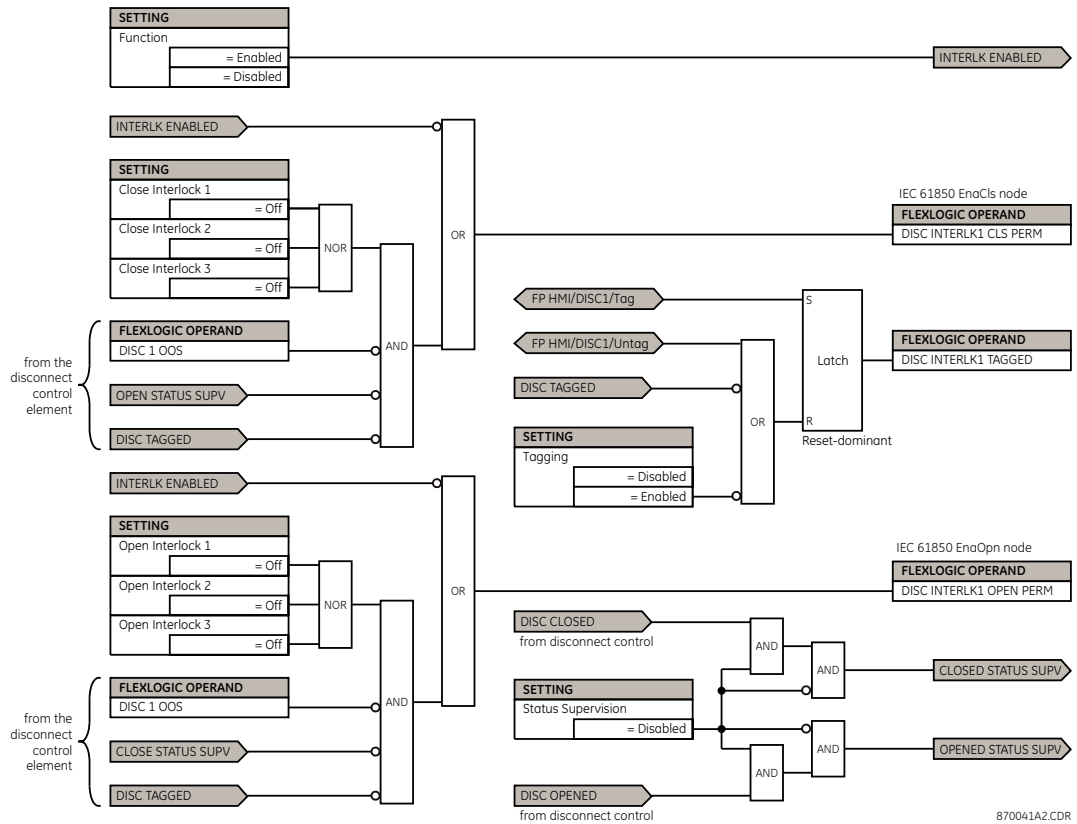
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of disconnect interlocking events in the sequence of events recorder.

The figure shows the disconnect interlocking logic. The logic is identical for all available disconnects.

Figure 376: Disconnect interlocking logic



Automation control

This section outlines the control elements used for automation.

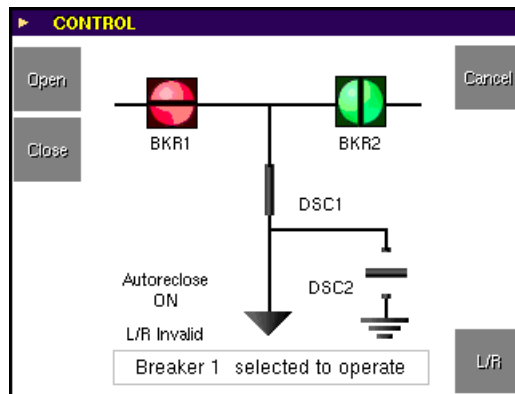
Front panel status and control

There can be a maximum of six breakers and 6 disconnect switches (referred to as devices) plus autoreclose and local-remote status and control. All devices have a short name setting and a full name setting. The short name is used to designate the device and the associated select pushbutton.

The top-level control screen presents the status of each enabled breaker and disconnect. The status of the local-remote function and the autoreclose function is shown if these functions are enabled. All devices are displayed in grey.

If the pushbutton control setting is enabled for a device or function, then the pushbutton on the front panel interface is assigned as shown in the figure. A device that does not have pushbutton control enabled does not have a pushbutton on this screen.

Figure 377: Device selected to operate



A confirmation message is displayed using the full name for the device to be controlled. If no buttons are pressed, the control action is canceled after the select time timer expires. The control action can be canceled by pushing the **CANCEL** key. Pressing the **OPEN** or **CLOSE** keys initiates an open or close control action for the selected device.

If control bypass has been enabled, a **BYPASS** key displays. Press this button to bypass the interlocking logic for the device permitting non-interlocked control of this device. When bypassed, control remains active for a single control operation, until the bypass time timer expires, or the cancel button is pressed.

NOTICE

Non-interlocked control can result in equipment damage.

If tagging has been enabled, a **TAG** key also displays. When the **TAG** key is operated, a small "T" displays next to the device. The open and close operations are inhibited on a tagged device. When a device is tagged, the **TAG** button changes to **UNTAG**.

If substitution is enabled, the **SUBST** key displays. When the **SUBST** key is operated, a new screen is presented that allows the user to enable or disable substitution. Once substitution has been enabled, a small "S" displays next to the device. The user can now manually change the indication of the device using the **SUBST OPENED** and **SUBST CLOSED** keys.

Figure 378: Breaker 1 tagged

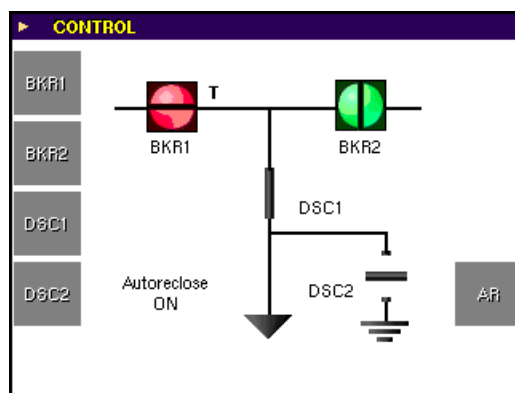
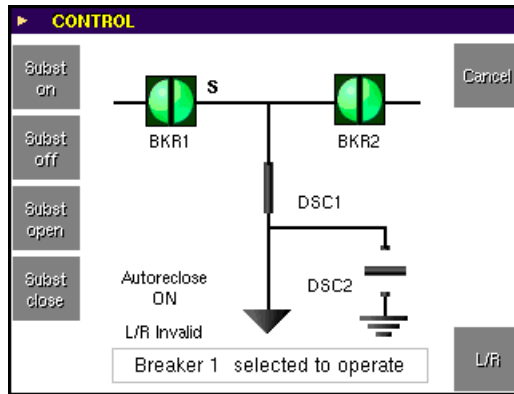
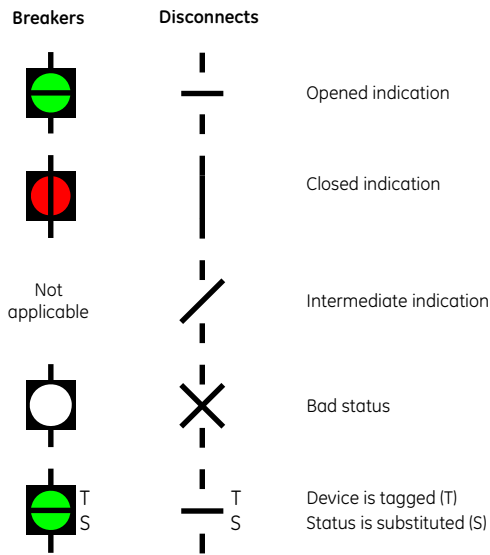


Figure 379: Breaker 1 status substituted



The following indications are provided for breakers and disconnects.

Figure 380: Front panel indicators for breakers and disconnects



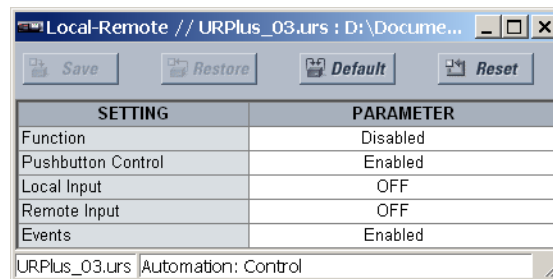
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Local-remote control scheme

The local-remote control scheme is used to define the current location for operator control of power system devices (for example, breakers, disconnects). The function accepts inputs from the front panel interface or from an external source. The automation logic outputs (*L/R-L On* and *L/R-R On*) are assigned as inputs to the breaker and disconnect elements. The position of the latch is stored in non-volatile memory.

Select the **Settings > Automation > Control > Local-Remote** menu to open the local-remote control scheme configuration window.

Figure 381: Local-remote control configuration settings



SETTING	PARAMETER
Function	Disabled
Pushbutton Control	Enabled
Local Input	OFF
Remote Input	OFF
Events	Enabled

URPlus_03.urs | Automation: Control

The following settings are available for the local-remote control scheme.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the local-remote control scheme automation logic and front panel indications.

Pushbutton Control

Range: Enabled, Disabled

Default: Enabled

This setting enables local-remote control selection via the front panel interface and populates the front panel display with control soft-keys.

Local Input

Range: any automation logic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, the local-remote latch is set to local. This setting is normally used in cases where the local-remote selection is derived from an external switch or from a central location.

Remote Input

Range: any automation logic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, the local-remote latch is set to remote. This setting is normally used in cases where the local-remote selection is derived from an external switch or from a central location.

Events

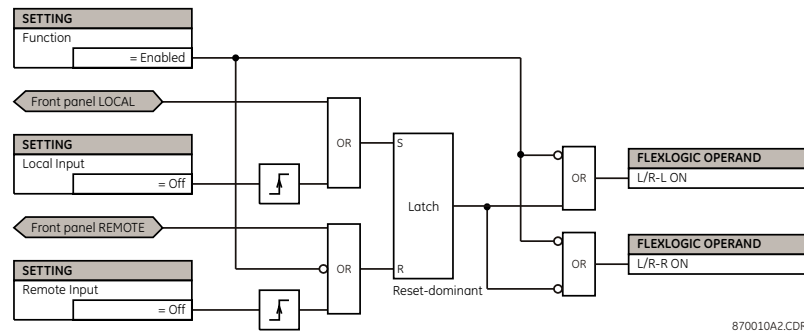
Range: Enabled, Disabled

Default: Enabled

This settings enables and disables the recording of local-remote control scheme events in the sequence of events recorder.

The figure shows the logic diagram for the local-remote control scheme.

Figure 382: Local-remote control logic



Synchrocheck

There are two identical synchrocheck elements available, numbered 1 and 2.

The synchrocheck (synchronism check) function is intended for supervising the paralleling of two parts of a system that are to be joined by the closure of a circuit breaker. The synchrocheck elements typically are used at locations where the two parts of the system are interconnected through at least one other point in the system.

Synchrocheck verifies that the voltages (V_1 and V_2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences. The time that the two voltages remain within the admissible angle difference is determined by the setting of the phase angle difference $\Delta\phi$ and the frequency difference ΔF (slip frequency). It can be defined as the time it takes the voltage phasor V_1 or V_2 to traverse an angle equal to $2 \times \Delta\phi$ at a frequency equal to the frequency difference ΔF . This time can be calculated by

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\phi} \times \Delta F} \tag{Eq. 42}$$

where $\Delta\phi$ represents the phase angle difference in degrees and ΔF represents the frequency difference in hertz.

For example, for default values of $\Delta\phi = 30^\circ$ and $\Delta F = 0.1$ Hz, the time the angle between the two voltages is less than the set value is

$$T = \frac{1}{\frac{360^\circ}{2 \times 30^\circ} \times 0.1 \text{ Hz}} = \frac{1}{\frac{360^\circ}{2 \times 30^\circ} \times 0.1 \text{ Hz}} = 1.66 \text{ sec.} \tag{Eq. 43}$$

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to bypass the synchrocheck measurements (via the dead source function).

Using the synchrocheck function

The selected sources for synchrocheck inputs V_1 and V_2 (which must not be the same source) can include both a three-phase and an auxiliary voltage. The relay automatically selects the specific voltages to be used by the synchrocheck element in accordance with the following table.

Table 27: Voltages used by the synchrocheck element

V_1 or V_2 (source Y)	V_2 or V_1 (source Z)	Auto-selected combination		Auto-selected voltage
		Source Y	Source Z	
Phase VTs and auxiliary VT	Phase VTs and auxiliary VT	Phase	Phase	V_{AB}

V_1 or V_2 (source Y)	V_2 or V_1 (source Z)	Auto-selected combination		Auto-selected voltage
		Source Y	Source Z	
Phase VTs and auxiliary VT	Phase VT	Phase	Phase	V_{AB}
Phase VT	Phase VT	Phase	Phase	V_{AB}
Phase VT and auxiliary VT	Auxiliary VT	Phase	Auxiliary	V_{aux} (as set for source Z)
Auxiliary VT	Auxiliary VT	Auxiliary	Auxiliary	V_{aux} (as set for selected sources)

The voltages V_1 and V_2 are automatically matched so the corresponding voltages from the two sources are used to measure conditions. A phase-to-phase voltage is used if available in both sources. If one or both of the sources have only an auxiliary voltage, then this voltage is used.

For example, if an auxiliary voltage is programmed to V_{AG} , the synchrocheck element automatically selects V_{AG} from the other source. If the comparison is required on a specific voltage, the user can externally connect that specific voltage to auxiliary voltage terminals and then use this auxiliary voltage to check the synchronism conditions.

If using a single CT/VT module with both phase voltages and an auxiliary voltage, ensure that only the auxiliary voltage is programmed in one of the sources used for synchrocheck.



NOTE

Exception: synchronism cannot be checked between delta-connected phase VTs and a wye-connected auxiliary voltage.

The D90^{Plus} measures frequency and volts per hertz from an input on a given source with priorities as established by the configuration of input channels to the source. The relay uses the phase channel of a three-phase set of voltages if programmed as part of that source. The relay uses the auxiliary voltage channel only if that channel is programmed as part of the source and a three-phase set is not.

Synchrocheck settings

Select the **Settings > Automation > Control > Synchrocheck** menu to open the synchrocheck configuration window.

Figure 383: Synchrocheck configuration settings

PARAMETER	SYNCHROCHECK1	SYNCHROCHECK2
Function	Disabled	Disabled
Block	BKR1 CLOSED	BKR2 CLOSED
V1 Source	LINE (SRC 1)	LINE (SRC 1)
V2 Source	BKR 1 (SRC 2)	BKR 1 (SRC 2)
Maximum Voltage Difference	10000 V	10000 V
Maximum Angle Difference	30 deg	30 deg
Maximum Frequency Difference	1.000 Hz	1.000 Hz
Frequency Hysteresis	0.060 Hz	0.060 Hz
Dead Source Select	LV1 and DV2	LV1 and DV2
Dead V1 Maximum Voltage	0.30 pu	0.30 pu
Dead V2 Maximum Voltage	0.30 pu	0.30 pu
Live V1 Minimum Voltage	0.70 pu	0.70 pu
Live V2 Minimum Voltage	0.70 pu	0.70 pu
Events	Enabled	Enabled

The following settings are available for each synchrocheck element. The default values outlined are for the synchrocheck 1 element.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the synchrocheck position indications and control logic. If disabled, all synchrocheck outputs and front panel indications are switched off.

Block

Range: any automation logic operand or shared operand

Default: BKR1 CLOSED

Assertion of the operand assigned to this setting blocks operation of the synchrocheck element.

V1 Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the source for the V_1 voltage.

V2 Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: BKR 1 (SRC 2)

This setting selects the source for the V_2 voltage.

Maximum Voltage Difference

Range: 0 to 400000 volts in steps of 1

Default: 10000 volts

This setting specifies the maximum primary voltage difference (in volts) between the two sources. A primary voltage magnitude difference between the two input voltages less than this value is within the permissible limit for synchronism.

Maximum Angle Difference

Range: 0 to 100° in steps of 1

Default: 30°

This setting specifies the maximum angular difference (in degrees) between the two sources. An angular difference between the two input voltage phasors less than this value is within the permissible limit for synchronism.

Maximum Frequency Difference

Range: 0.00 to 2.00 Hz in steps of 0.01

Default: 1.00 Hz

This setting selects the maximum frequency difference (in hertz) between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.

Frequency Hysteresis

Range: 0.00 to 0.10 Hz in steps of 0.01

Default: 0.06 Hz

This setting specifies the required hysteresis for the maximum frequency difference condition. The condition becomes satisfied when the frequency difference is less than the value specified by the **Maximum Frequency Difference** setting. Once the synchrocheck element has operated, the frequency difference must increase above the sum of this setting and the Maximum Frequency Difference setting to drop out (assuming the other two conditions, voltage and angle, remain satisfied).

Dead Source Select

Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2, DV1 Xor DV2, DV1 and DV2

Default: LV1 and DV2

This setting selects the combination of dead and live sources that bypass the synchronism check function and permit the breaker to be closed when one or both of the two voltages (V_1 and V_2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level. The following six options are available:

- "None" — The dead source function is disabled
- "LV1 and DV2" — Live V_1 and dead V_2
- "DV1 and LV2" — Dead V_1 and live V_2
- "DV1 or DV2" — Dead V_1 or dead V_2
- "DV1 Xor DV2" — Dead V_1 exclusive-or dead V_2 (one source is dead and the other is live)
- "DV1 and DV2" — Dead V_1 and dead V_2

Dead V1 Maximum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01

Default: 0.30 pu

This setting specifies a maximum voltage magnitude for V_1 in per-unit values. At values less than this magnitude, the V_1 voltage input that is used for synchrocheck is considered dead or de-energized.

Dead V2 Maximum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01

Default: 0.30 pu

This setting specifies a maximum voltage magnitude for V_2 in per-unit values. At values less than this magnitude, the V_2 voltage input that is used for synchrocheck is considered dead or de-energized.

Live V1 Minimum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01

Default: 0.70 pu

This setting specifies a minimum voltage magnitude for V_1 in per-unit values. At values greater than this magnitude, the V_1 voltage input that is used for synchrocheck is considered live or energized.

Live V2 Minimum Voltage

Range: 0.00 to 1.25 pu in steps of 0.01

Default: 0.70 pu

This setting specifies a minimum voltage magnitude for V_2 in per-unit values. At values greater than this magnitude, the V_2 voltage input that is used for synchrocheck is considered live or energized.

Events

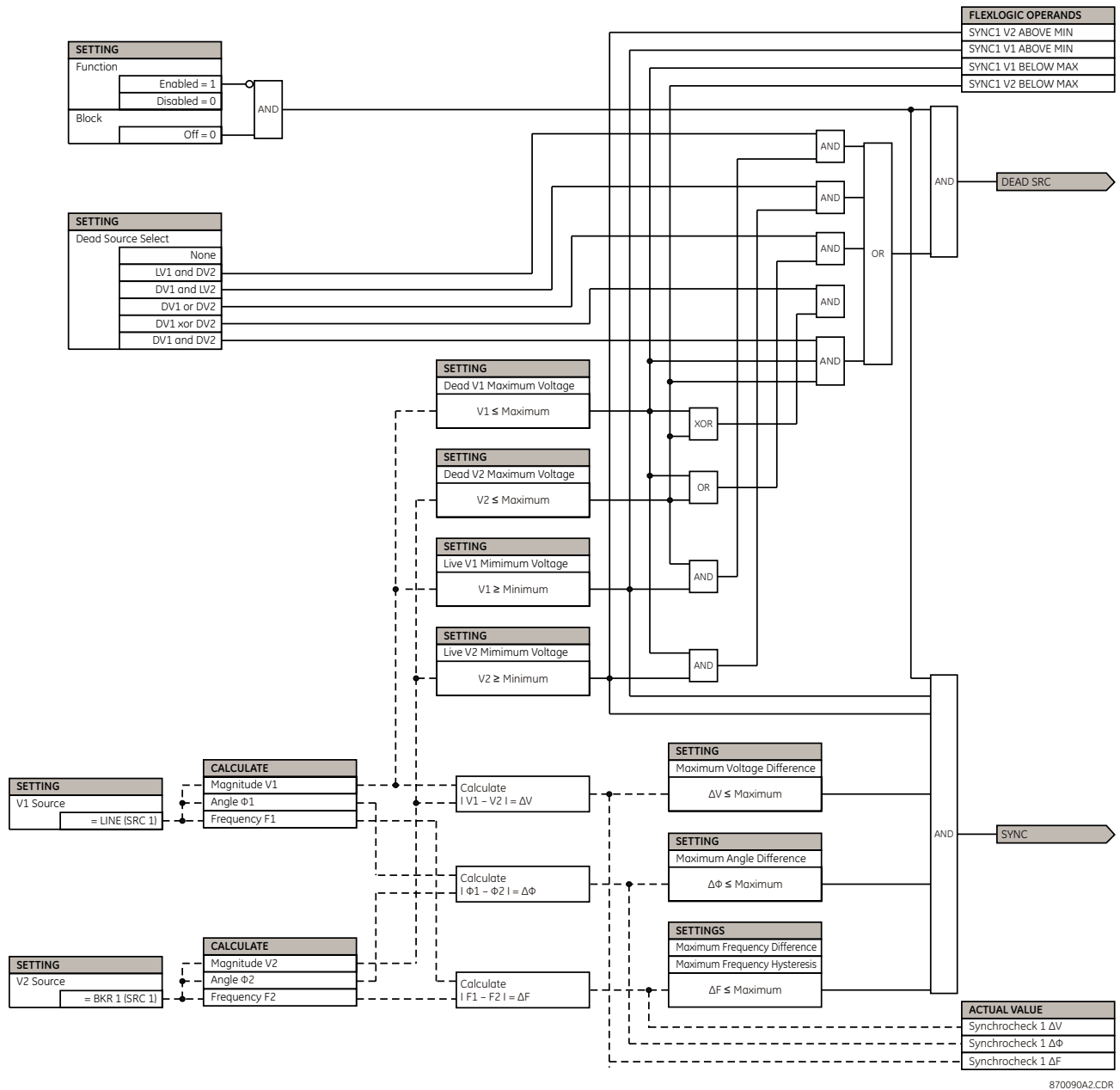
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of synchrocheck events in the sequence of events recorder.

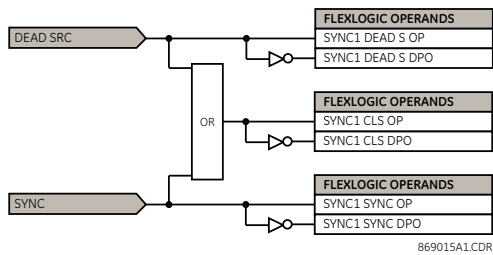
The figures show the logic for the synchrocheck element.

Figure 384: Synchrocheck logic, sheet 1 of 2



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Figure 385: Synchrocheck logic, sheet 2 of 2



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Selector switch

The selector switch element replaces a mechanical selector switch. Typical applications include setting group control or control of multiple logic sub-circuits in user-programmable logic.

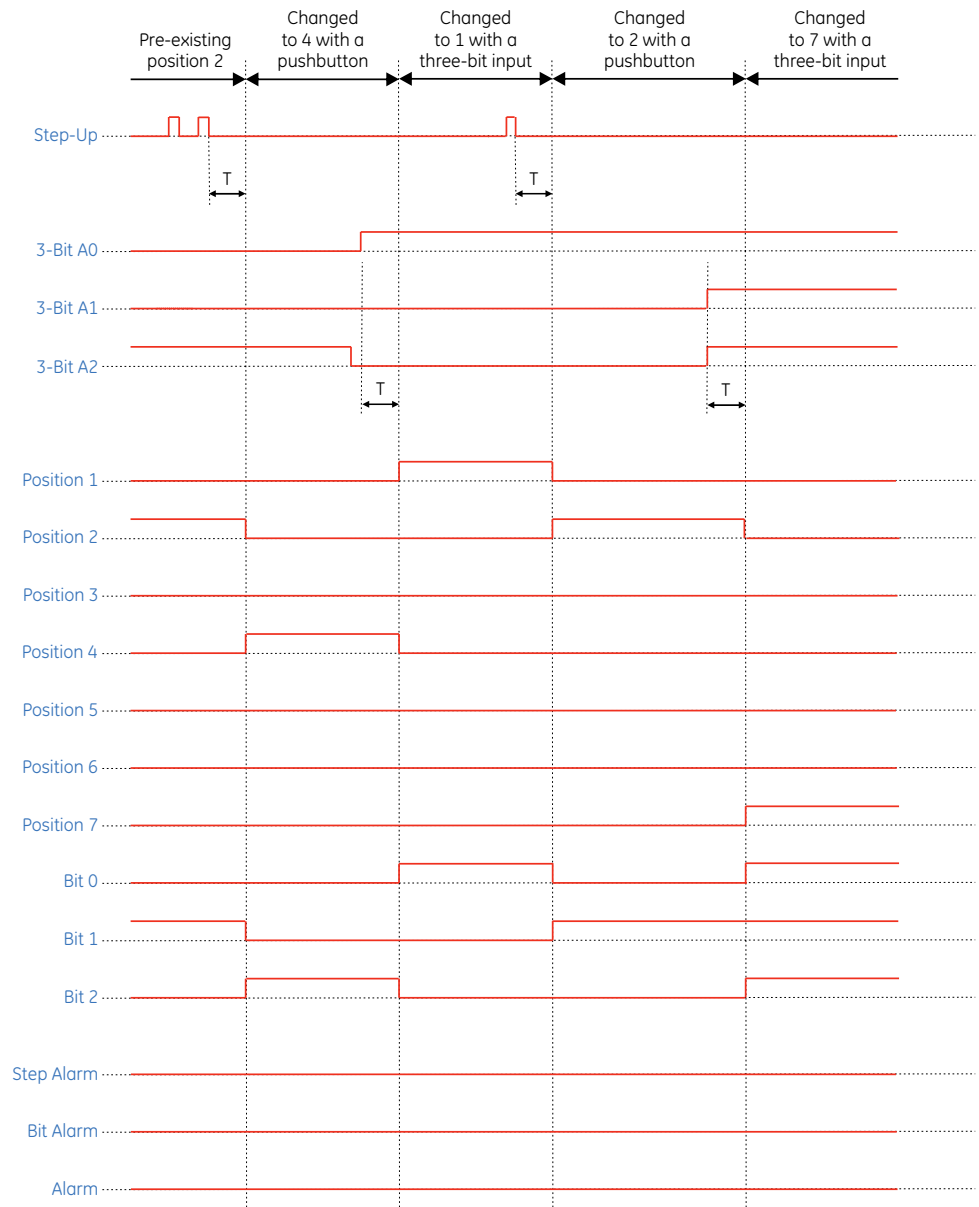
Selector switch operation

The selector switch provides for two control inputs. The step-up control allows stepping through selector position one step at a time with each pulse of the control input, such as a user-programmable pushbutton. The three-bit control input allows setting the selector to the position defined by a three-bit word.

The element allows pre-selection of a new position without applying it. The pre-selected position gets applied either after time-out or upon acknowledgement via separate inputs (user setting). The selector position is stored in non-volatile memory. Upon power-up, either the previous position is restored or the relay synchronizes to the current three-bit word (user setting). Basic alarm functionality alerts the user under abnormal conditions, for example, the three-bit control input being out of range.

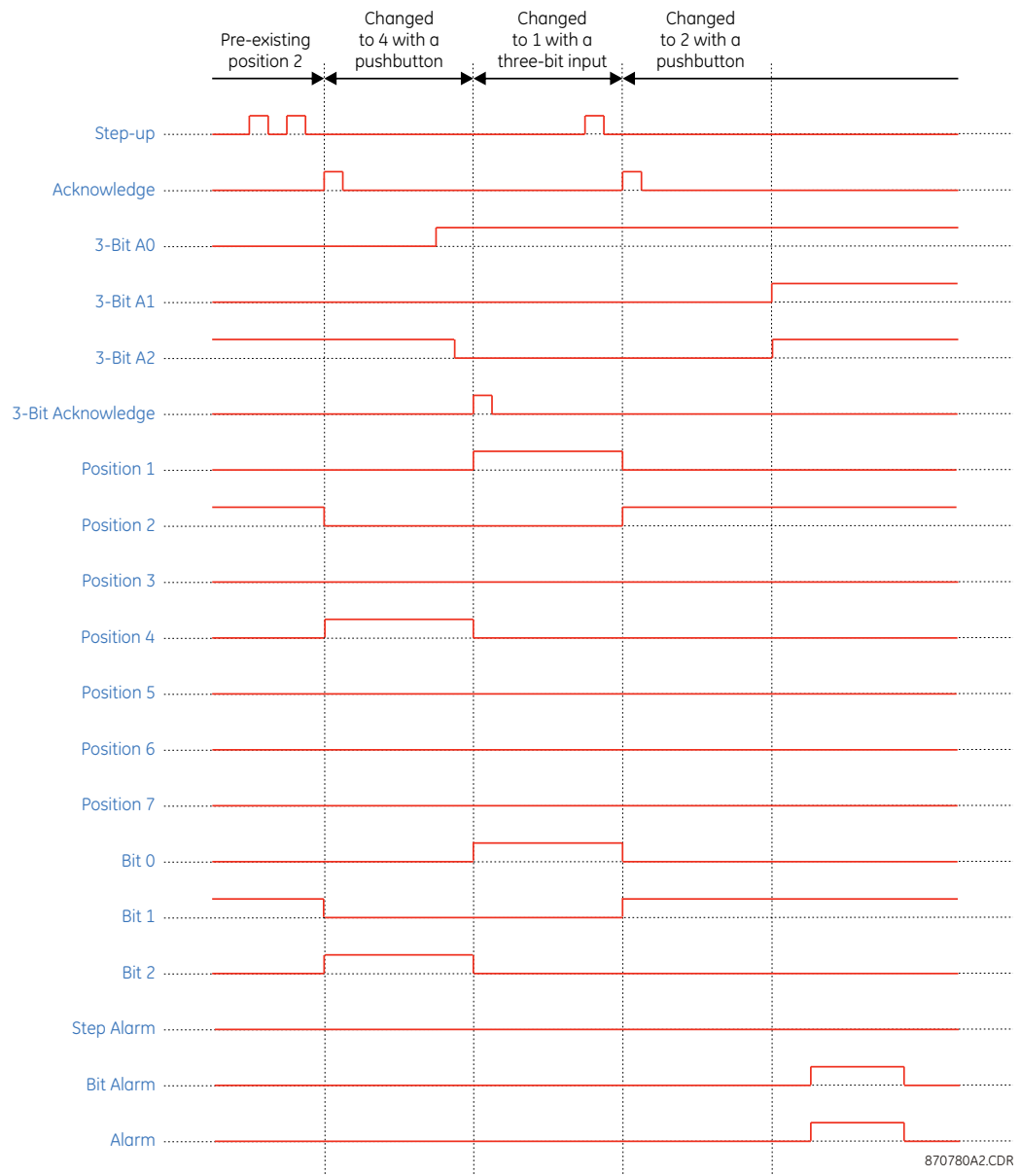
The following figures illustrate the operation of the selector switch. In these diagrams, “T” represents a time-out setting.

Figure 386: Time-out mode



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Figure 387: Acknowledge mode



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Selector switch settings

Select the **Settings > Automation > Control > Selector Switches** menu to open the selector switch configuration window.

Figure 388: Selector switch configuration settings

PARAMETER	SELECTOR SWITCH 1	SELECTOR SWITCH 2
Function	Disabled	Disabled
Full Range	7	7
Timeout	5.0 s	5.0 s
Step-Up	OFF	OFF
Step-Up Mode	Time-out	Time-out
Acknowledge	OFF	OFF
3-Bit A0	OFF	OFF
3-Bit A1	OFF	OFF
3-Bit A2	OFF	OFF
3-Bit Mode	Time-out	Time-out
3-Bit Acknowledge	OFF	OFF
Power-Up Mode	Restore	Restore
Events	Disabled	Disabled

The following settings are available for each selector switch.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the selector switch.

Full Range

Range: 1 to 7 in steps of 1

Default: 7

This setting specifies the upper position of the selector switch. When stepping up through available positions of the selector, the upper position wraps up to the lower position (position 1). When using a direct three-bit control word for programming the selector to a required position, the change takes place only if the control word is within the range of 1 to the full range. If the control word is outside the range, an alarm is established by activating the **SELECTOR ALARM** operand for three seconds.

Timeout

Range: 3.0 to 60.0 seconds in steps of 0.1

Default: 5.0 seconds

This setting specifies the time-out period for the selector. This value is used by the relay in two ways. When the **Step-Up Mode** is “Time-out,” the setting specifies the required period of inactivity of the control input after which the pre-selected position is automatically applied. When the **Step-Up Mode** is “Acknowledge,” the setting specifies the period of time for the acknowledging input to appear. The timer is re-started by any activity of the control input. The acknowledging input must come before this timer expires, otherwise the change does not take place and an alarm is set.

Step-Up

Range: any automation logic operand or shared operand

Default: OFF

This setting selects a control input for the selector switch. The switch is shifted to a new position at each rising edge of this signal. The position changes incrementally, wrapping up from the last (the **Full Range** value) to the first (position 1). Consecutive pulses of this control operand must not occur faster than every 50 ms. After each rising edge of the assigned operand, the time-out timer restarts. The pre-selected position is applied after the selector times out (time-out mode), or when the acknowledging signal appears before the element times out (acknowledge mode). Typically, a user-programmable pushbutton is configured as the stepping up control input.

Step-Up Mode*Range: Time-out, Acknowledge**Default: Time-out*

This setting defines the selector mode of operation. When set to “Time-out,” the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require any explicit confirmation of the intent to change the selector’s position. When set to “Acknowledge,” the selector changes its position only after the intent is confirmed through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector does not accept the change and an alarm is established by setting the [SELECTOR STP ALARM](#) output FlexLogic operand for three seconds.

To activate a selector switch via the front panel, have this setting select the corresponding pushbutton operand (for example, [PUSHBUTTON 1 ON](#)). This operand is asserted only if the corresponding pushbutton element has been enabled.

Acknowledge*Range: any automation logic operand or shared operand**Default: OFF*

This setting selects an acknowledging input for the stepping up control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under the acknowledge mode of operation. The acknowledging signal must appear within the time defined by the [Timeout](#) setting after the last activity of the control input. A user-programmable pushbutton typically is configured as the acknowledging input.

3-Bit A0, 3-Bit A1, 3-Bit A2*Range: any automation logic operand or shared operand**Default: OFF*

These settings specify a three-bit control input of the selector. The three-bit control word pre-selects the position using the following encoding convention.

Table 28: Selector switch three-bit control word

A2	A1	A0	Position
0	0	0	rest
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

The rest position (0, 0, 0) does not generate an action and is intended for situations when the device generating the three-bit control word is having a problem. When in time-out mode, the pre-selected position is applied in the time specified (in seconds) by the [Timeout](#) setting after the last activity of the three-bit input. When in acknowledge mode, the pre-selected position is applied on the rising edge of the acknowledging input specified by the [3-Bit Acknowledge](#) setting.

The stepping up control input (selected by the [Step-Up](#) setting) and the three-bit control inputs (A0, A1, and A2) lock-out mutually. Once the stepping up sequence is initiated, the three-bit control input is inactive. Once the three-bit control sequence is initiated, the stepping up input is inactive.

3-Bit Mode*Range: Time-out, Acknowledge**Default: Time-out*

This setting selects the selector mode of operation. When set to “Time-out,” the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require explicit confirmation to change the selector position. When set to “Acknowledge,” the selector changes its position only after confirmation through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector rejects the change and an alarm established by invoking the [SELECTOR BIT ALARM](#) FlexLogic operand for three seconds.

3-Bit Acknowledge*Range: any automation logic operand or shared operand**Default: OFF*

This setting selects an acknowledging input for the three-bit control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under the acknowledge mode of operation. The acknowledging signal must appear within the time defined by the [Timeout](#) setting after the last activity of the three-bit control inputs. Note that the stepping up control input and three-bit control input have independent acknowledging signals (the [SELECTOR 1 ACK](#) and [SELECTOR 1 3BIT ACK](#) operands, accordingly).

Power-Up Mode*Range: Restore, Synchronize, Sync/Restore**Default: Restore*

This setting selects the selector switch behavior on power up of the relay.

When set to “Restore,” the last position of the selector (stored in the non-volatile memory) is restored after powering up the relay. If the position restored from memory is out of range, position 0 (no output operand selected) is applied and an alarm is set ([SELECTOR 1 PWR ALARM](#)).

When set to “Synchronize,” the selector switch acts as follows. For two power cycles, the selector applies position 0 to the switch and activates the [SELECTOR 1 PWR ALARM](#) operand. After two power cycles expire, the selector synchronizes to the position dictated by the three-bit control input. This operation does not wait for time-out or the acknowledging input. When the synchronization attempt is unsuccessful (that is, the three-bit input is not available (0,0,0) or out of range) then the selector switch output is set to position 0 (no output operand selected) and an alarm is established (the [SELECTOR 1 PWR ALARM](#) operand is asserted).

The operation of the “Synch/Restore” mode is similar to the “Synchronize” mode. The only difference is that the switch attempts to restore the position stored in the relay memory after an unsuccessful synchronization attempt. The synch/restore mode is useful for applications where the selector switch is employed to change the setting group in redundant (two relay) protection schemes.

Events*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables the logging of selector switch events in the sequence of events recorder. If enabled, the following events are logged.

Selector switch events

SELECTOR 1 POS 1 Selector 1 changed its position to 1.

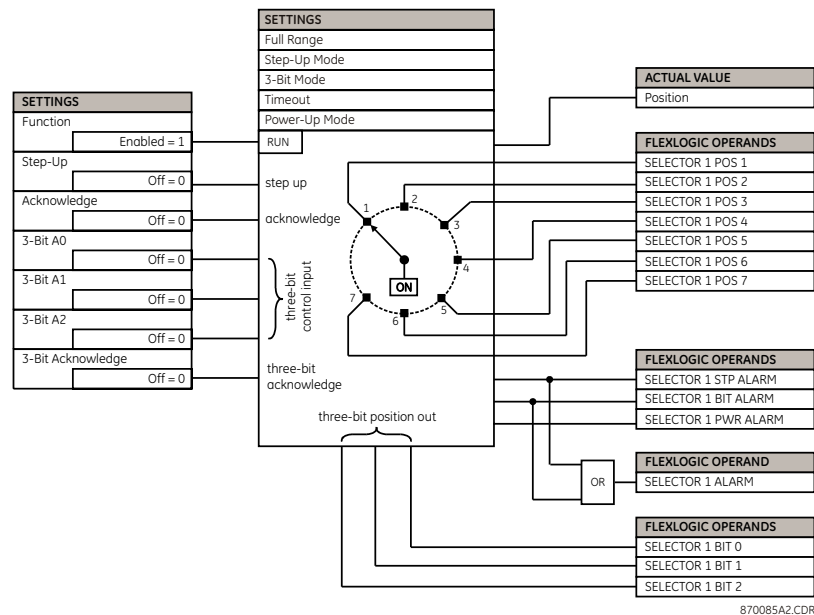
SELECTOR 1 POS 2 Selector 1 changed its position to 2.

SELECTOR 1 POS 3 Selector 1 changed its position to 3.

- SELECTOR 1 POS 4.....Selector 1 changed its position to 4.
- SELECTOR 1 POS 5.....Selector 1 changed its position to 5.
- SELECTOR 1 POS 6.....Selector 1 changed its position to 6.
- SELECTOR 1 POS 7.....Selector 1 changed its position to 7.
- SELECTOR 1 STP ALARMThe selector position pre-selected via the stepping up control input has not been confirmed before the time out.
- SELECTOR 1 BIT ALARM.....The selector position pre-selected via the three-bit control input has not been confirmed before the time out.
- SELECTOR 2The set of events shown above are available for selector switch 2.

The figure shows the logic diagram for the selector switch.

Figure 389: Selector switch logic



Automation inputs and outputs

Three groupings of automation inputs and outputs are defined: physical (contacts), shared, and virtual. Within these three groupings there are two types: analog and digital.

Automation virtual inputs

There are 128 virtual inputs that can be programmed individually to respond to input signals from the front panel interface and communications protocols. All virtual input operands are defaulted to off (logic 0) unless the appropriate input signal is received.

Automation virtual inputs can be paired as control outputs. See the DNP Number of Paired Controls setting in the Communications chapter for information.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Inputs** menu to access the virtual input configuration settings.

Figure 390: Automation virtual inputs configuration settings

AUT VIRT INPUT	FUNCTION	ID	TYPE	EVENTS
VIRT INPUT 1	Disabled	Aut VI 1	Latched	Disabled
VIRT INPUT 2	Disabled	Aut VI 2	Latched	Disabled
VIRT INPUT 3	Disabled	Aut VI 3	Latched	Disabled
VIRT INPUT 4	Disabled	Aut VI 4	Latched	Disabled
VIRT INPUT 5	Disabled	Aut VI 5	Latched	Disabled
VIRT INPUT 6	Disabled	Aut VI 6	Latched	Disabled
VIRT INPUT 7	Disabled	Aut VI 7	Latched	Disabled
VIRT INPUT 8	Disabled	Aut VI 8	Latched	Disabled
VIRT INPUT 9	Disabled	Aut VI 9	Latched	Disabled
VIRT INPUT 10	Disabled	Aut VI 10	Latched	Disabled
VIRT INPUT 11	Disabled	Aut VI 11	Latched	Disabled
VIRT INPUT 12	Disabled	Aut VI 12	Latched	Disabled
VIRT INPUT 13	Disabled	Aut VI 13	Latched	Disabled
VIRT INPUT 14	Disabled	Aut VI 14	Latched	Disabled
VIRT INPUT 15	Disabled	Aut VI 15	Latched	Disabled
VIRT INPUT 16	Disabled	Aut VI 16	Latched	Disabled

The following settings are available for each automation virtual input. The default values outlined are for virtual input 1.

Function

Range: Enabled, Disabled
Default: Disabled

If this setting is “Disabled,” the virtual input is forced to off (logic 0) regardless of any attempt to alter the input. If set to “Enabled,” the input operates as shown on the logic diagram and generates output logic operands in response to received input signals and the applied settings.

ID

Range: up to 12 alphanumeric characters
Default: Aut VI 1

This setting specifies an identifier that can be assigned to each virtual input.

Type

Range: Self-Reset, Latched
Default: Latched

There are two types of operation: self-reset and latched. If this setting is “Self-Reset,” the output operand is asserted (logic 1) for only one evaluation of the automation logic equations and then it returns to 0 when the input signal transits from off to on. If set to “Latched,” the virtual input sets the state of the output operand to the same state as the most recent received input.



The self-reset operating mode generates an output operand for a single evaluation of the automation logic equations. If the operand is to be used anywhere other than internally in an automation logic equation, it likely has to be lengthened in time. An automation logic timer with a delayed reset can perform this function.

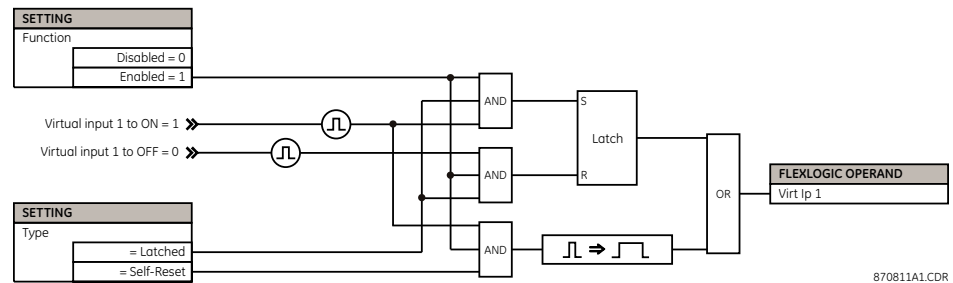
Events

Range: Enabled, Disabled
Default: Disabled

If this setting is “Enabled,” every change in the automation virtual input state triggers an event in the sequence of events recorder.

The figure shows the automation virtual input logic. The logic is identical for all automation virtual inputs.

Figure 391: Automation virtual input logic



Automation virtual outputs

There are 255 virtual outputs that can be assigned via automation logic. Virtual outputs are resolved in each pass through the evaluation of the automation logic equations.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Outputs** menu to access the automation virtual output configuration settings.

Figure 392: Automation virtual output settings

AUT VIRT OUTPUT	ID	EVENTS
VIRT OUTPUT 1	Aut VO 1	Disabled
VIRT OUTPUT 2	Aut VO 2	Disabled
VIRT OUTPUT 3	Aut VO 3	Disabled
VIRT OUTPUT 4	Aut VO 4	Disabled
VIRT OUTPUT 5	Aut VO 5	Disabled
VIRT OUTPUT 6	Aut VO 6	Disabled
VIRT OUTPUT 7	Aut VO 7	Disabled
VIRT OUTPUT 8	Aut VO 8	Disabled
VIRT OUTPUT 9	Aut VO 9	Disabled
VIRT OUTPUT 10	Aut VO 10	Disabled
VIRT OUTPUT 11	Aut VO 11	Disabled
VIRT OUTPUT 12	Aut VO 12	Disabled
VIRT OUTPUT 13	Aut VO 13	Disabled
VIRT OUTPUT 14	Aut VO 14	Disabled
VIRT OUTPUT 15	Aut VO 15	Disabled
VIRT OUTPUT 16	Aut VO 16	Disabled

The following settings are available for each automation virtual output. If not assigned, the virtual output is forced to off (logic 0).

ID

Range: up to 12 alphanumeric characters

Default: Aut VO 1

This setting specifies an identifier that can be assigned to each automation virtual output.

Events

Range: Enabled, Disabled

Default: Disabled

If this setting is “Enabled,” every change in the automation virtual output state triggers an event in the sequence of events recorder.

As an example, if automation virtual output 1 is the trip signal from automation logic and the trip relay is used to signal events, the settings are programmed as follows.

Figure 393: Automation virtual output programming example

AUT VIRT OUTPUT	ID	EVENTS
VIRT OUTPUT 1	TRIP	Enabled
VIRT OUTPUT 2	Aut VO 2	Disabled
VIRT OUTPUT 3	Aut VO 3	Disabled
VIRT OUTPUT 4	Aut VO 4	Disabled
VIRT OUTPUT 5	Aut VO 5	Disabled
VIRT OUTPUT 6	Aut VO 6	Disabled
VIRT OUTPUT 7	Aut VO 7	Disabled
VIRT OUTPUT 8	Aut VO 8	Disabled
VIRT OUTPUT 9	Aut VO 9	Disabled
VIRT OUTPUT 10	Aut VO 10	Disabled
VIRT OUTPUT 11	Aut VO 11	Disabled
VIRT OUTPUT 12	Aut VO 12	Disabled
VIRT OUTPUT 13	Aut VO 13	Disabled
VIRT OUTPUT 14	Aut VO 14	Disabled
VIRT OUTPUT 15	Aut VO 15	Disabled
VIRT OUTPUT 16	Aut VO 16	Disabled

Contact input and output default assignment

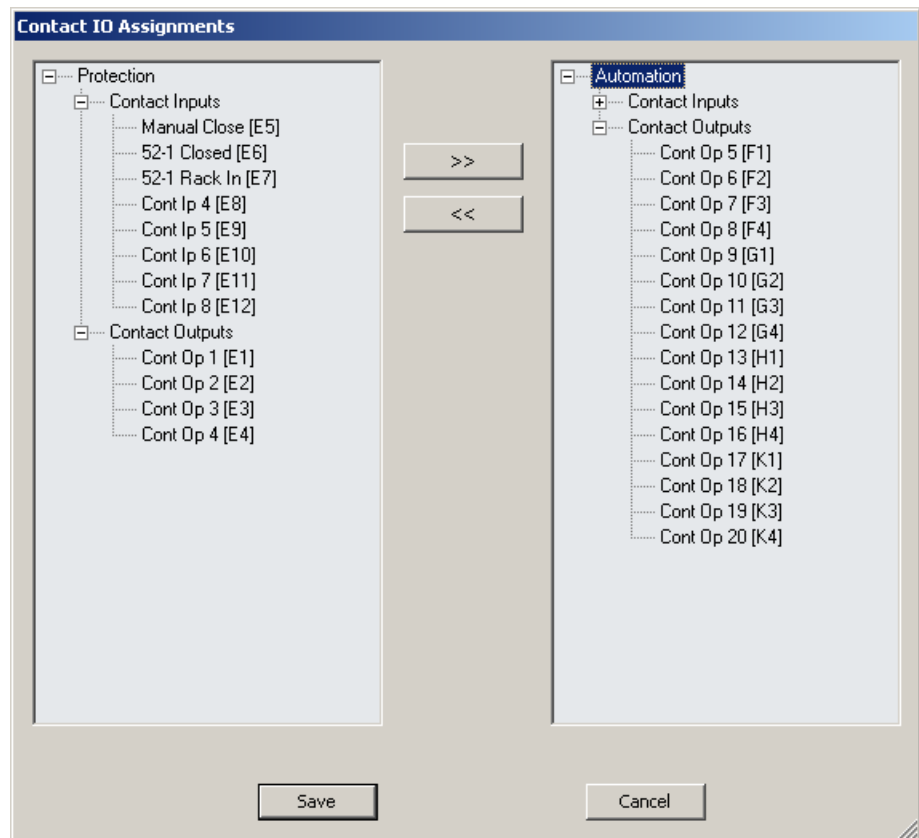
When a new settings file is created, the available contacts are assigned automatically to the protection or automation functions according to the following convention:

- First I/O module → protection
- All subsequent I/O modules → automation

For example, if a D90^{PLUS} is configured with contact input/output cards in slots E, F, and G, then the inputs and outputs associated with slot E are assigned to protection and the inputs and outputs associated with slots F and G are assigned to automation.

These default assignments can be changed to match the requirements of the application. This is done by right-clicking the setting filename and choosing the **Manage Settings File > I/O Assignments** item. The following window displays.

Figure 394: Contact input and output assignments



All available contact inputs and outputs can be reassigned using the >> and << buttons.

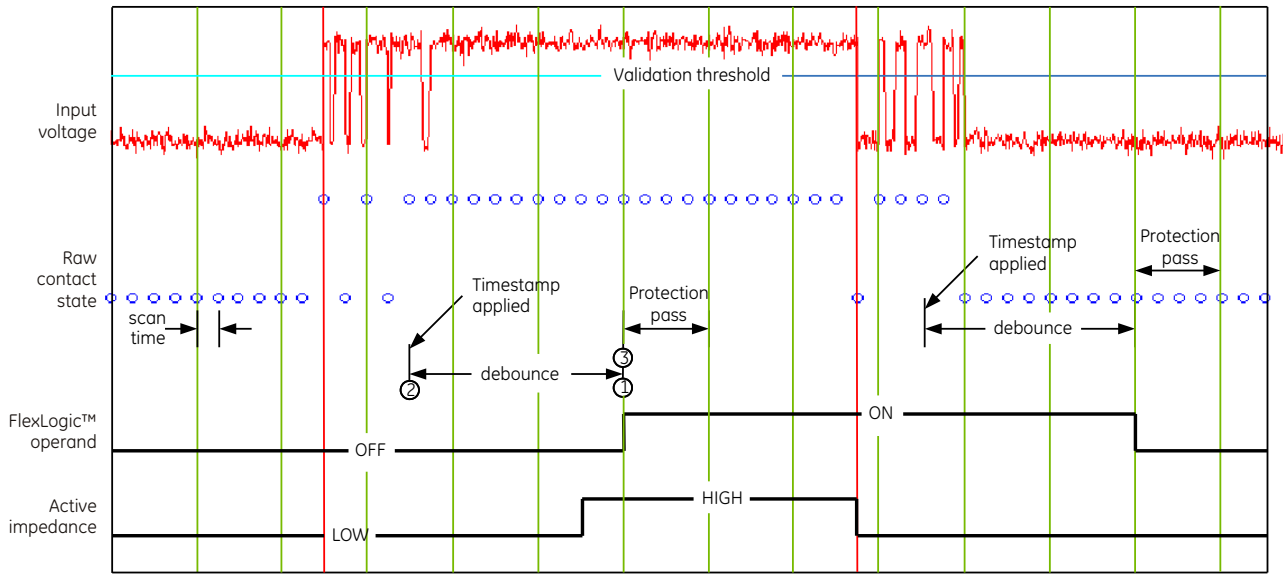
Contact input configuration

The D90^{Plus} can monitor the status of up to 115 field contacts. Each input can be wetted from the D90^{Plus} 48 volt auxiliary supply or from an external power supply. Each digital input has a dedicated delay timer for filtering of contact bouncing. The D90^{Plus} can also detect an oscillating input via the chatter feature. Each contact input can provide security against false turn-on of an input due to excessive stray capacitance of field wiring.

A raw status is scanned synchronously for all contact inputs at the rate of 0.25 ms as shown in the following figure. A new contact input state must be maintained for a user-programmable debounce time for the D90^{Plus} to validate the new contact state. The debounce time is set at 2.0 ms in the figure. As such, the eighth sample validates the change of state (mark 1 in the figure). Once validated (debounced), the automation contact input asserts a corresponding automation operand and logs an event (if event logging is enabled).

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the event recorder (mark 2 in the figure).

Figure 395: Automation contact input debouncing mechanism and time-stamping



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Automation equations and timers are executed at the automation scan rate. The automation operand reflecting the debounced state of the contact is updated at the automation pass following the validation (mark 3 in the figure). The update is performed at the beginning of the 1 ms scanning pass so all automation functions and equations are fed with the updated states of the contact inputs.

The automation operand response time to the contact input change is equal to the debounce time setting plus a maximum of one protection pass. If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass (that is, by the entire duration of the protection pass). If the change occurs just prior to a protection pass, the state is recognized immediately. Statistically, a delay of half the protection pass is expected. Owing to the 0.25 ms scan rate, the time resolution for the contact input is less than 1 ms.

For example, 16 protection passes per cycle on a 60 Hz system correspond to a protection pass every 1.04 ms. With a contact debounce time setting of 3.0 ms, the automation operand assertion time limits are $3.0 + 0.0 = 3.0$ ms and $3.0 + 1.04 = 4.04$ ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1 ms accuracy using the time of the first scan corresponding to the new state. Therefore, the time stamp reflects a change in the DC voltage across the digital input terminals that was not accidental because it was validated subsequently using the debounce timer. Keep in mind that the associated automation operand is asserted or de-asserted later, after validating the change. The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the OFF-ON and ON-OFF transitions.

The active impedance feature controls the input impedance presented to the system according to the current state of the input. When the contact input circuitry initially detects a voltage increase, it draws 10 mA of current. If the state change is due to a transient coupled through the stray capacitance of the field wiring, then the high current sink charges the capacitance causing the transient to rapidly decay. If voltage increase is due to a state change of the field contact, then the increased current has no impact on the input voltage, and the state change is validated. Once the input has been declared to be on, the input circuitry reduces the current drawn to 1 mA to minimize the power dissipated by the input.

When the input detects a voltage decrease, the input circuitry draws 10 mA of current. If the voltage decrease is due to a state change then the voltage quickly decreases, speeding up the recognition of the reset of the field contact by quickly discharging any input capacitance.



The contact input update time is 1 ms. However, depending on where the contact input status change is triggered within a 1 ms window, the worst-case contact input recognition time is 2 ms.

Contact input settings

Select the **Settings > Automation > Automation Inputs/Outputs > Contact Inputs > Contact Inputs** menu to access the automation contact input configuration settings.

Figure 396: Automation contact input configuration settings

CONTACT INPUT	ID	DEBOUNCE TIME	NOMINAL VOLTAGE	EVENTS
F5	DSC1 89a	2.00 ms	125 V	Enabled
F6	DSC2 89a	2.00 ms	125 V	Enabled
F7	Cont Ip 11	2.00 ms	125 V	Enabled
F8	Cont Ip 12	2.00 ms	125 V	Enabled
F9	Cont Ip 13	2.00 ms	125 V	Enabled
F10	Cont Ip 14	2.00 ms	125 V	Enabled
F11	Cont Ip 15	2.00 ms	125 V	Enabled
F12	Cont Ip 16	2.00 ms	125 V	Enabled

The contact inputs menu contains configuration settings for each input. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then displays settings for only those inputs. The following settings are available for each contact input.

ID

Range: up to 12 alphanumeric characters

Default: Cont Ip 1

An alphanumeric identifier can be assigned to a contact input for diagnostic, setting, and event recording purposes. The “CONTACT IP 1” text in event records and automation logic operands are replaced by the text programmed in this setting.

Debounce Time

Range: 1.50 to 16.00 ms in steps of 0.25

Default: 2.00 ms

This setting defines the time required for the contact to overcome contact bouncing conditions. As this time differs for different contact types and manufacturers, program it as a maximum contact debounce time (per manufacturer specifications) plus additional margin to ensure proper operation.

Nominal Voltage

Range: 24 to 250 volts in steps of 1

Default: 125 volts

This setting specifies the range required to validate a closed contact input. This range is fixed at 70 to 130% of this setting value, with an absolute minimum of 20 volts and an absolute maximum of 285 volts.

Table 29: Nominal voltage setting for typical battery voltages

Nominal voltage	Validation threshold
24 V	20 V

Nominal voltage	Validation threshold
48 V	33.6 V
125 V	87.5 V
250 V	175 V

Events

Range: Enabled, Disabled

Default: Enabled

If this setting is “Enabled,” every change in the contact input state triggers an event in the event recorder.

Contact input chatter detection

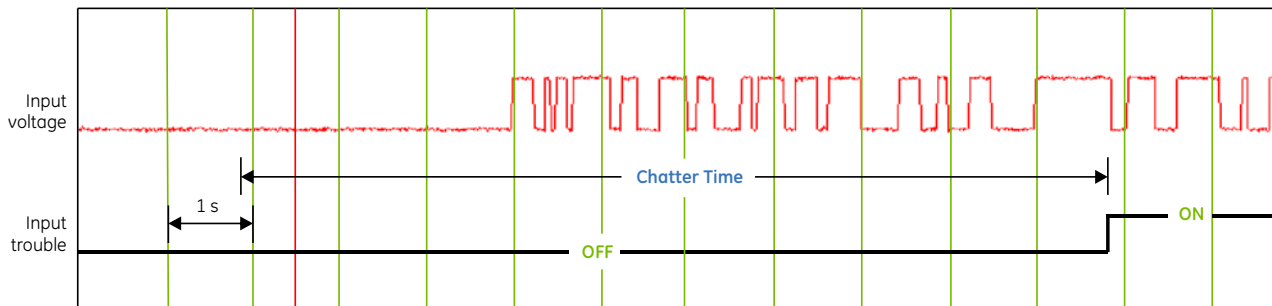
The D90^{Plus} has a chatter detection feature. When enabled, the IED monitors the number of state changes that occur within a set duration. If this value exceeds a set value, then a trouble condition is declared for the input and the **CONTACT INPUT TROUBLE** operand asserts.

The input trouble alarm impacts relay functionality as follows:

- Automation logic operands – Operand state is blocked
- DNP 3.0 communications – Reporting of the input is blocked
- IEC 60870-5-104 communications – Reporting of the input is blocked
- IEC 61850 GSSE and IEC 61850 GOOSE – Reporting of the input is blocked
- Sequence of events recorder – Reporting of the input is blocked

The trouble condition resets if the input undergoes no state changes for a duration equal to twice the chatter time setting.

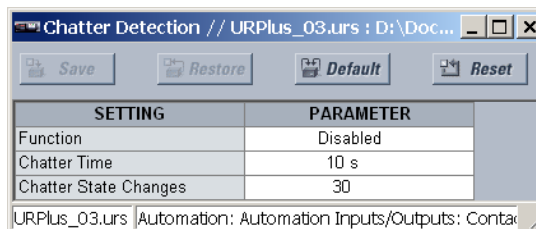
Figure 397: Chatter detection example



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Select the **Settings > Automation > Automation Inputs/Outputs > Contact Inputs > Chatter Detection** menu to access the contact input chatter detection settings.

Figure 398: Contact input chatter detection configuration



The following settings are applied to all available protection and automation contact inputs.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the chatter detection feature.

Chatter Time

Range: 1 to 100 seconds in steps of 1

Default: 10 seconds

This setting specifies the length of time that the relay contacts are monitored for contact input state changes.

Chatter State Changes

Range: 10 to 100 in steps of 1

Default: 30

This setting specifies the number of state changes that must occur in the time window defined by the **Chatter Time** setting before issuing the trouble operand.

Since chatter detection is a hardware diagnostic, a trouble indication is logged regardless of the **Events** setting being enabled or disabled for a particular input.

Contact outputs

Upon startup of the relay, the main processor determines from an assessment of the modules installed in the chassis which contact outputs are available and presents the settings for only these outputs.

Select the **Settings > Automation > Automation Inputs/Outputs > Contact Outputs** menu to access the contact output configuration settings.

Figure 399: Automation contact output configuration settings

CONTACT OUTPUT	ID	OPERATE	SEAL-IN	VOLTAGE THRESHOLD	EVENTS
F1	DSC1 TR COIL	DSC1 OPEN CMD	OFF	20	Enabled
F2	DSC1 CL COIL	DSC1 CLOSE CMD	OFF	20	Enabled
F3	DSC2 TR COIL	DSC2 OPEN CMD	OFF	20	Enabled
F4	DSC2 CL COIL	DSC2 CLOSE CMD	OFF	20	Enabled

The settings for contact output 1 are used as an example. These settings are available for all contact outputs.

ID

Range: up to 12 alphanumeric characters

Default: Cont Op 1

This setting specifies an alphanumeric identifier for the contact output.

Operate

Range: any automation logic operand or shared operand

Default: OFF

This setting selects an operand (virtual output, element state, contact input, or virtual input) that operates the contact output when asserted.

Seal-In

Range: any automation logic operand or shared operand

Default: OFF

This setting selects an operand (virtual output, element state, contact input, or virtual input) that seals-in the contact output when asserted.

Voltage Threshold

Range: 20 to 250 volts in steps of 1
 Default: 20

This setting specifies the level at which the Contact Op 1 VOn and Contact Op 1 VOff operands function. It is only shown for contact outputs that have monitoring.

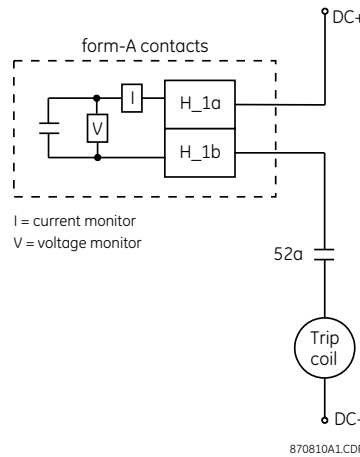
Events

Range: Enabled, Disabled
 Default: Enabled

If this setting is “Enabled,” every change in the contact output state triggers an event in the event recorder.

For example, consider a trip circuit current being monitored by providing a current threshold detector in series with some form-A contacts as shown.

Figure 400: Trip circuit monitoring example



The name of the automation logic operand set by the monitor consists of the contact output identifier followed by the name of the flag. For example, using the default identifiers, we can have **Cont Op 1 Ion** and **Cont Op 1 Von**.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact used to interrupt current flow after the breaker has tripped, to prevent damage to the less robust initiating contact. This can be done by monitoring an auxiliary contact on the breaker that opens when the breaker has tripped. However, this scheme is subject to incorrect operation caused by differences in timing between breaker auxiliary contact change-of-state and interruption of current in the trip circuit. The most dependable protection of the initiating contact is provided by directly measuring current in the tripping circuit, and using this parameter to control reset of the initiating relay. This scheme is often referred to as a *trip seal-in* scheme.

This trip seal-in scheme can be realized in the D90^{PLUS} by using the **Cont Op 1 Ion** automation logic operand to seal-in the contact output as follows.

Figure 401: Trip seal-in scheme settings

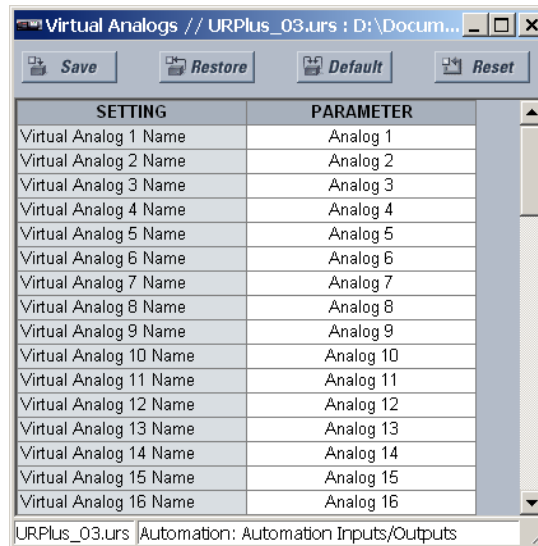
CONTACT OUTPUT	ID	OPERATE	SEAL-IN	VOLTAGE THRESHOLD	EVENTS
F1	CONT OP 1	BKR1 INTLK TAGGED	CONT OP 1 IO _n (F1)	20	Enabled
F2	DSC1 CL COIL	DSC1 CLOSE CMD	OFF	20	Enabled
F3	DSC2 TR COIL	DSC2 OPEN CMD	OFF	20	Enabled
F4	DSC2 CL COIL	DSC2 CLOSE CMD	OFF	20	Enabled

Virtual analog outputs

There are 128 virtual analog outputs that can be assigned using automation logic. Virtual analog outputs are resolved in each pass through the evaluation of the automation logic equations.

Select the **Settings > Automation > Automation Inputs/Outputs > Virtual Analogs** menu to access the virtual analog output configuration settings.

Figure 402: Virtual analog output configuration settings



SETTING	PARAMETER
Virtual Analog 1 Name	Analog 1
Virtual Analog 2 Name	Analog 2
Virtual Analog 3 Name	Analog 3
Virtual Analog 4 Name	Analog 4
Virtual Analog 5 Name	Analog 5
Virtual Analog 6 Name	Analog 6
Virtual Analog 7 Name	Analog 7
Virtual Analog 8 Name	Analog 8
Virtual Analog 9 Name	Analog 9
Virtual Analog 10 Name	Analog 10
Virtual Analog 11 Name	Analog 11
Virtual Analog 12 Name	Analog 12
Virtual Analog 13 Name	Analog 13
Virtual Analog 14 Name	Analog 14
Virtual Analog 15 Name	Analog 15
Virtual Analog 16 Name	Analog 16

The following setting is available, with that for virtual analog output 1 outlined. The settings are identical for all virtual analog outputs.

Virtual Analog 1 Name

Range: up to 12 alphanumeric characters

Default: Analog 1

This setting specifies an identifier for virtual analog output 1. This value is included in the actual values and also is used to reference output to features that use this parameter.

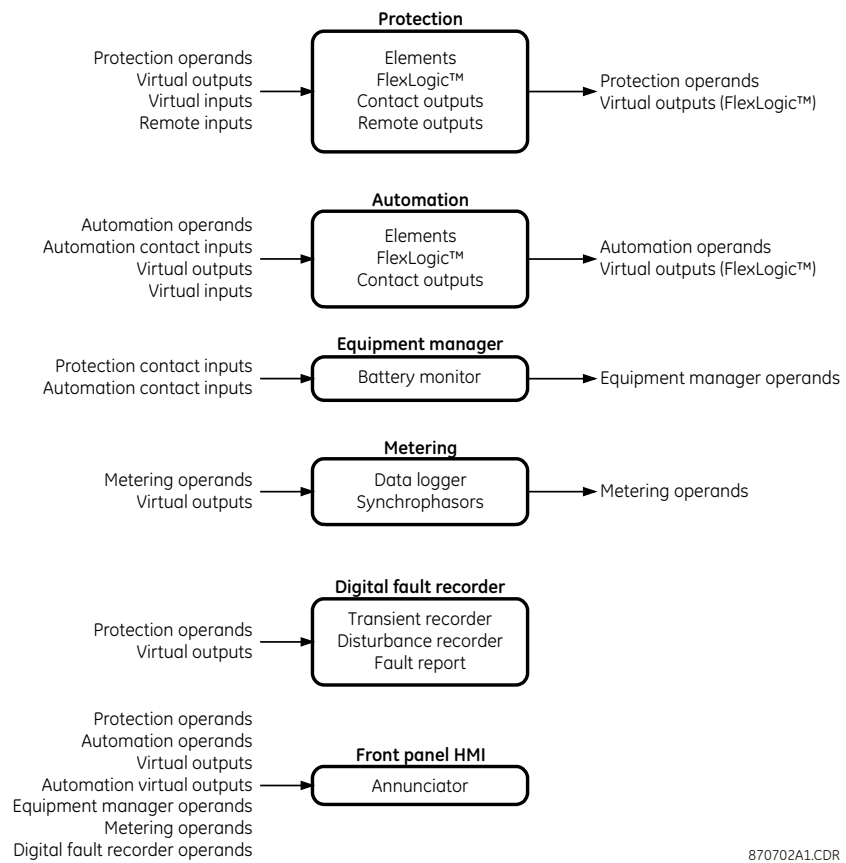
Using shared operands in automation

The EnerVista UR^{Plus} Setup software groups the D90^{Plus} system into the following eight primary functions. Each function has its own settings and each generates its own outputs in the form of operands.

- Communications
- Protection
- Automation
- Digital fault recorder (DFR)
- Metering
- Equipment manager
- Self-tests
- Front panel interface (HMI)

It is often desirable for an output from an element within one function to be available to an element within another function. For example, it can be useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available to each function, as shown.

Figure 403: Default operand list by function



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The content of each operand list depends on the order code.

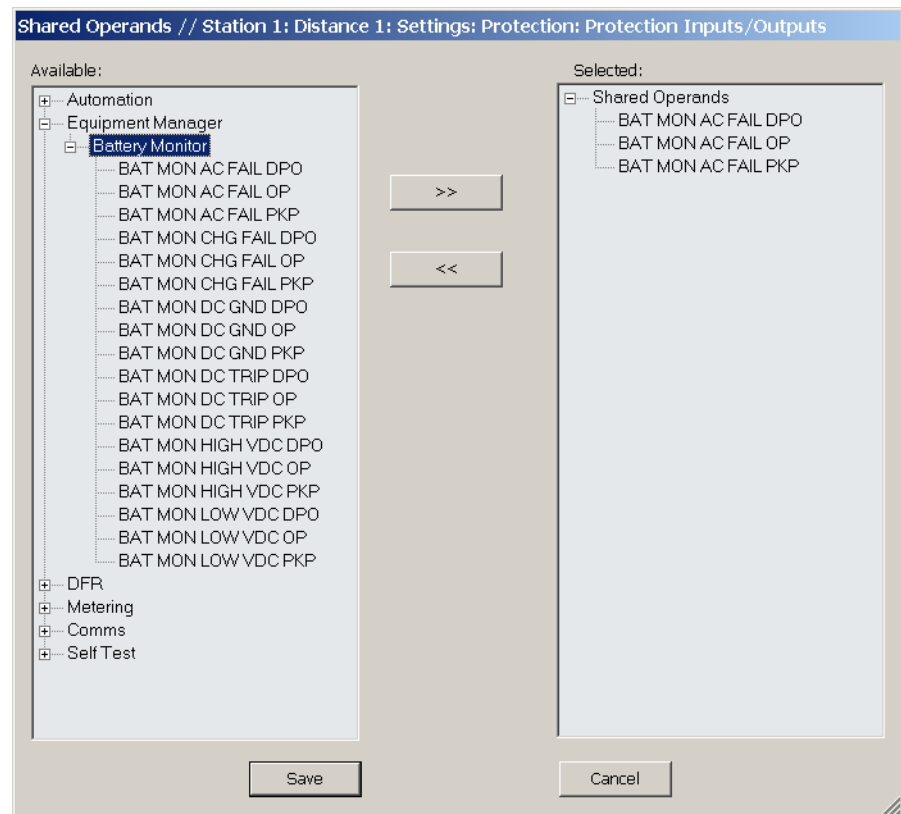
The shared operands functionality expands upon this system. An output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals then can be assigned as inputs to other functions.

For example, assume that the [GND TOC1 OP](#) protection operand is required as a signal within the automation function. This operand then is assigned as a shared operand and subsequently becomes available to the automation function. A total of 64 operands can be assigned as shared operands within each function.

Shared automation operands

Select the **Settings > Automation > Automation Inputs/Outputs > Shared Operands** menu to select the shared automation logic operands.

Figure 404: Shared operands configuration window

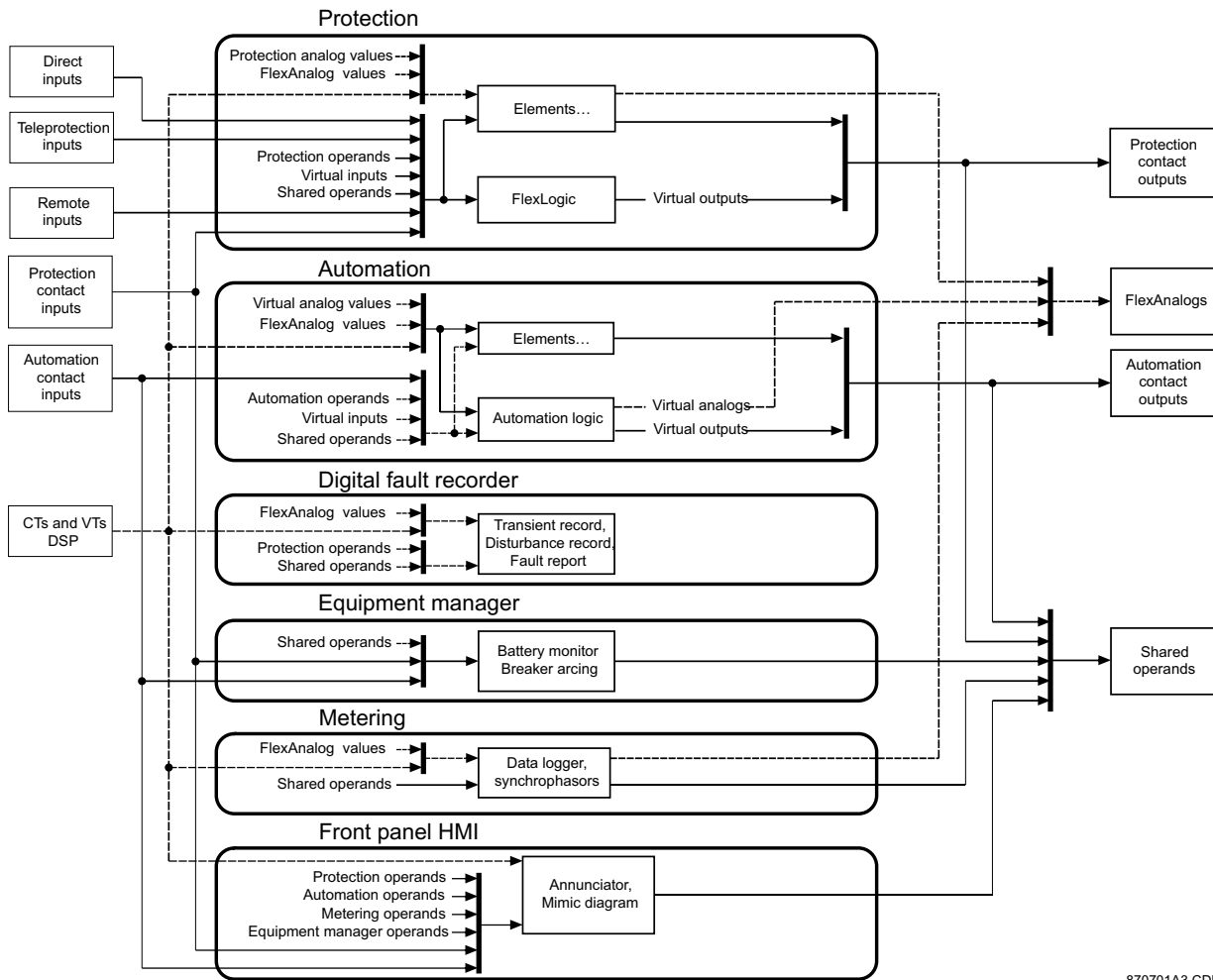


The left side of this screen displays all D90^{Plus} operands that are available to the automation function as shared operands. Select any operands from the other five primary features by clicking the >> button. Operands can be de-assigned as shared operands by pressing the << button.

Automation logic

The D90^{Plus} internal digital logic combines fixed and user-programmable parameters. The logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through automation logic. In general, the system receives digital inputs that it uses to produce digital outputs and analog inputs that it uses to produce analog outputs. The figure shows the major sub-systems of a generic UR^{Plus}-series relay involved in this process.

Figure 405: UR^{Plus}-series architecture overview



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The states of all digital signals used in the D90^{Plus} are represented by flags (or automation logic operands, described later in this section). A logic 1 state is represented by a set flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in an automation logic equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is required, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic than presented above is required, it is implemented via automation logic. For example, if it is required to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the breaker control element, the two control input states are programmed in an automation logic equation. This equation ANDs the two control inputs to produce a virtual digital output, which then is selected when programming the phase time overcurrent to be used as a blocking input. Virtual digital outputs can only be created by automation logic equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. Automation logic minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is field programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed logic).

Automation logic allows users to customize the relay through a series of equations that consist of operators and operands. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers, and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a virtual output. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

An automation logic equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a timer. Each equation defines the combinations of parameters to be used to set a virtual output flag. Evaluation of an equation results in either a logic 1 (=ON, flag set) or logic 0 (=OFF, flag not set). Each equation is evaluated at the automation scan rate.

Some types of operands are present in the relay in multiple instances (for example, contact and remote inputs). These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are tabulated as follows.

Table 30: Automation logic operand types

Type	State	Example	Characteristics (input is logic 1 or "on" if...)
Digital input	On	DIG IP1 ON	Voltage is presently applied to the input (external contact closed)
	Off	DIG IP1 OFF	Voltage is presently not applied to the input (external contact open)
Digital output	Voltage on	DIG OP1 VON	Voltage exists across the contact
	Voltage off	DIG OP1 VOFF	Voltage does not exist across the contact
	Current on	DIG OP1 ION	Current is flowing through the contact
	Current off	CONT OP1 IOFF	Current is not flowing through the contact
Digital counter	Greater than	COUNTER 1 HI	The number of pulses counted is above the set number
	Equal to	COUNTER 1 EQL	The number of pulses counted is equal to the set number
	Less than	COUNTER 1 LO	The number of pulses counted is below the set number
Direct input	On	DIRECT INPUT 1 ON	The direct input is presently in the ON state
Element	Pickup	DIG ELEM 1 PKP	The output operand is at logic 1
	Dropout	DIG ELEM 1 DPO	This operand is the logical inverse of the pickup operand
	Operate	DIG ELEM 1 OP	The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing
Fixed	On	ON	Logic 1
	Off	OFF	Logic 0
Remote input	On	REMOTE IN 1 ON	The remote input is presently in the on state
Virtual input	On	VIRT IP 1 ON	The virtual input is presently in the on state

Type	State	Example	Characteristics (input is logic 1 or "on" if...)
Virtual output	On	VIRT OP 1 ON	The virtual output is presently in the on state

Automation operators

The following operators are available for the creation of automation logic:

- One-shots
- Boolean operators and latches
- Math operators
- Virtual outputs
- Comparators
- Timers

Unlike earlier versions of the D90^{PLUS}, automation timers are implemented like gates or latches and not through setting menus.

The following sections provide detail on these operators.

Editing operators

The table outlines automation editing operators.

Table 31: Automation logic editing operators

Syntax	Description
INSERT	Insert an operand in an equation list
DELETE	Delete an operand from an equation list
END	The first END encountered signifies the last line in the list of processed logic operands

Automation one-shots

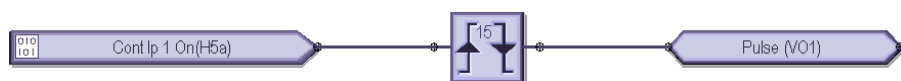
The table outlines automation one-shot syntax.

Table 32: Automation logic one shots

Syntax	Description
POSITIVE ONE SHOT	One shot that responds to a positive-going edge
NEGATIVE ONE SHOT	One shot that responds to a negative-going edge
DUAL ONE SHOT	One shot that responds to both the positive and negative-going edges

A *one-shot* accepts any digital input or the output of any logical operator. Its output asserts for one scan following a transition of its input. A negative one-shot operates on a falling edge of its input, and a positive one-shot operates on a rising edge of its input. A dual one-shot operates on a rising edge or falling edge of its input. A total of 64 one-shots are available in the D90^{PLUS} automation controller.

Figure 406: One-shot used in automation logic



Boolean operators and latches

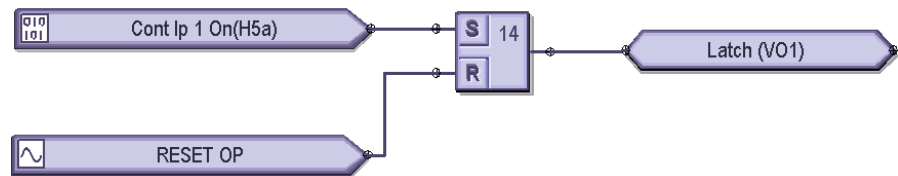
The table outlines Boolean logic and latch syntax.

Table 33: Automation logic Boolean operators and latches

Syntax	Description	Output is ON if...
NOT	Logical NOT gate. Operates on the previous operand.	the input is logic 0
OR(2) to OR(16)	Logical OR gates. Operate on the previous 2 to 16 operands.	any input is logic 1
AND(2) to AND(16)	Logical AND gates. Operate on the previous 2 to 16 operands.	all inputs are logic 1
NOR(2) to NOR(16)	Logical NOR gates. Operate on the previous 2 to 16 operands.	all inputs are logic 0
NAND(2) to NAND(16)	Logical NAND gates. Operate on the previous 2 to 16 operands.	any input is logic 0
XOR(2)	Logical exclusive OR gate. Operates on the previous two operands.	only one input is logic 1
LATCH (S,R)	Reset-dominant latch. The operand preceding LATCH(S,R) is the reset input. The operand preceding the reset input is the set input.	there is a positive transition on the set input

Boolean operators perform Boolean logic operations on any digital input or the output of any preceding logical operator. The output of a logic operator can be used in further logic processing. The final output of a sequence of logic operations is stored as a virtual digital output (VDO). The logic operators available in the automation controller are tabulated as follows.

A latch is asserted on a positive transition of its set input and retains this state until the positive transition of its reset input. A latch accepts any digital input or the output of any logical operator to either of its inputs. A total of 256 latches are available in the D90^{Plus} automation controller.

Figure 407: Latch used in automation logic

Automation math operators

The table outlines automation logic math syntax. Operators shown with the (a, b) suffix operate on two operands, whereas the others operate on one operand.

Table 34: Automation math operators

Syntax	Description
ABS	Return the absolute value of the previous operand
ACOS	Return the arccosine value of the previous operand
ADD (a, b)	Add the previous 2 operands
ASIN	Return the arcsine value of the previous operand
ATAN	Return the arctangent value of the previous operand
ATAN2 (a, b)	Return the arctangent value of the first operand divided by the second operand, with a range of -180 to 180°
CEIL	Return the smallest integer greater than or equal to the operand
COS	Return the cosine value of the previous operand
DIV(a, b)	Divide the first operand by the second operand
EXP	Return the power of e (the base of natural logarithms) value of the previous operand

Syntax	Description
FLOOR	Return the largest integer less than or equal to the operand
FMOD (a, b)	Return the remainder of the first operand divided by the second operand
IMAG (a,b)	Return the imaginary value of the previous two operands, where the first operand is the magnitude and the second operand is the angle
LOG	Return the natural logarithm (base e) value of the previous operand
LOG10	Return the base 10 logarithm value of the previous operand
MAG (a, b)	Return magnitude of the previous two operands, where the first operand is the real value and the second operand is the imaginary value
MUL (a, b)	Multiply the previous two operands
NEG	Multiply the previous operand by -1
POW (a, b)	Raise the first operand to a power of the second operand
REAL (a, b)	Return real value of the previous two operands, where the first operand is the magnitude and the second operand is the angle
SIN	Return the sine value of the previous operand
SQRT	Return the square root of the previous operand
SUB (a, b)	Subtract the second operand from the first operand
TAN	Return the tangent value of the previous operand

The automation controller can perform *math* operations on any analog input, any numerical constant, or the output of a preceding math operator. The final output of a sequence of math operations is stored as a virtual analog output (VAO). Numerical constants are IEEE 32-bit floating-point values and are fixed during operation of the controller. The math operators available in the automation controller are tabulated as follows.

Any analog input or the result of any math operation can be assigned to a FlexElement, which is a general purpose analog comparator. A FlexElement compares a single input with a threshold value or can compare two inputs. The output from a FlexElement can be used for further logic processing. The number of FlexElements dedicated is 16.

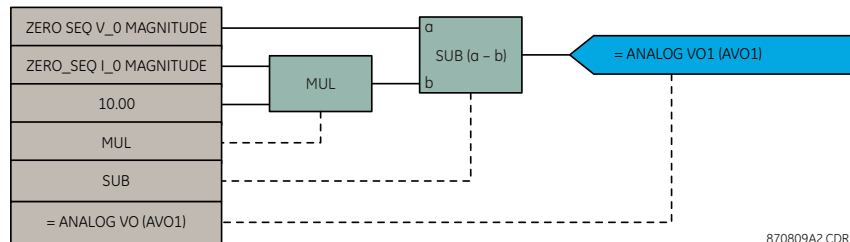
All math calculations are carried out using 32-bit IEEE floating-point numbers as defined by IEEE 754-185. This format has a range of -3.402823×10^{38} to 3.402823×10^{38} .

Consider the following math calculation.

$$\text{Analog VO1} = |V_{-0}| - |I_{-0}| \times 10.000 \tag{Eq. 44}$$

The following figure is the automation logic diagram for this example.

Figure 408: Math example



When using programming language, it is a best practice to initialize a variable before using it within a program. The same principle applies to using virtual analog values in automation logic. For example, if we want an automation logic equation of the form $\text{AVO1} + \text{SRC 4 lg RMS} = \text{AVO3}$, then the result of AVO3 depends of the previous value of the AVO1 (this can any value between $-\infty$ and $+\infty$). As a result, the AVO3 value is indeterministic. In this case, a better approach is to initialize virtual analog output 1 as follows:

```
AVO1 = 20 // initialize virtual analog output 1 to 20
AVO1 + SRC4 Ig RMS = AVO3 // add an offset of 20 to the Ig RMS
```

Automation virtual outputs

The table outlines automation virtual output syntax.

Table 35: Automation virtual output operators

Syntax	Description
VDO(1) to VDO(96)	Assigns the previous automation logic operand to the corresponding automation virtual digital output
VAO1 to VAO64	Assigns the previous automation logic operand to the corresponding automation virtual analog output

Automation comparators

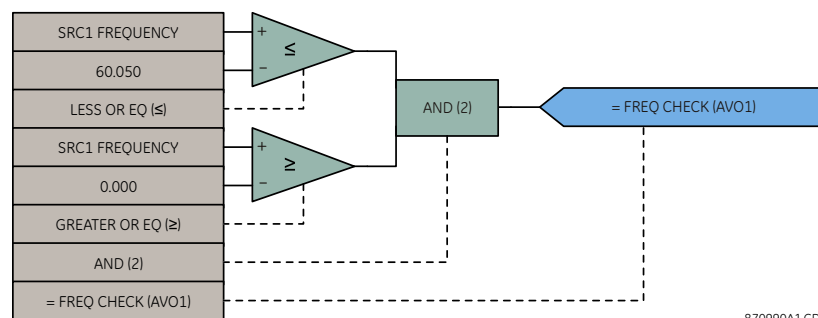
Automation comparators have two inputs that are denoted "+" and "-". Each input is assigned to a FlexAnalog value or an analog constant. There are six types of comparators in automation logic, as follows:

- Greater than (>)
- Less than (<)
- Equal to (=)
- Not equal to (≠)
- Greater than or equal to (≥)
- Less than or equal to (≤)

The output of the comparator is logic 1 if the inputs satisfy the condition of the particular comparator. Otherwise, the output is logic 0. The comparator output can be used as an input to Boolean logic or be assigned to an automation virtual output (AVO).

The following automation logic uses the greater than or equal to and the less than or equal to comparators to test that a value is within a specified range.

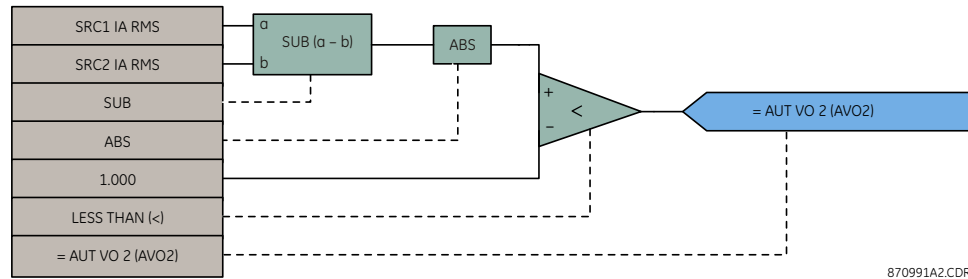
Figure 409: Using comparators to verify a value is within a specified range



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The following automation logic uses the less than comparator to check if two values are approximately equal.

Figure 410: Using comparators to verify approximate equivalence



870991A2.CDR

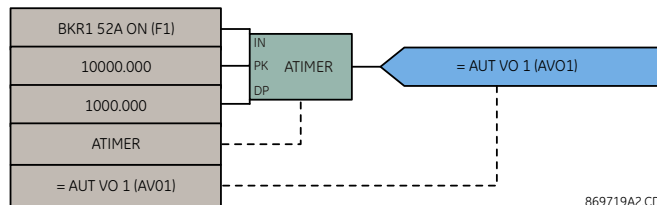
Automation timers

Unlike earlier versions of the D90^{Plus}, automation timers are implemented like gates or latches and not through setting menus. Automation timers have the following syntax: **TIMER (IN, PKP, DPO)**.

A *timer* accepts any digital input or the output of any logical operator as its **IN** parameter. The timer output asserts when its input is asserted for a time equal to or greater than the **PKP** parameter. Likewise, the timer output resets when its input has been reset for a time equal to or greater than its **DPO** parameter.

For example, the following logic produces an output that picks up 10 seconds after contact input F1 closes and drops out one second after the contact opens.

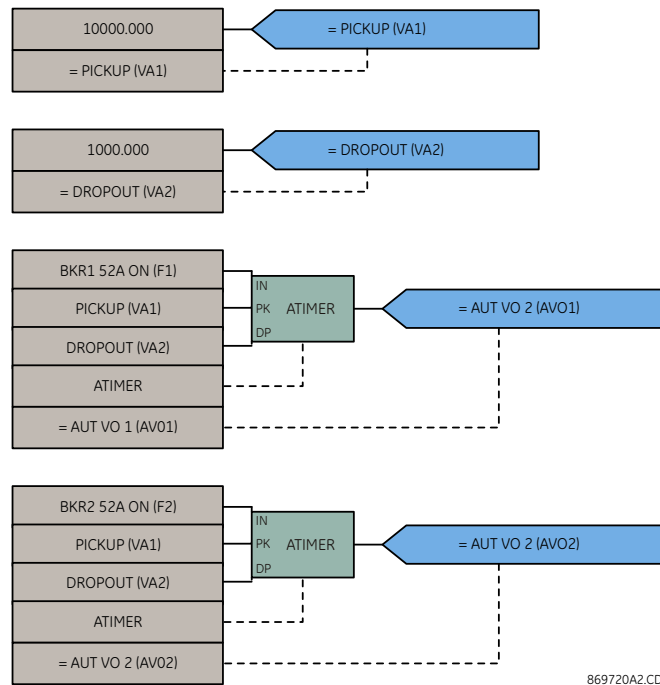
Figure 411: Using an automation timer



869719A2.CDR

Virtual analogs also can be assigned to control the pickup and dropout of timers. In the following example, two virtual analogs are used to define the pickup and dropout of two timers.

Figure 412: Using virtual analogs to control automation timers



869720A2.CDR

Automation logic equation editor

An automation logic equation can contain up to 4096 entries, including the **END** operator. If a disabled element is selected as an automation logic entry, the associated state flag is never asserted (set to logic 1).

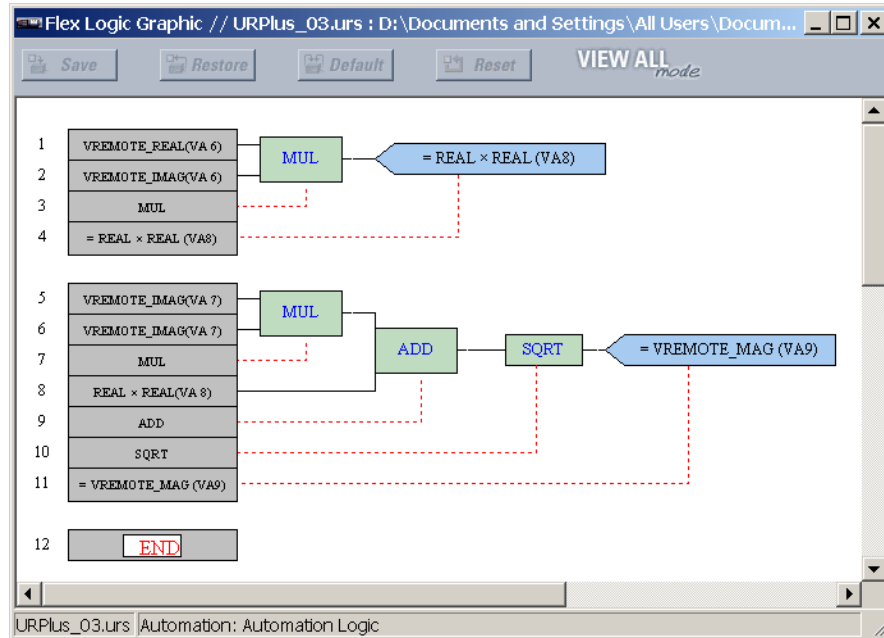
Select the **Settings > Automation > Automation FlexLogic > FlexLogic Equation Editor** menu to open the automation logic equation editor window.

Figure 413: Automation logic configuration settings

FLEXLOGIC ENTRY	TYPE	SYNTAX	COMMENTS
View Graphic	View	View	
Logic Entry 1	Analog Operand	VREMOTE_REAL(VA6)	
Logic Entry 2	Analog Operand	VREMOTE_IMAG(VA7)	
Logic Entry 3	MUL	2 Inputs	
Logic Entry 4	Assign Virtual Analog	= REAL × REAL (VA8)	
Logic Entry 5	Analog Operand	VREMOTE_IMAG(VA7)	
Logic Entry 6	Analog Operand	VREMOTE_IMAG(VA7)	
Logic Entry 7	MUL	2 Inputs	
Logic Entry 8	Analog Operand	REAL × REAL(VA8)	
Logic Entry 9	ADD	2 Inputs	
Logic Entry 10	SQRT	1 Input	
Logic Entry 11	Assign Virtual Analog	= VREMOTE_MAG (VA9)	
Logic Entry 12	End of List		

A graphical representation of the automation logic can be displayed by clicking the **View** button at the top of the equation column.

Figure 414: Typical automation logic display



Automation logic rules

When forming an automation logic equation, the sequence in the linear array of parameters must follow these general rules:

1. There are two types of operators: logic operators and math operators.
2. Logic operands must precede the logic operator that uses the operands as inputs.
3. Logic operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.
4. Assigning the output of a logic operator to a virtual output terminates the equation.
5. A timer operator (for example [Aut Timer 1](#)) or virtual output assignment (for example, [= Virt Op 1](#)) can be used only once. If this rule is broken, a syntax error is declared.
6. Math operands must precede the math operator that uses the operands as inputs.
7. Math operators have only one output. The output of a math operator must be used to create a virtual analog if it is to be used as an input to two or more operators.
8. Assigning the output of a math operator to a virtual analog terminates the equation.

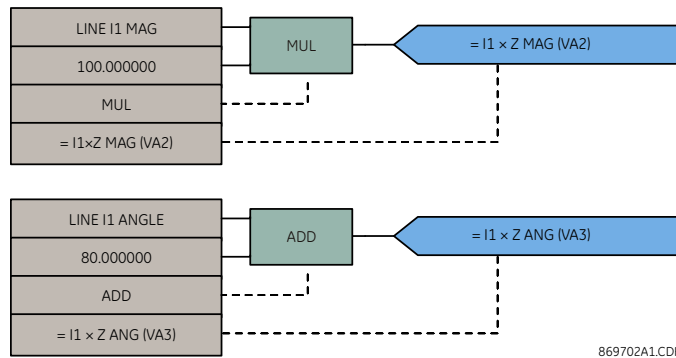
Automation logic programming example

The following automation logic programming example illustrates the implementation of a voltage regulation scheme with line drop compensation. In this scheme, the D90^{PLUS} measures the local end positive-sequence voltage and calculates the remote end positive-sequence line voltage (the load center voltage) to compensate for the voltage drop on the line.

In this example, the line positive-sequence impedance is 100.0 primary ohms at 80° and the PT ratio is 1000:1. The difference between the remote end voltage and the setting voltage (69.9 volts secondary = 69900 volts primary) is assigned to the virtual analog 1 value and named DELTA_V (note that all analog quantities in the automation logic are primary values). The automation logic includes a voltage reduction command represented by virtual input 1 and named V_REDUCT. If voltage reduction is enabled, then the setpoint voltage is reduced by 5%.

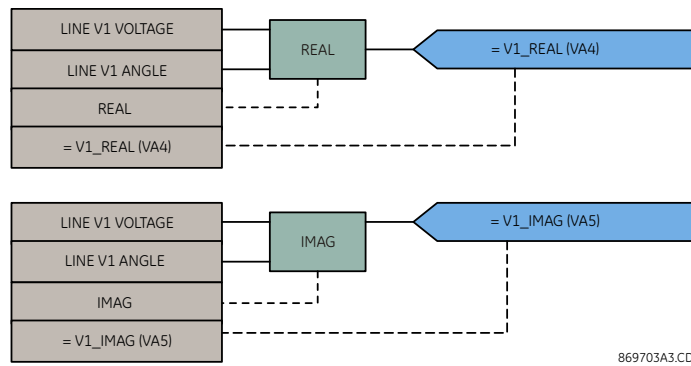
The following logic calculates the magnitude and angle of $I_1 \times Z$ and assigns these results to virtual analog 2 and virtual analog 3, respectively.

Figure 415: Magnitude and angle calculation logic for $I_1 \times Z$



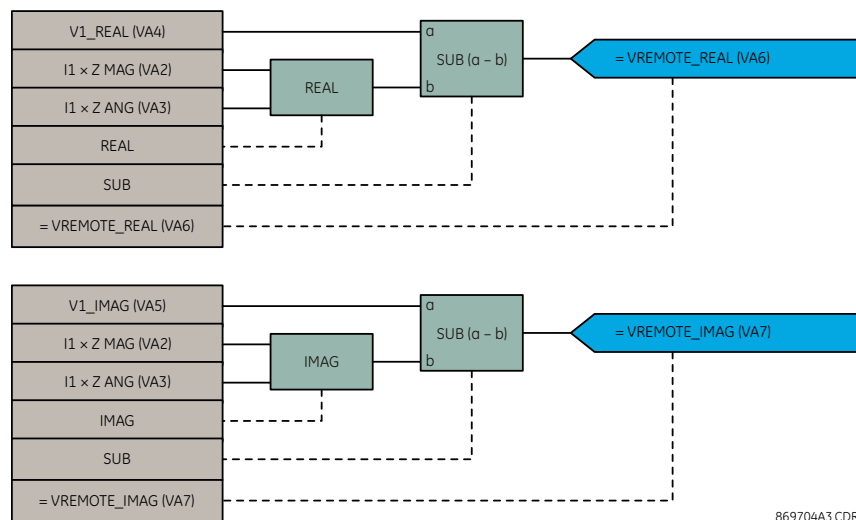
The following logic calculates the real and imaginary parts of the local positive-sequence voltage and assigns these results to virtual analog 4 and virtual analog 5, respectively.

Figure 416: Real and imaginary component calculation logic for local voltage



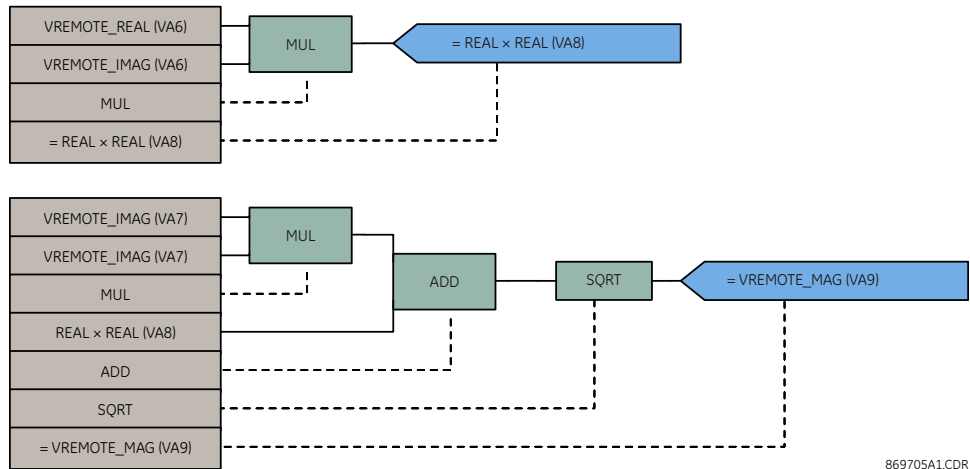
Next, the real and imaginary components of the remote voltage are calculated and assigned to virtual analog 6 and virtual analog 7, respectively.

Figure 417: Real and imaginary component calculation logic for remote voltage



The magnitude of the remote voltage is calculated next and assigned to virtual analog 9. Note that virtual analog 8 is used as an intermediate value in the logic.

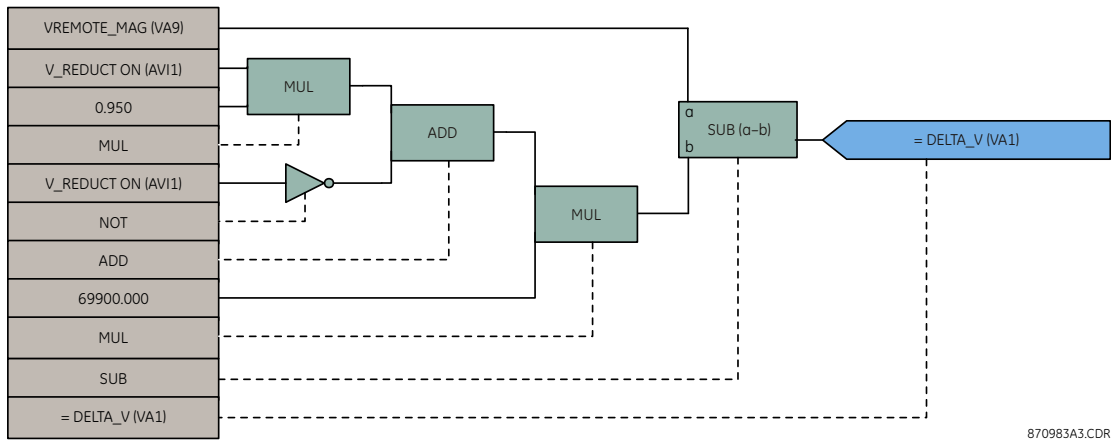
Figure 418: Remote voltage magnitude calculation logic



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Now that the remote voltage magnitude has been calculated, the following logic calculates the voltage difference between this and the setting voltage.

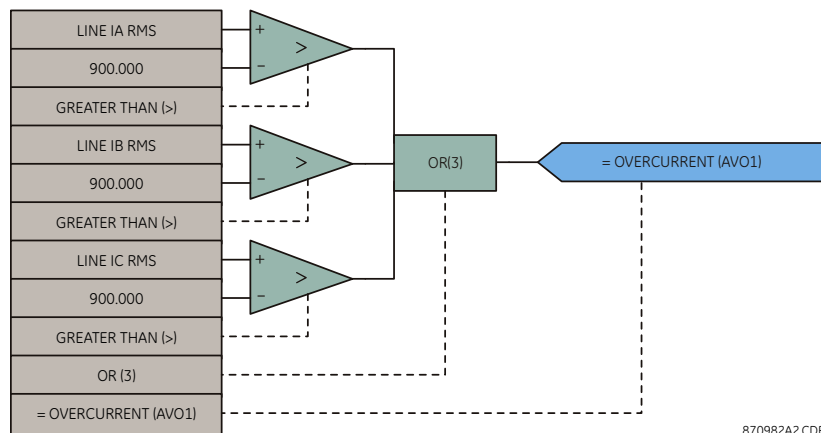
Figure 419: Voltage difference automation logic



870983A3.CDR

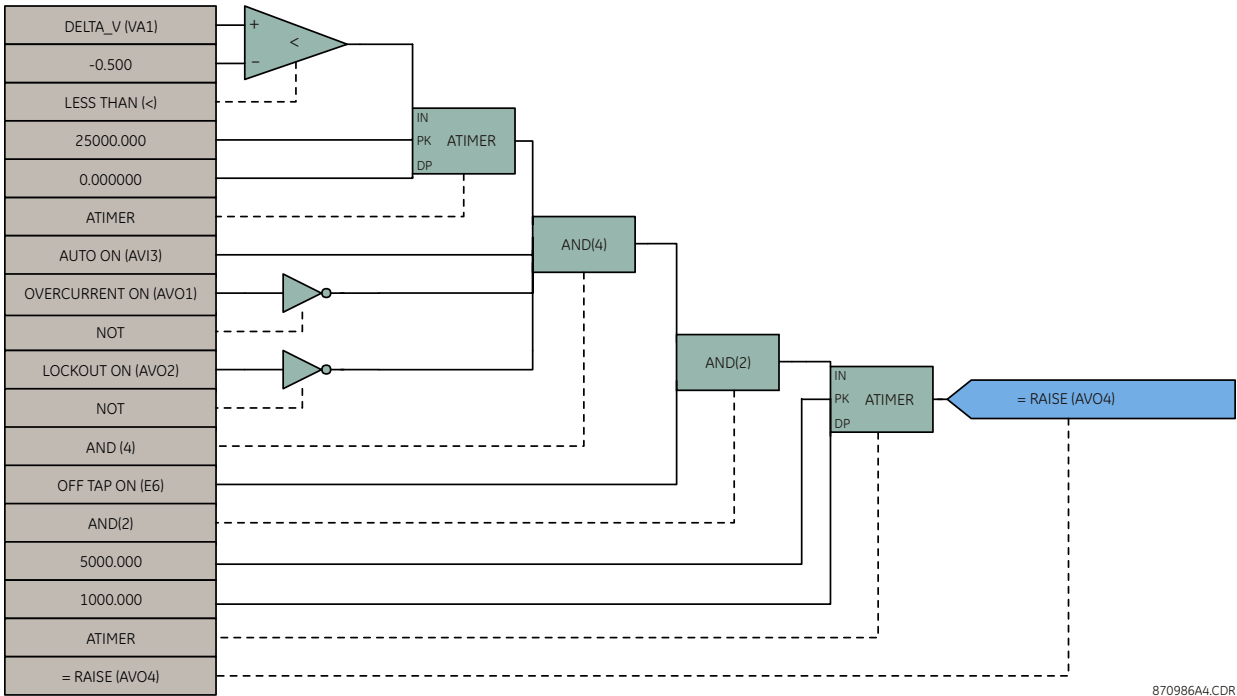
The current on each phase is checked to ensure that it is less than the maximum allowable for a tap changer operation.

Figure 420: Overcurrent check automation logic



870982A2.CDR

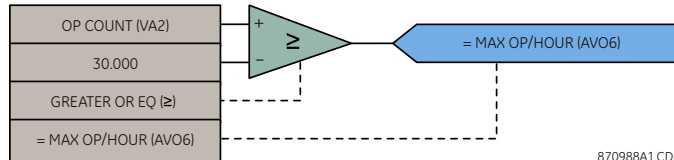
Figure 423: Raise command automation logic



870986A4.CDR

The following automation logic detects excessive tap changer operations. First, a TIMEOUT signal is created that produces a one second pulse once an hour.

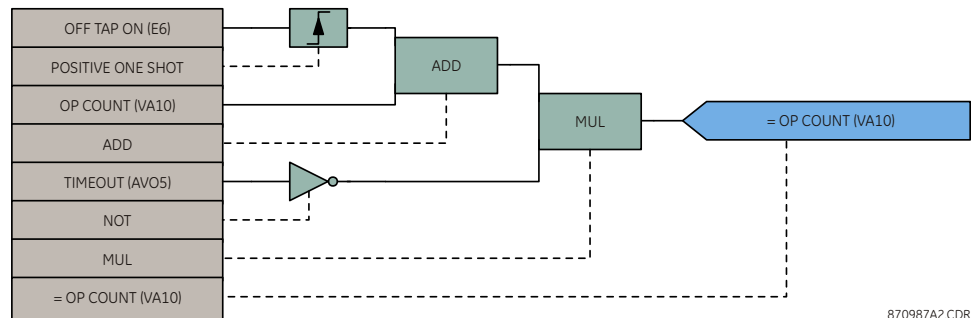
Figure 424: Timeout signal automation logic



870988A1.CDR

A counter is then implemented to accumulate the number of operations (indicated by the OFF TAP signal). The value of OP COUNT is reset to zero by the TIMEOUT signal once per hour.

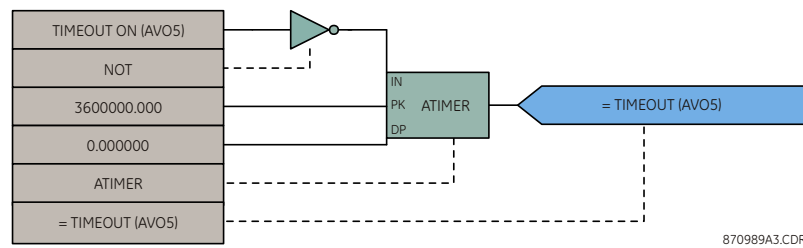
Figure 425: Operation counter automation logic



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If the number of operations is equal to or greater than the maximum number of permitted operations (30 in this example), then a MAX OP/HOUR alarm is declared.

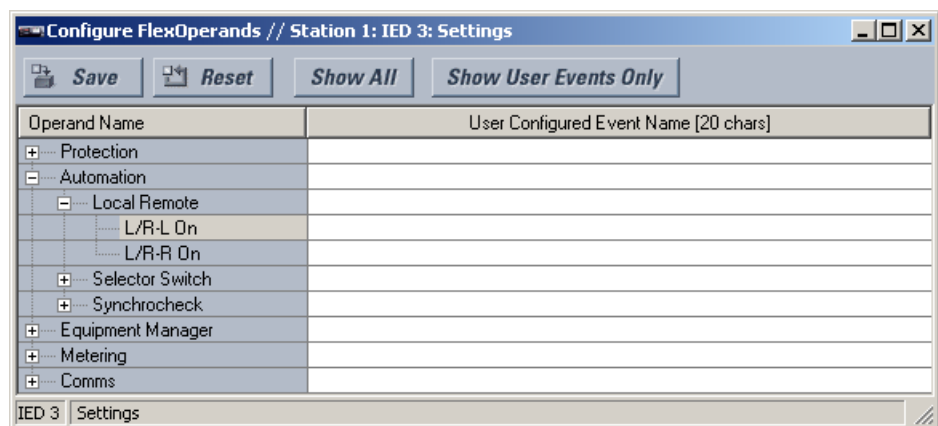
Figure 426: Maximum operations per hour alarm automation logic



Customizing the automation logic operands

Select the **Settings > Configure FlexOperands** menu to open the user-configurable operands window.

Figure 427: User-configurable automation logic operands window



The left side of this window displays all operands that are currently available to the D90^{PLUS}. The automation logic operands are displayed by expanding the **Automation** entry. Each operand can be renamed with a user-specified value to provide additional information or match specific applications.

User Configured Event Name

Range: up to 20 alphanumeric characters

Default: ---

Each available automation operand can be renamed to a user-specified value. This feature allows users to rename operands to allow for clearer identification or to match specific applications. The new operand name appears in protection and automation logic, in settings that take operands as their value, and in event reports.

Automation logic operands

The following automation logic operands are available for the D90^{PLUS}. They are listed alphabetically by operand syntax. Some operands can be renamed within their settings window, including the names of breakers, contact inputs, virtual inputs, and virtual outputs. Operands can be assigned user-defined names through the **Settings > Configure FlexOperands** menu.

Automation virtual output operands

Aut VO 1 ON.....Asserted when automation virtual output 1 is in the ON state (logic 1).

Aut VO 2 to 255.....The operands listed above are available for the automation virtual outputs 2 through 255. These operands reflect the programmed names for the automation virtual outputs.

Breaker control operands

BKR CNTRL1 CLOSE CMD Asserted when a close command is issued on breaker 1 from breaker control.

BKR CNTRL1 INTERLCK BYPS Asserted when interlocking is bypassed for breaker 1.

BKR CNTRL1 OPEN CMD Asserted when an open command is issued on breaker 1 from breaker control.

BKR CNTRL2 The operands listed above are also available for all breakers.

Breaker interlocking operands

BKR INTERLK1 CLS PERM Asserted when all conditions have been satisfied for closing breaker 1.

BKR INTERLK1 OPEN PERM Asserted when all conditions have been satisfied for opening breaker 1.

BKR INTERLK1 TAGGED Asserted when a tag is applied to breaker 1.

BKR INTERLK2 The operands listed above are available for all breaker interlocking elements.

Automation contact input operands

Cont Ip 1 OFF Asserted when the field contact connected to contact input 1 is opened.

Cont Ip 1 ON Asserted when the field contact connected to contact input 1 is closed.

Cont Ip 1 TRB OFF Asserted when there are no problems with contact input 1.

Cont Ip 1 TRB ON Asserted when there is an internal or external problem with contact input 1.

Cont Ip 2 to 40 The operands listed above are available for automation contact inputs 2 through 40. These operands reflect the programmed names for the automation contact inputs.

Automation contact output operands

Cont Op 1 IOff Asserted when contact output 1 with current monitoring is opened.

Cont Op 1 IOOn Asserted when contact output 1 with current monitoring is closed.

Cont Op 1 VOff Asserted when contact output 1 with voltage monitoring is opened.

Cont Op 1 VOOn Asserted when contact output 1 with voltage monitoring is closed.

Cont Op 2 to 40 The operands listed above are available for automation contract outputs 2 through 40. These operands reflect the programmed names for the automation contact outputs.

Disconnect control operands

DISC CNTRL1 CLOSE CMD Asserted when disconnect 1 is closed.

DISC CNTRL1 INTERLCK BYPS Asserted when interlocking has been bypassed for disconnect 1.

DISC CNTRL1 LOCAL SELECT Asserted when disconnect 1 has been selected from the front panel HMI.

DISC CNTRL1 OPEN CMD Asserted when disconnect 1 is open.

DISC CNTRL1 REMOTE SELECT Asserted when disconnect 1 has been selected from SCADA.

DISC CNTRL2 The operands listed above are available for all disconnects.

Disconnect interlock operands

DISC INTERLK1 CLS PERM	Asserted when all conditions have been satisfied for closing disconnect 1.
DISC INTERLK1 OPEN PERM	Asserted when all conditions have been satisfied for opening disconnect 1.
DISC INTERLK1 TAGGED	Asserted when a tag is applied to disconnect 1.
DISC INTERLK2	The operands listed above are available for all disconnect interlocking elements.

Disconnect configuration operands

DISC1 ANY POLE OPEN	Asserted when at least one pole of disconnect 1 is open.
DISC1 BAD STATE	Asserted when the normally open and normally closed disconnect indications disagree.
DISC1 CLOSE CMD	Asserted when a close command has been executed on disconnect 1.
DISC1 CLOSED	Asserted when disconnect 1 has been closed.
DISC1 DISCREPANCY	Asserted when the three poles of the disconnect disagree (that is, when they are not all opened or all closed).
DISC1 INTERMED	Asserted when the disconnect is in transition between the opened and closed states.
DISC1 ONE POLE OPEN	Asserted when only one pole of disconnect 1 is open.
DISC1 OPEN CMD	Asserted when an open command is executed on disconnect 1.
DISC1 OPENED	Asserted when disconnect 1 is opened.
DISC1 SUBST CLOSED	Asserted when the status of disconnect 1 has been substituted with a closed indication.
DISC1 SUBST ON	Asserted when disconnect status substitution is enabled for disconnect 1.
DISC1 SUBST OPENED	Asserted when the status of disconnect 1 has been substituted with an opened indication.
DISC1A BAD STATE	Asserted when the normally open and normally closed breaker indications disagree for pole A of disconnect 1.
DISC1A CLOSED	Asserted when disconnect 1 pole A is closed.
DISC1A INTERMED	Asserted when breaker 1 pole A is in transition between the opened and closed states.
DISC1A OPENED	Asserted when disconnect 1 pole A is opened.
DISC1B BAD STATE	Asserted when the normally open and normally closed breaker indications disagree for pole B of disconnect 1.
DISC1B CLOSED	Asserted when disconnect 1 pole B is closed.
DISC1B INTERMED	Asserted when breaker 1 pole B is in transition between the opened and closed states.
DISC1B OPENED	Asserted when disconnect 1 pole B is opened.
DISC1C BAD STATE	Asserted when the normally open and normally closed breaker indications disagree for pole C of disconnect 1.
DISC1C CLOSED	Asserted when disconnect 1 pole C is closed.
DISC1C INTERMED	Asserted when breaker 1 pole C is in transition between the opened and closed states.
DISC1C OPENED	Asserted when disconnect 1 pole C is opened.
DISC2	The operands listed above are available for all disconnects.

Local-remote control scheme operands

L/R L ON	Asserted while the local control scheme is enabled.
L/R R ON	Asserted while the remote control scheme is enabled.

Selector switch operands

SELECTOR 1 ALARM.....	Asserted when the position of selector 1 has been pre-selected but not acknowledged.
SELECTOR 1 BIT 0.....	Represents the first bit of the three-bit word encoding position of selector 1.
SELECTOR 1 BIT 1.....	Represents the second bit of the three-bit word encoding position of selector 1.
SELECTOR 1 BIT 2.....	Represents the third bit of the three-bit word encoding position of selector 1.
SELECTOR 1 BIT ALARM.....	Asserted when the position of selector 1 has been pre-selected with the three-bit control input but not acknowledged.
SELECTOR 1 POS 1.....	Asserted when selector switch 1 is in position 1.
SELECTOR 1 POS 2.....	Asserted when selector switch 1 is in position 2.
SELECTOR 1 POS 3.....	Asserted when selector switch 1 is in position 3.
SELECTOR 1 POS 4.....	Asserted when selector switch 1 is in position 4.
SELECTOR 1 POS 5.....	Asserted when selector switch 1 is in position 5.
SELECTOR 1 POS 6.....	Asserted when selector switch 1 is in position 6.
SELECTOR 1 POS 7.....	Asserted when selector switch 1 is in position 7.
SELECTOR 1 PWR ALARM.....	Asserted when the position of selector switch 1 is undetermined or restored from memory when the relay powers up and synchronizes to the three-bit input.
SELECTOR 1 STP ALARM.....	Asserted when the position of selector 1 has been pre-selected with the stepping up control input but not acknowledged.
SELECTOR 2.....	The same set of operands shown above are available for selector switch 2.

Synchrocheck operands

SYNC 1 CLS DPO.....	Asserted when the synchrocheck 1 close has dropped out.
SYNC 1 CLS OP.....	Asserted when the synchrocheck 1 close has operated.
SYNC 1 DEAD S DPO.....	Asserted when the synchrocheck 1 dead source has dropped out.
SYNC 1 DEAD S OP.....	Asserted when the synchrocheck 1 dead source has operated.
SYNC 1 SYNC DPO.....	Asserted when the synchrocheck 1 has dropped out while in synchronization.
SYNC 1 SYNC OP.....	Asserted when the synchrocheck 1 has operated while in synchronization.
SYNC 1 V1 ABOVE MIN.....	Asserted when the synchrocheck 1 V_1 value is above the minimum live voltage.
SYNC 1 V1 BELOW MAX.....	Asserted when the synchrocheck 1 V_1 value is below the maximum dead voltage.
SYNC 1 V2 ABOVE MIN.....	Asserted when the synchrocheck 1 V_2 value is above the minimum live voltage.
SYNC 1 V2 BELOW MAX.....	Asserted when the synchrocheck 1 V_2 value is below the maximum dead voltage.
SYNC 2.....	The set of operands shown above are available for synchrocheck 2.

Automation FlexAnalog parameters

The following automation FlexAnalog parameters (analog operands) are available for the D90^{Plus}. They are listed alphabetically by operand syntax.

Synchrocheck analog operands

Synchchk 1 Delta V	Metered voltage difference for the synchrocheck 1 element
Synchchk 1 Delta F	Metered frequency difference for the synchrocheck 1 element
Synchchk 1 Delta Phs	Metered phase difference for the synchrocheck 1 element
Synchchk 2 Delta V	Metered voltage difference for the synchrocheck 2 element
Synchchk 2 Delta F	Metered frequency difference for the synchrocheck 2 element
Synchchk 2 Delta Phs	Metered phase difference for the synchrocheck 2 element

D90^{Plus} Line Distance Protection System

Chapter 9: Equipment manager

A program for equipment monitoring can result in extended equipment life, improved system reliability, and increased equipment availability. Effective equipment monitoring allows maintenance to be targeted towards the equipment with the greatest need.

Overview of equipment manager

The D90^{Plus} equipment manager has six functions according to the specific equipment sub-system.

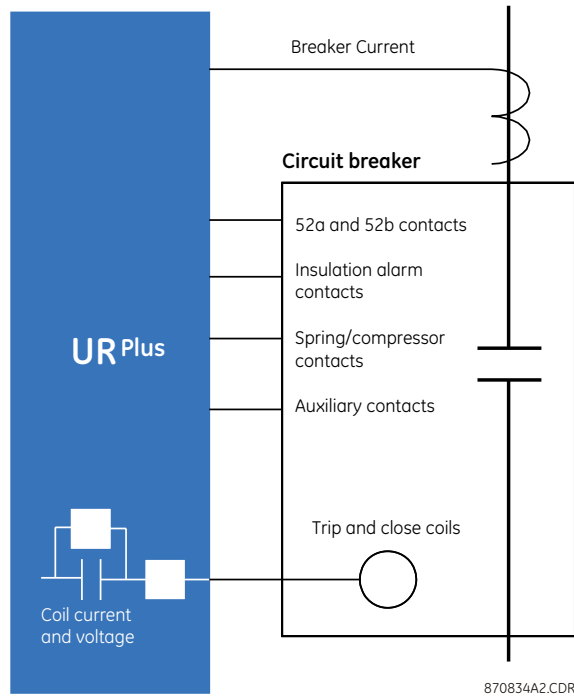
- Breaker arcing (supported in D90^{Plus})
- Breaker timing
- Coil signature
- Breaker insulation
- Breaker auxiliaries
- Battery monitor (supported in D90^{Plus})



NOTE

Only the battery monitor and breaker arcing features are supported in the current version of the D90^{Plus}.

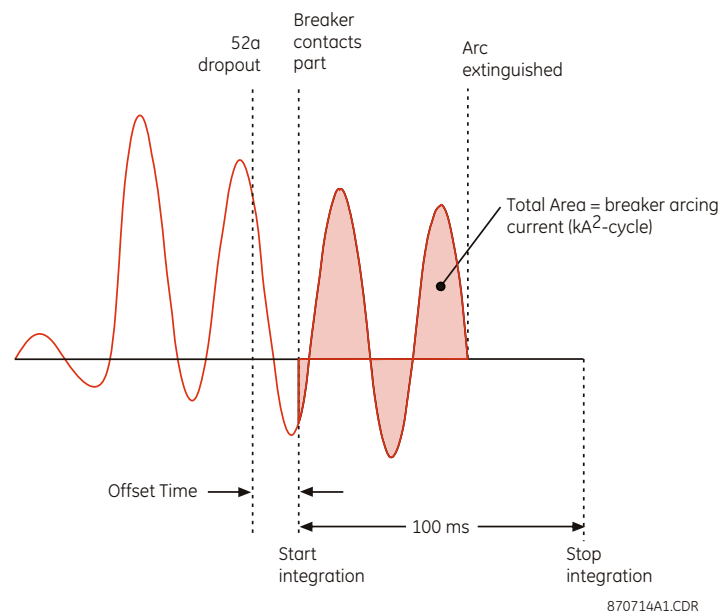
Figure 428: Equipment manager block diagram



Circuit breaker arcing management

The breaker arcing management function indicates the condition of the circuit breaker interrupter. The primary function is measurement of accumulated contact wear. This is accomplished by integrating the current passing through the breaker during interruption. The function compares the accumulated arcing current with manufacturer data to provide an indication that the breaker requires maintenance. The function also measures the total clearing time, and the maximum interrupted current. This latter value is compared with manufacturer data to determine if the interrupt rating of the breaker has been exceeded.

Figure 429: Breaker arcing current measurement



Select the **Settings > Equipment Manager > Breaker > Breaker Arcing** menu to open the breaker arcing current configuration window.

Figure 430: Breaker arcing current configuration settings

PARAMETER	BREAKER 1 ARC	BREAKER 2 ARC
Function	Disabled	Disabled
Source	SRC 1 (SRC 1)	SRC 1 (SRC 1)
Limit	1000 kAx-cyc	1000 kAx-cyc
Exponent	2.000	2.000
Rated lint	31.5 kA	31.5 kA
Toffset	0 ms	0 ms
Block	OFF	OFF
Events	Disabled	Disabled

The following settings are available for each breaker arcing current element.

Function

Range: Enabled, Disabled

Default: Disabled

This settings enables or disables the breaker arcing current function.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the signal source for the breaker arcing current element.

Limit

Range: 0 to 50000 kA²-cycle in steps of 1

Default: 1000 kA²-cycle

This setting specifies the limit of the accumulated current arcing time for maintenance.

Exponent

Range: 1.000 to 5.000 in steps of 0.001

Default: 2.000

This setting specifies the accumulated breaker wear that is proportional in the following equation,

$$\sum I^x t \quad \text{Eq. 45}$$

where x is the arcing exponent. The typical value for the arcing exponent is 2.

Interruption Rating

Range: 0.0 to 100.0 kA in steps of 0.1

Default: 31.5 kA

This setting specifies the maximum symmetrical interruption rating of the circuit breaker.

Arcing Time Offset

Range: 0 to 50 ms in steps of 1

Default: 0 ms

This setting specifies the time difference between the dropout of the 52a auxiliary contact and the parting of the circuit breaker contacts (measured from a circuit breaker timing diagram).

Block

Range: any equipment manager operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the circuit breaker arcing element.

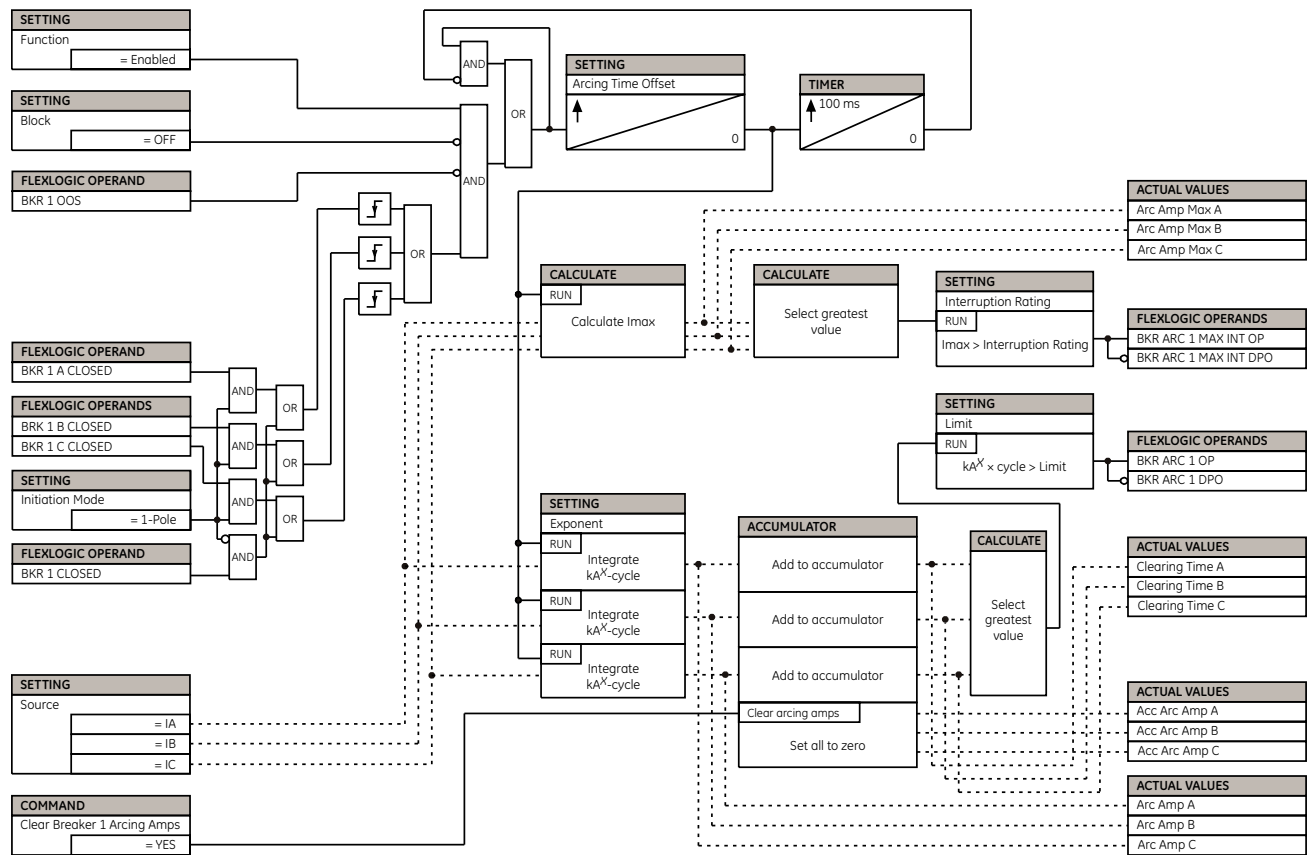
Events

Range: Enabled, Disabled

Default: Disabled

This setting enables or disables the recording of breaker arcing current events in the sequence of events record.

Figure 431: Breaker arcing current logic



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Battery monitor

The battery monitor checks the health of the DC battery system. It provides an analog indication of the current DC voltage derived from a contact input wired between the positive and negative rails of the battery system. This signal is used to generate high and low DC voltage alarms. This function also monitors and conditions the auxiliary alarm contacts from the battery charger.

There is no battery inside the D90^{Plus}.

Indications and wiring

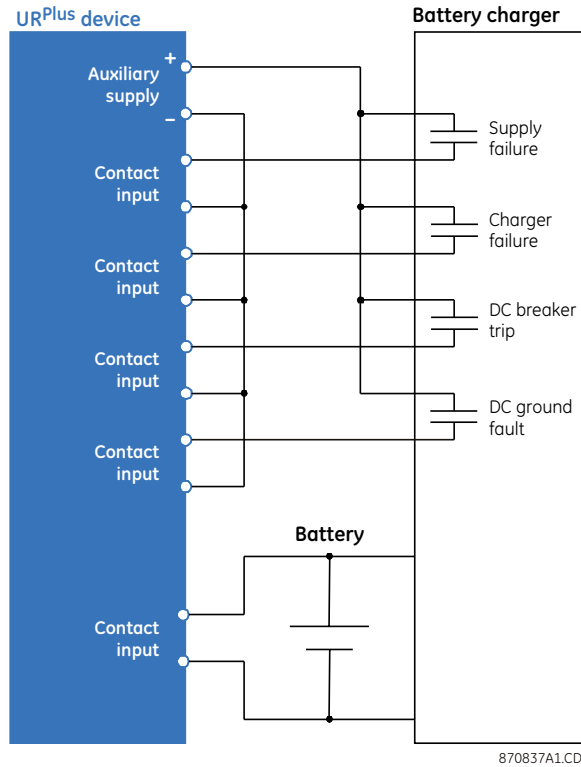
The following indications and alarms are provided for the battery monitor function.

Battery monitor alarms and indications

- BATTERY VOLTAGE..... Displays the present value of the battery voltage.
- HIGH DC VOLTAGE..... Indicates the battery DC voltage is greater than the maximum setting value.
- LOW DC VOLTAGE..... Indicates the battery DC voltage is less than the minimum setting value.
- SUPPLY FAIL..... Indicates the AC supply to the battery charger has failed.
- CHARGER FAIL..... Indicates the battery charger has failed.
- BREAKER TRIP..... Indicates a DC distribution breaker has operated.

DC GND FLT..... Indicates a battery DC ground fault.
 The figure shows typical wiring for the battery monitor element.

Figure 432: Battery monitor wiring diagram



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Battery monitor settings

Select the **Settings > Equipment Manager > Battery Monitor** menu to open the battery monitor configuration window.

Figure 433: Battery monitor configuration settings

SETTING	PARAMETER
Function	Disabled
Input	OFF
High DC Voltage	143 V
Low DC Voltage	107 V
Supply Fail	OFF
Charger Fail	OFF
Breaker Trip	OFF
DC Ground Fault	OFF
Alarm Delay	60 s
Block	OFF
Events	Enabled
Associated CI - Nominal Voltage	---
Associated CI - Events	---

The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the battery monitor element.

Input

Range: any contact input or OFF

Default: OFF

This setting specifies the contact input used to monitor the battery voltage.

High DC Volts

Range: 38 to 275 volts in steps of 1

Default: 143 volts

This setting is used to detect battery overcharging. This can result in loss of life, loss of electrolyte, and thermal runaway. Set this setting above the expected voltage during an equalization charge.

Low DC Volts

Range: 38 to 275 volts in steps of 1

Default: 107 volts

This setting is used to detect battery undercharging, which can lead to reduced cell capacity and sulfation. An undervoltage condition also occurs due to a charger failure.

Supply Fail

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the AC supply failure contact.

Charger Fail

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the charger critical failure contact.

Breaker Trip

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the DC distribution breaker trip contact.

DC Ground Fault

Range: any equipment manager operand or shared operand

Default: OFF

This setting selects the input connected to the DC ground fault contact.

Alarm Delay

Range: 2 to 300 seconds in steps of 1

Default: 60 seconds

This setting specifies the time required for a field contact to be asserted before the corresponding alarm is declared.

Block

Range: any equipment manager operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the battery monitor element.

Events

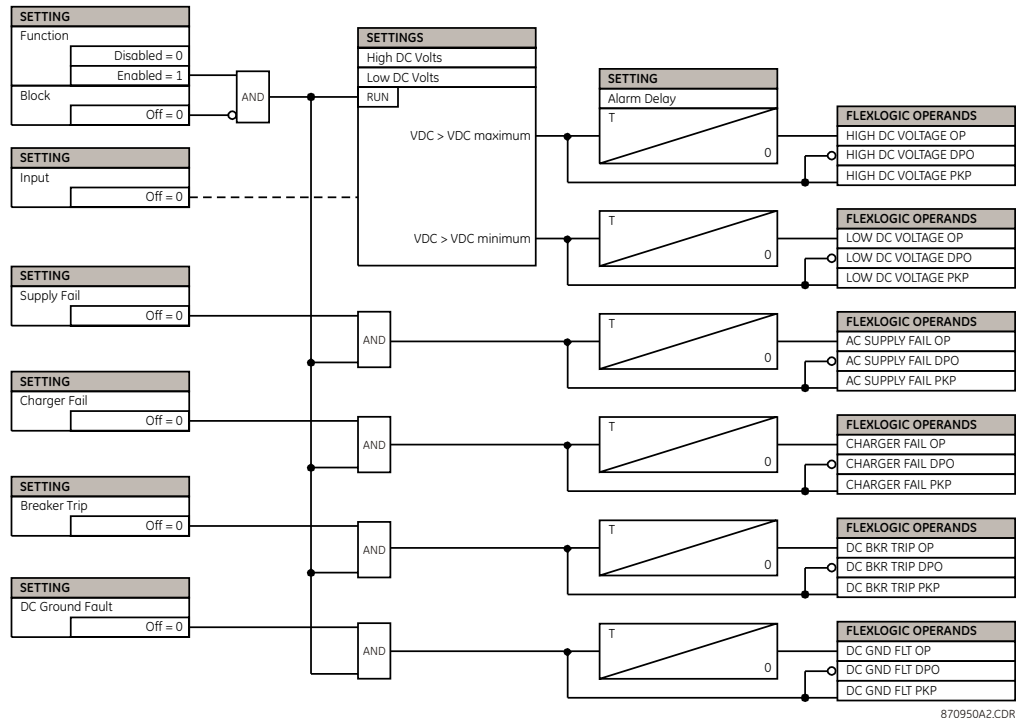
Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the logging of battery monitoring events in the sequence of events recorder.

The figure shows the battery monitoring logic diagram.

Figure 434: Battery monitor logic



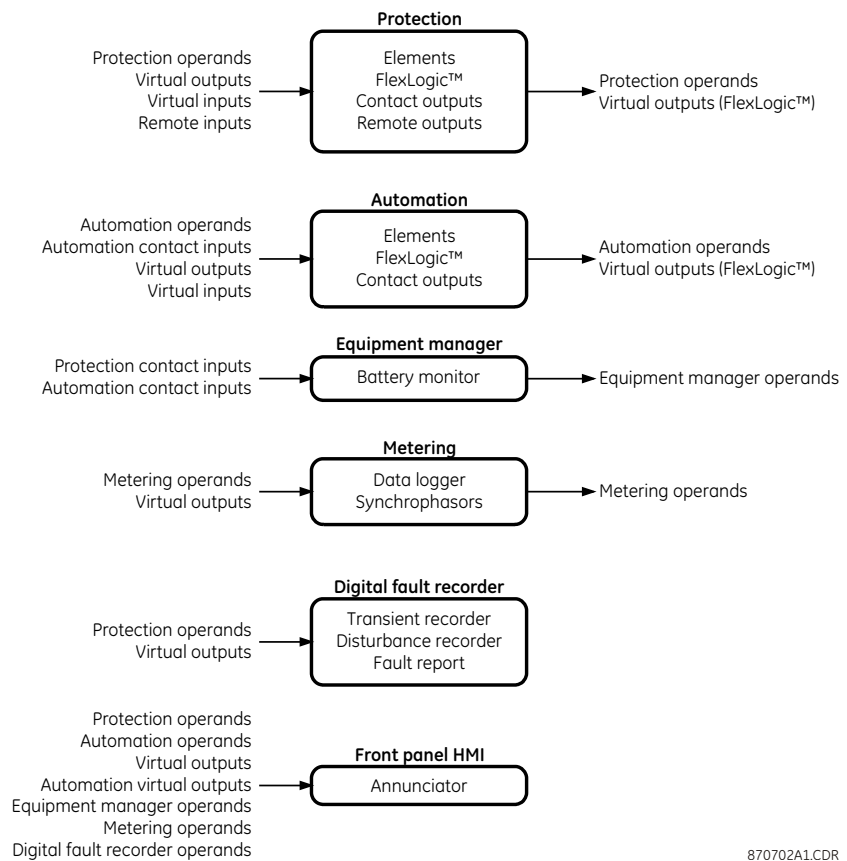
Using shared operands in equipment manager

The EnerVista UR^{Plus} Setup software groups the D90^{Plus} system into the following eight primary functions. Each function has its own settings and each generates its own outputs in the form of operands.

- Communications
- Protection
- Automation
- Digital fault recorder (DFR)
- Metering
- Equipment manager
- Self-tests
- Front panel interface (HMI)

It is often desirable for an output from an element within one function to be available to an element within another function. For example, it can be useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available to each function, as shown.

Figure 435: Default operand list by function



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The content of each operand list depends on the order code.

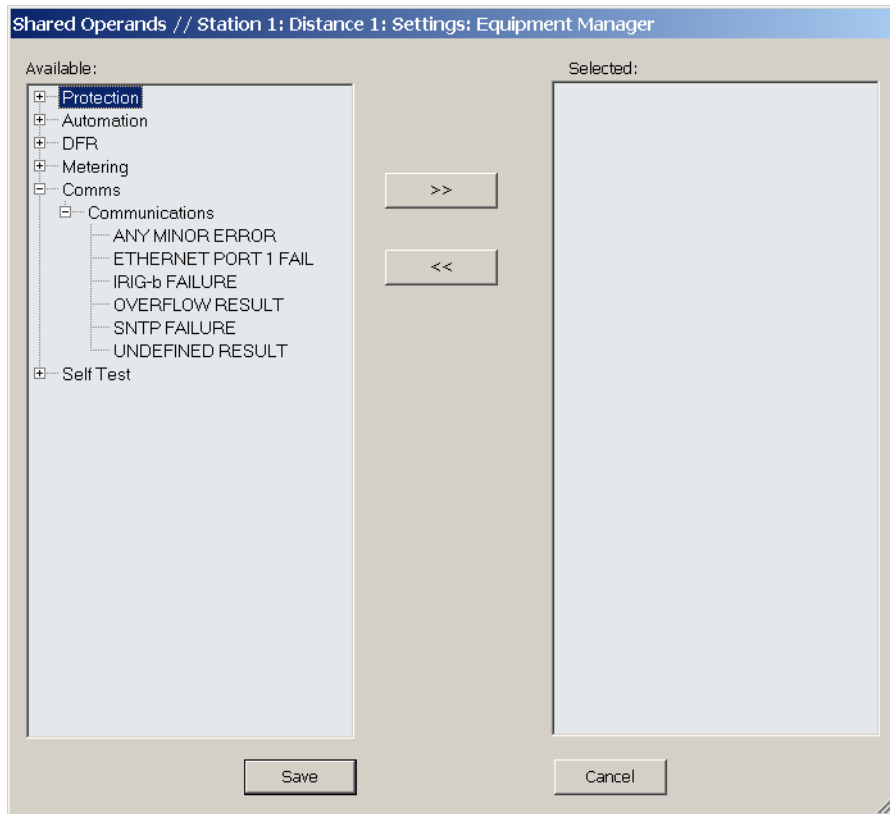
The shared operands functionality expands upon this system. An output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals then can be assigned as inputs to other functions.

For example, assume that the [GND TOC1 OP](#) protection operand is required as a signal within the automation function. This operand then is assigned as a shared operand and subsequently becomes available to the automation function. A total of 64 operands can be assigned as shared operands within each function.

Shared equipment manager operands

Select the **Settings > Equipment Manager > Shared Operands** menu to select the shared equipment manager operands.

Figure 436: Shared operands configuration window

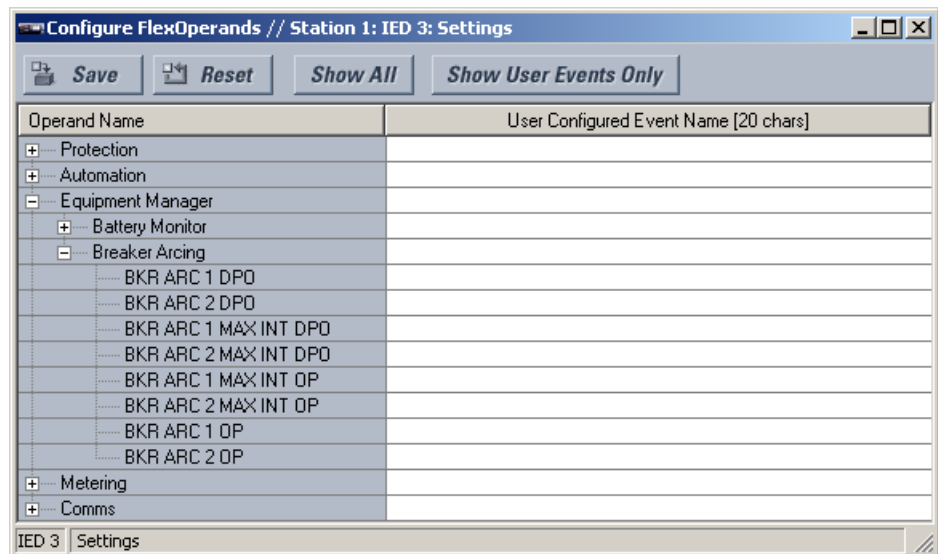


The left side of this screen displays all D90^{Plus} operands that are available to the equipment manager as shared operands. Select any operands from the other five primary features by clicking the >> button. Operands can be de-assigned as shared operands by clicking the << button.

Renaming equipment manager operands

Select the **Settings > Configure FlexOperands** menu to open the user-configurable operands window.

Figure 437: User-configurable equipment manager logic operands window



The left side of this window displays all operands that are currently available to the D90^{PLUS}. The equipment manager logic operands are displayed by expanding the **Equipment Manager** entry. Each operand can be renamed with a user-specified value to provide additional information or to match specific applications.

User Configured Event Name

Range: up to 20 alphanumeric characters

Default: ---

Each available equipment manager operand can be renamed. This feature allows users to rename operands to allow for clearer identification or to match specific applications. The new operand name appears in protection and automation logic, in settings that take operands as their value, and in event reports.

Equipment manager operands

The following equipment manager operands are available for the D90^{PLUS}. They are listed alphabetically by operand syntax. These operands can be assigned user-defined names through the **Settings > Configure FlexOperands** menu item.

Battery monitor operands

BAT MON AC FAIL DPO.....Asserted when the AC supply failure monitor drops out.
 BAT MON AC FAIL OPAsserted when the AC supply failure monitor operates.
 BAT MON AC FAIL PKP.....Asserted when the AC supply failure monitor picks up.
 BAT MON CHG FAIL DPO.....Asserted when the battery charger failure monitor drops out.
 BAT MON CHG FAIL OPAsserted when the battery charger failure monitor operates.
 BAT MON CHG FAIL PKP.....Asserted when the battery charger failure monitor picks up.
 BAT MON DC GND DPO.....Asserted when the DC ground fault monitor drops out.
 BAT MON DC GND OP.....Asserted when the DC ground fault monitor operates.
 BAT MON DC GND PKP.....Asserted when the DC ground fault monitor picks up.
 BAT MON DC TRIP DPO.....Asserted when the DC distribution breaker monitor drops out.
 BAT MON DC TRIP OPAsserted when the DC distribution breaker monitor operates.
 BAT MON DC TRIP PKP.....Asserted when the DC distribution breaker monitor picks up.
 BAT MON HIGH VDC DPO.....Asserted when the battery high DC voltage monitor drops out.
 BAT MON HIGH VDC OP.....Asserted when the battery high DC voltage monitor operates.

BAT MON HIGH VDC PKP	Asserted when the battery high DC voltage monitor picks up.
BAT MON LOW VDC DPO	Asserted when the battery low DC voltage monitor drops out.
BAT MON LOW VDC OP	Asserted when the battery low DC voltage monitor operates.
BAT MON LOW VDC PKP	Asserted when the battery low DC voltage monitor picks up.

Breaker arcing current operands

BKR ARC 1 DPO	Asserted when breaker arcing 1 element drops out.
BKR ARC 1 MAX IN DPO	Asserted when the maximum symmetrical interruption of the breaker arcing 1 element drops out.
BKR ARC 1 MAX IN OP	Asserted when the maximum symmetrical interruption of the breaker arcing 1 element operates.
BKR ARC 1 OP	Asserted when breaker arcing 1 element operates.
BKR ARC 2	The operands listed above are available for the breaker arcing 2 element.

Equipment manager FlexAnalog parameters

The following equipment manager FlexAnalog parameters (analog operands) are available for the D90^{PLUS}. They are listed alphabetically by operand syntax.

Battery monitor analog operand

Battery Voltage	Metered battery voltage for the battery monitoring feature
-----------------------	--

Breaker arcing analog operands

Bkr 1 Arc Amp A	Metered phase A arcing current for breaker 1
Bkr 1 Arc Amp B	Metered phase B arcing current for breaker 1
Bkr 1 Arc Amp C	Metered phase C arcing current for breaker 1
Bkr 1 Op Time A	Metered phase A operating time for breaker 1
Bkr 1 Op Time B	Metered phase B operating time for breaker 1
Bkr 1 Op Time C	Metered phase C operating time for breaker 1
Bkr 1 Op Time	Metered three-phase operating time for breaker 1
Bkr 2 Arc Amp A	Metered phase A arcing current for breaker 2
Bkr 2 Arc Amp B	Metered phase B arcing current for breaker 2
Bkr 2 Arc Amp C	Metered phase C arcing current for breaker 2
Bkr 2 Op Time A	Metered phase A operating time for breaker 2
Bkr 2 Op Time B	Metered phase B operating time for breaker 2
Bkr 2 Op Time C	Metered phase C operating time for breaker 2
Bkr 2 Op Time	Metered three-phase operating time for breaker 2

D90^{Plus} Line Distance Protection System

Chapter 10: Digital fault recorder

The digital fault recorder (DFR) captures detailed information regarding abnormal occurrences in the power system. The information captured by the DFR is stored in the D90^{Plus} in non-volatile memory and can be accessed through the front panel interface. The DFR consists of the following four functions:

- An event recorder that provides a time-stamped record of the operation of breakers, protection elements, and alarms. Event recording is enabled on a per-element basis.
- A fault report that records fault type, magnitude, and duration of the fault, and the response of protection functions
- A transient recorder that records analog and digital signals for short duration events at a high resolution
- A disturbance recorder that records analog and digital signals for long duration events, such as power swings and voltage sags, at a resolution of one sample per cycle

Sequence of events recorder

This event recorder provides a time-stamped record of state changes of signals monitored by the D90^{Plus}. These signals include the state of circuit breakers and disconnect switches, external alarms and indications, and any of the internal functions of the IED. The D90^{Plus} can store a total of 8192 events. Once this memory is filled, the oldest events are overwritten.

Most D90^{Plus} elements contain an **Events** setting. When this setting is enabled, state changes for FlexLogic operands associated with the element are written to the event recorder. If this setting is disabled then state changes for the element are not recorded.

Front panel operation

The sequence of events record can be accessed from the front panel through the digital fault recorder (DFR) page. Using the navigation keys, the user can scroll or page through the events list. Two cursors are provided for measurement of the time difference between events.

Figure 438: Example of sequence of events record

DFR – SEQUENCE OF EVENTS		
Delta	0 day, 00:00:00.000000	Event# 112283 & 112283
Event #	Date/Time	Cause
112283	Aug 08 2007 11:39:35.096375	AR ZONE 1 EXTENT
112282	Aug 08 2007 11:39:35.096375	AR ENABLED
112281	Aug 08 2007 11:39:33.095112	MAN CLOSE Off
112280	Aug 08 2007 11:39:32.895133	AR RESET
112279	Aug 08 2007 11:39:32.895133	AR DISABLED
112278	Aug 08 2007 11:39:32.893868	MAN CLOSE On
112277	Aug 08 2007 11:39:32.893868	BKR1 CLOSED
112276	Aug 08 2007 11:38:54.788677	AR BKR1 BLK
112275	Aug 08 2007 11:38:54.757440	BKR1 SUBST ON
112274	Aug 08 2007 11:38:54.757440	BKR1 OPENED

Fault report

The D90^{Plus} device supports one fault report and an associated fault locator. The signal source and trigger condition, as well as the characteristics of the line or feeder, are entered in the fault report configuration settings.

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data contained in the fault report file includes

- Fault report number
- Device identification, programmed by the user
- Firmware revision of the relay
- Date and time of trigger
- Cause of trip
- Line and feeder identification via the name of a configured signal source
- Active protection setting group at the time of trigger
- Pre-fault current and voltage phasors (two cycles before 50DD disturbance associated with fault report source)
- Fault current and voltage phasors (one cycle after the trigger)
- Elements operated at the time of triggering
- Events: nine before the trigger and seven after the trigger

The captured data also includes the fault type and the distance to the fault location, as well as the reclose shot number (when applicable).

Front panel indications

The digital fault reporter summary screen indicates when the fault report is ready to capture data and has memory available.

In protected mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The fault report feature is enabled
- The source for the fault report is properly configured
- The block trigger input is not asserted
- Memory is available
- A record capture is not currently in progress

Otherwise the indication is red.

In automatic overwrite mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The fault report feature is enabled
- The source for the fault report is properly configured
- The block trigger input is not asserted
- A record capture is not currently in progress

The **Memory Available** indication is green when less than 80% of the memory has been filled. It is yellow when the amount of memory filled is between 80% and 99%, and it is red if 100% of the memory is filled.

Figure 439: Digital fault reporter summary screen

Records	Latest	Total
EVENTS	2007/08/08 11:38:54	112283
FAULTS	2007/08/08 11:01:53	43640
TRANSIENTS	2007/08/08 11:01:54	8
DISTURBANCES	2007/08/08 11:10:57	3

The fault report screen displays the detailed fault data for each fault. This data includes the fault and prefault current and voltage data, as well as the cause of trip, trip type, active setting group, shot count, and duration data.

Figure 440: Fault report front panel screen

Prefault		Fault	
Van	292.482 KV 360.1 °	Ia	370.874 A 10.6 °
Vbn	292.373 KV 240.0 °	Ib	373.163 A 250.6 °
Vcn	292.407 KV 120.0 °	Ic	372.009 A 131.3 °
Van	286.431 KV 0.2 °	Ia	364.003 A 353.2 °
Vbn	250.418 KV 238.5 °	Ib	2.317 KA 166.7 °
Vcn	254.867 KV 124.9 °	Ic	2.070 KA 19.7 °

Fault report operation

The fault report trigger can be any FlexLogic operand, but in most applications it is expected to be the same operand that is used to drive an output relay to trip a breaker (usually a virtual output). To prevent the overwriting of fault events, do not use the disturbance detector to trigger a fault report. A FAULT RPT TRIG event is automatically created when the report is triggered.

If a number of protection elements are ORed to create a fault report trigger, the first operation of any element causing the OR gate output to become high triggers a fault report. However, if other elements operate during the fault and the first operated element

has not been reset (the OR gate output is still high), the fault report is not triggered again. Considering the reset time of protection elements, there is very little chance that fault report can be triggered twice in this manner.

Each fault report is stored as a file, and the relay capacity is 15 files. A 16th trigger overwrites the oldest file. The 16th report overwrites the first one regardless of which fault report feature produced the 16th and the first records.

The EnerVista software is required to view all captured data. The front panel interface can be used to view the following information:

- Prefault and fault current and voltage phasors
- Active setting group
- Date and time of trigger
- Reclose shot number
- Fault type
- Distance location of the fault

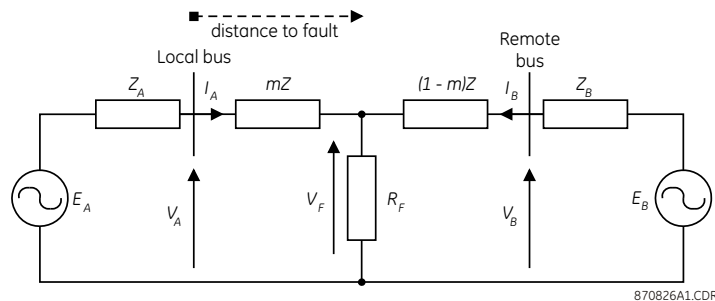
Fault type determination

Fault type determination is required for calculation of fault location. The fault determination algorithm uses the angle between the negative-sequence and positive-sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used. That is, the pre-fault phasors are subtracted from the measured current phasors. In addition to the angle relationships, certain extra checks are performed on magnitudes of the negative-sequence and zero-sequence currents.

Fault location

The single-ended fault location method assumes that the fault components of the currents supplied from the local and remote systems are in phase. The figure shows an equivalent system for fault location.

Figure 441: Equivalent system for fault location



The following equation describes the voltage at the local bus for this equivalent system, where m represents the required per-unit distance to the fault and Z represents the positive-sequence impedance of the line:

$$V_A = mI_A Z + R_F(I_A + I_B) \tag{Eq. 46}$$

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components as follows:

$$I_A = I_{A(F)} + I_{A(pre)} \tag{Eq. 47}$$

Neglecting the shunt parameters of the line, as follows:

$$I_B = I_{B(F)} - I_{A(pre)} \tag{Eq. 48}$$

Inserting the I_A and I_B equations into the V_A equation and solving for R_F yields the fault resistance.

$$R_F = \frac{V_A - mI_A Z}{I_{AF} \left(1 + \frac{I_{BF}}{I_{AF}} \right)} \quad \text{Eq. 49}$$

Assuming the fault components of the currents $I_{A(F)}$ and $I_{B(F)}$ are in phase, and observing that the fault resistance, as impedance, does not have any imaginary part gives the following equation:

$$\text{Im} \left(\frac{V_A - mI_A Z}{I_{AF}} \right) = 0 \quad \text{Eq. 50}$$

where the $\text{Im}(\)$ function represents the imaginary part of a complex number. Solving the equation for the unknown m creates the following fault location algorithm:

$$m = \frac{\text{Im}(V_A I_{AF}^*)}{\text{Im}(Z I_A I_{AF}^*)} \quad \text{Eq. 51}$$

where * denotes the complex conjugate and $I_{A(F)} = I_A - I_{A(\text{pre})}$.

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying the two equations above (the superscripts denote phases, the subscripts denote stations). For AG, BG, and CG faults, we have

$$\begin{aligned} V_A &= V_A^A, \quad I_A = I_A^A + K_0 + I_{0A} && \text{for AG faults} \\ V_A &= V_A^B, \quad I_A = I_A^B + K_0 + I_{0A} && \text{for BG faults} \\ V_A &= V_A^C, \quad I_A = I_A^{BC} + K_0 + I_{0A} && \text{for CG faults} \end{aligned} \quad \text{Eq. 52}$$

For AB, ABG, BC, BCG, CA, and CAG faults, we have

$$\begin{aligned} V_A &= V_A^A - V_A^B, \quad I_A = I_A^A - I_A^B && \text{for AB and ABG faults} \\ V_A &= V_A^B - V_A^C, \quad I_A = I_A^B - I_A^C && \text{for BC and BCG faults} \\ V_A &= V_A^C - V_A^A, \quad I_A = I_A^C - I_A^A && \text{for CA and CAG faults} \end{aligned} \quad \text{Eq. 53}$$

In the above equations, K_0 represents the zero-sequence compensation factor. For ABC faults, all three AB, BC, and CA loops are analyzed and the final result is selected based upon consistency of the results.

The fault location element calculates the distance to the fault (with m in miles or kilometers) and the phases involved in the fault.

Fault report settings

Select the **Settings > DFR > Fault Report** menu to open the fault report configuration window.

Figure 442: Fault report configuration settings

SETTING	PARAMETER
Source	LINE (SRC 1)
Trigger	OFF
Positive-Sequence (Z1) Magnitude	3.00 ohms
Positive-Sequence (Z1) Angle	75 deg
Zero-Sequence (Z0) Magnitude	9.00 ohms
Zero-Sequence (Z0) Angle	75 deg
Line Length Units	km
Line Length	100.0
Fault Report VT Substitution	None
Fault Report System Z0 Mag	2.00
Fault Report System Z0 Angle	75

The following settings are available.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)
 Default: SRC1

This setting selects the source for input currents, voltages, and disturbance detection.

Trigger

Range: any FlexLogic operand
 Default: OFF

This setting assigns the FlexLogic operand representing the protection elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal.

Positive-Sequence (Z1) Magnitude

Range: 0.01 to 250.00 ohms in steps of 0.01
 Default: 3.00 ohms

This setting specifies the magnitude of positive-sequence impedance of the transmission line or feeder in secondary ohms.

Positive-Sequence (Z1) Angle

Range: 25 to 90° in steps of 1
 Default: 75°

This setting specifies the angle of positive-sequence impedance of the transmission line or feeder in secondary ohms.

Zero-Sequence (Z0) Magnitude

Range: 0.01 to 650.00 ohms in steps of 0.01
 Default: 9.00 ohms

This setting specifies the magnitude of zero-sequence impedance of the transmission line or feeder in secondary ohms.

Zero-Sequence (Z0) Angle

Range: 25 to 90° in steps of 1
 Default: 75°

This setting specifies the angle of zero-sequence impedance of the transmission line or feeder in secondary ohms.

Line Length Units*Range: km, miles**Default: km*

This setting selects the units used for fault location calculations.

Line Length*Range: 0.0 to 2000.0 in steps of 0.1**Default: 100.0*

This setting specifies the length of the transmission line or feeder in the defined line length units.

Fault Report VT Substitution*Range: None, I0, V0**Default: None*

Program this setting to “None” if the D90^{PLUS} is fed from wye-connected VTs. If delta-connected VTs are used, and the D90^{PLUS} is supplied with the neutral (3V0) voltage, set to “V0.” The method is still exact, as the fault locator combines the line-to-line voltage measurements with the neutral voltage measurement to re-create the line-to-ground voltages. It required to configure the delta and neutral voltages under the source indicated as input for the fault report. Also, the D90^{PLUS} checks if the auxiliary signal configured is marked as “Vn” by the user (under VT setup) and inhibits the fault location if the auxiliary signal is labeled differently.

If the broken-delta neutral voltage is not available to the relay, an approximation is possible by assuming the missing zero-sequence voltage to be an inverted voltage drop produced by the zero-sequence current and the user-specified equivalent zero-sequence system impedance behind the relay: $V_0 = -Z_0 \times I_0$. In order to enable this mode of operation, set the value to “I0”.

Fault Report System Z0 Magnitude*Range: 0.01 to 650.00 ohms in steps of 0.01**Default: 2.00 ohms*

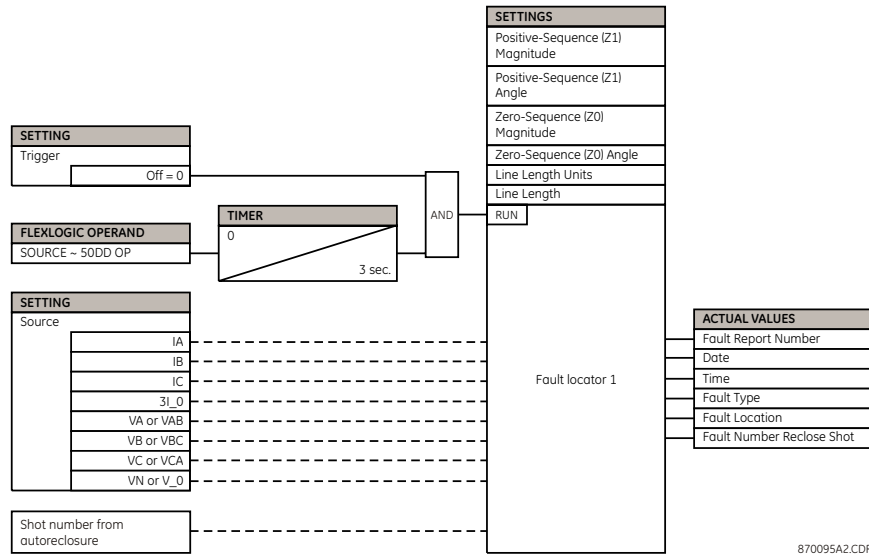
This setting is used when the [Fault Report VT Substitution](#) value is “I0”. Enter the magnitude in secondary ohms. This impedance is an average system equivalent behind the relay. It can be calculated as zero-sequence Thevenin impedance at the local bus with the protected line/feeder disconnected. The method is accurate only if this setting matches perfectly the actual system impedance during the fault. If the system exhibits too much variability, this approach is questionable and the fault location results for single-line-to-ground faults are trusted accordingly. Keep in mind that grounding points in vicinity of the installation impact the system zero-sequence impedance (grounded loads, reactors, zig-zag transformers, shunt capacitor banks, and so on).

Fault Report System Z0 Angle*Range: 25 to 90° in steps of 1**Default: 75°*

This setting is used when the [Fault Report VT Substitution](#) value is “I0” and represents the corresponding angle for the [Fault Report System Z0 Magnitude](#) setting.

The figure shows the fault locator logic.

Figure 443: Fault locator logic

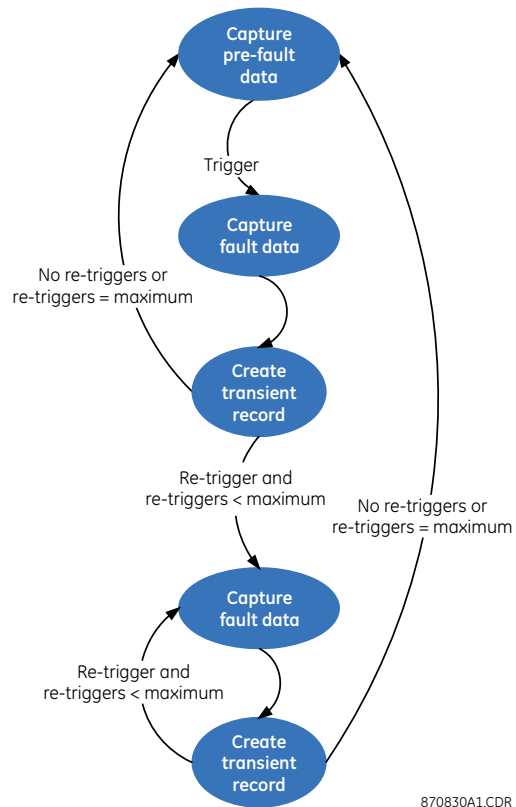


Transient recorder

The transient recorder captures short duration events, such as faults at a high resolution. Under normal operation, the transient recorder continuously captures pre-fault data and stores this data in memory. When a trigger is received, the transient recorder captures the data during the period of the fault. Both the pre-fault and fault data are stored as records in non-volatile memory within the D90^{PLUS}.

The transient recorder captures the instantaneous values of all voltage and current signals connected to the D90^{PLUS}. In addition, the user can configure digital and analog channels, each of which can be used to trigger or re-trigger the transient recorder. A re-trigger captures an additional record but with no pre-fault data. Triggered and re-triggered records are merged into a single file, and the maximum number of re-triggers for a particular fault is user-programmable.

Figure 444: Trigger and re-trigger sequence



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The length of a transient record also is user-configurable. The number of transient records stored by the D90^{Plus} is a function of the record length, the time-resolution of the recording, and of the number of configured channels. The D90^{Plus} automatically calculates the number of transient records based on the user-defined setting values.

The transient recorder has two storage modes: protected and automatic overwrite. When the memory is filled, either no new records are written to memory (protected mode) or the oldest record is overwritten (automatic overwrite mode).

The D90^{Plus} contains a finite amount of memory for record storage. The table shows how transient recorder configuration affects the number of available records.

Table 36: Transient records stored by the D90^{Plus} (examples)

Records	Sampling rate	Digital channels	Analog channels	Record length
8	256 samples/cycle	128	16	57 cycles
24	256 samples/cycle	128	16	22 cycles
48	256 samples/cycle	128	16	11 cycles
8	128 samples/cycle	128	16	104 cycles
24	128 samples/cycle	128	16	40 cycles
48	128 samples/cycle	128	16	20 cycles
20	64 samples/cycle	128	16	80 cycles
64	64 samples/cycle	128	16	26 cycles
24	32 samples/cycle	64	8	135 cycles
64	32 samples/cycle	64	8	53 cycles
41	16 samples/cycle	64	8	124 cycles
64	16 samples/cycle	64	8	81 cycles

Front panel indications

The digital fault reporter summary screen indicates when the transient recorder is ready to capture data and has memory available.

In protected mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The transient recorder is enabled
- The block trigger input is not asserted
- Memory is available
- A record capture is not currently in progress

Otherwise the indication is red.

In automatic overwrite mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The transient recorder is enabled
- The block trigger input is not asserted
- A record capture is not currently in progress

The **Memory Available** indication is green when less than 80% of the memory has been filled. It is yellow when the amount of memory filled is between 80% and 99%, and it is red if 100% of the memory is filled.

Figure 445: Digital fault reporter summary screen

DFR - SUMMARY		
Ready to Capture Memory Available		
FAULT REPORT	●	●
TRANSIENT RECORDER	●	●
DISTURBANCE RECORDER	●	●
Records	Latest	Total
EVENTS	2007/08/08 11:38:54	112283
FAULTS	2007/08/08 11:01:53	43640
TRANSIENTS	2007/08/08 11:01:54	8
DISTURBANCES	2007/08/08 11:10:57	3
Summary	SOE	Fault Report Transient Disturbance

The transient recorder screen shows the individual records stored on the device. This screen also indicates any active triggers (red indication) for the transient recorders. If a continuous trigger is active permanently, it does not fill the memory of the recorder. In this case, after the first record is generated, it is effectively disabled by the trigger logic, but its status displays on this screen. The user can also force triggering of the recorder from this screen.

Figure 446: Transient recorder screen

Record	Date
517	Aug 08 2007 11:01:54
516	Aug 08 2007 11:00:56
515	Aug 08 2007 11:00:15
514	Jan 01 1970 00:00:00
513	Jan 01 1970 00:00:00
512	Jan 01 1970 00:00:00
511	Jan 01 1970 00:00:00
510	Jan 01 1970 00:00:00

Channel Active

Up Down Retrieve Clear All Force Trig

Transient recorder settings

Select the **Settings > DFR > Transient Record** menu to open the transient recorder configuration window.

Figure 447: Transient recorder configuration settings

SETTING	PARAMETER
Function	Disabled
Number Of Records	48
Trigger Mode	Automatic Overwrite
Trigger Position	50 %
Maximum Retriggers	2
Sample Rate	32 samples/cycle
Block Trigger	OFF
Digital Channels	Select
Analog Channels	Select

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The following settings are available.

Function

Range: Enabled, Disabled

Default: Enabled

This setting enables and disables the transient recorder function.

Number Of Records

Range: 1 to 64 in steps of 1

Default: 48

This setting specifies the total number of transient records that can be stored in the D90^{Plus}. A larger setting results in a shorter record length, and a smaller setting results in a longer record length.

Trigger Mode

Range: Automatic Overwrite, Protected

Default: Automatic Overwrite

If this setting is selected as "Automatic Overwrite," then the oldest record is overwritten once the number of stored records reaches the setting value. If this setting is "Protected," then no new records are stored once the number of records reaches the setting value.

Trigger Position

Range: 1 to 100% in steps of 1

Default: 50%

This setting specifies the amount of pre-trigger data stored in a record expressed as a percentage of record length.

Maximum Re-Triggers

Range: 1 to 4 in steps of 1

Default: 2

This setting selects the maximum number of re-trigger records that can be generated for an event. The value is limited to one less than the number of records that can be stored (up to a maximum of four records).

Sample Rate

Range: 16, 32, 64, 128, or 256 samples per cycle, or OFF

Default: 32

This setting selects the time-resolution of the transient record. A larger setting necessarily results in a shorter record length.

Block Trigger

Range: any FlexLogic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, all triggers to the transient recorder are inhibited.



NOTE

When changes are made to the transient recorder settings, all existing transient records are cleared.

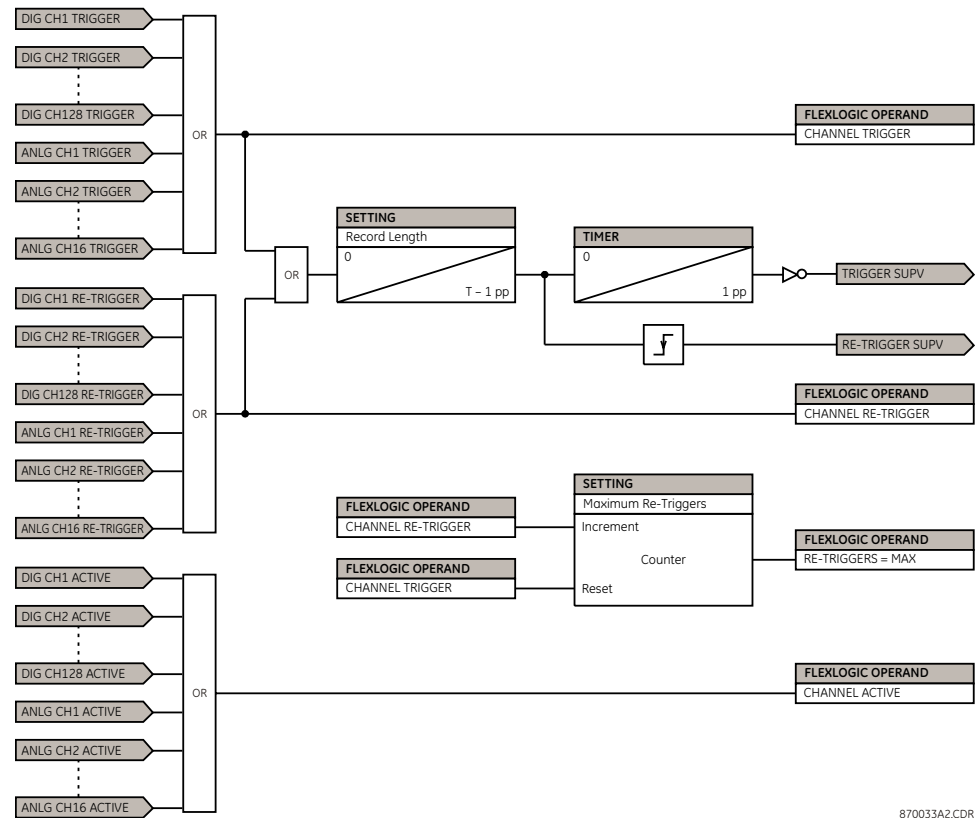


NOTE

The transient recorder starts collecting data upon power up or after the recorder is cleared. If a trigger occurs immediately after a power up or the clearing of transient records, and there is not enough pre-trigger data, then the pre-trigger is set to the amount of data collected and does not reflect the value specified by the user.

The figure shows the transient recorder trigger logic.

Figure 448: Transient recorder trigger logic



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Transient recorder digital channels

Up to 128 digital channels can be assigned to the transient recorder. Each channel can be configured individually by clicking the digital channels **Select** button in the transient recorder window to open the transient recorder digital channels window.

Figure 449: Digital channel configuration settings

Channel	Signals	Trigger
Digital Channel 1	OFF	OFF
Digital Channel 2	OFF	OFF
Digital Channel 3	OFF	OFF
Digital Channel 4	OFF	OFF
Digital Channel 5	OFF	OFF
Digital Channel 6	OFF	OFF
Digital Channel 7	OFF	OFF
Digital Channel 8	OFF	OFF
Digital Channel 9	OFF	OFF
Digital Channel 10	OFF	OFF
Digital Channel 11	OFF	OFF
Digital Channel 12	OFF	OFF
Digital Channel 13	OFF	OFF
Digital Channel 14	OFF	OFF
Digital Channel 15	OFF	OFF
Digital Channel 16	OFF	OFF

The following settings are available for each digital channel.

Signals

Range: any FlexLogic operand or shared operand
 Default: OFF

This setting specifies an operand to use as a transient recorder digital channel. The pull-down list of available signals is populated with enabled protection functions. Selected operands are assigned automatically as channels and as triggers according to their importance and can be de-assigned by the user.

For example, when ground time overcurrent 1 has been enabled, the following assignments are made from the list of available operands.

Table 37: Ground time overcurrent 1 signal example

Available signals (operands)	Operand assigned as a...	
	Digital channel	Trigger
GND TOC1 DPO	Yes	No
GND TOC1 OP	Yes	Yes
GND TOC1 PKP	Yes	No

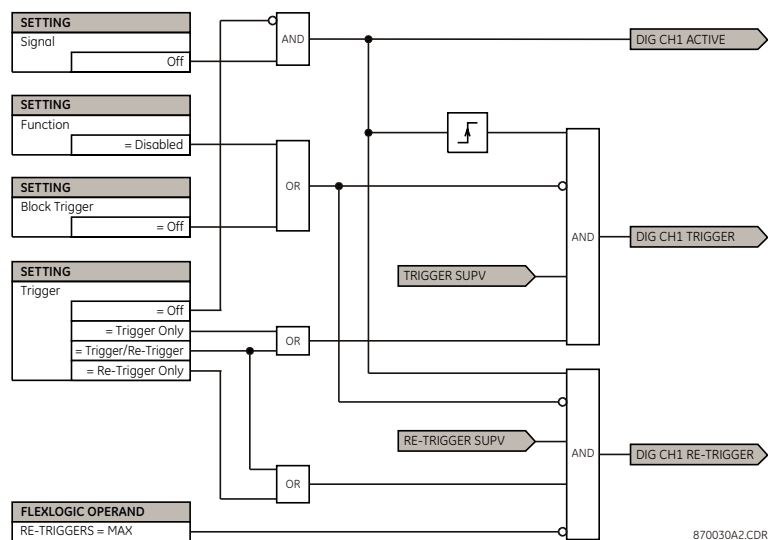
Trigger

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only
 Default: Off

This setting selects the trigger function of the digital channel. When set to “Trigger Only” or “Trigger/Re-Trigger,” the transient recorder initiates data capture for an OFF-ON transition of the channel signal. The resulting record contains both pre-fault and fault data and the channel must return to the off state before it can generate a subsequent trigger.

When set to “Trigger/Re-Trigger” or “Re-Trigger Only,” the transient recorder is re-triggered if the signal is still asserted at the end of the trigger period. The resulting record contains fault data only. A re-trigger is re-generated at the end of a transient record if the signal is still asserted and if the number of re-triggers is less than the value specified by the **Maximum Re-Triggers** setting.

Figure 450: Digital channel triggering logic



Transient recorder analog channels

Up to 16 analog channels can be assigned to the transient recorder. Each channel can be configured individually by clicking the analog channel **Select** button in the transient recorder window to open the transient recorder analog channels window.

Figure 451: Analog channel configuration settings

Channel	Available Signals	High Trigger	High Pickup	Low Trigger	Low Pickup	Block Trigger
Analog Channel 1	LINE Vag Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 2	LINE Vag Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 3	LINE Vbg Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 4	LINE Vbg Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 5	LINE Vcg Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 6	LINE Vcg Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 7	LINE Ia Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 8	LINE Ia Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 9	LINE Ib Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 10	LINE Ib Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 11	LINE Ic Mag	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 12	LINE Ic Angle	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 13	OFF	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 14	OFF	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 15	OFF	OFF	1000.0	OFF	1000.0	OFF
Analog Channel 16	OFF	OFF	1000.0	OFF	1000.0	OFF

The following settings are available for each analog channel.

Available Signal

Range: any FlexAnalog quantity

Default: as shown above

This setting selects the FlexAnalog value to be recorded for the channel. The size of each record depends in part on the number of parameters selected. Channels set to “Off” are ignored.

High Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only

Default: Off

This setting selects the high triggering function for the analog channel. When set to “Trigger Only” or “Trigger/Re-Trigger,” the transient recorder initiates data capture when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record contains pre-fault and fault data. The channel must return to the OFF state before it can generate a subsequent trigger.

When set to “Re-Trigger Only” or “Trigger/Re-Trigger,” the transient recorder is re-triggered when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record contains fault data only. A re-trigger is again generated at the end of a transient record if the magnitude is greater than the **High Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Note that only phasor magnitudes, RMS magnitudes, frequency, and power can be used as analog triggers.

High Pickup

Range: 0.0 to 1000000.0 in steps of 0.1

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units depend on the value of the **Available Signal** setting.

Low Triggering

Range: Enabled, Disabled

Default: Disabled

This setting selects the low triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger," the transient recorder initiates data capture when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting record contains both pre-fault and fault data. The channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Trigger Only," the transient recorder is re-triggered when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting transient record contains fault data only. A re-trigger is generated again at the end of the record if the magnitude is less than the **Low Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Note that only phasor magnitudes, RMS magnitudes, frequency, and power can be used as analog triggers.

Low Pickup

Range: 0.0 to 1000000.0 in steps of 0.1

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units depend on the value of the **Available Signal** setting.

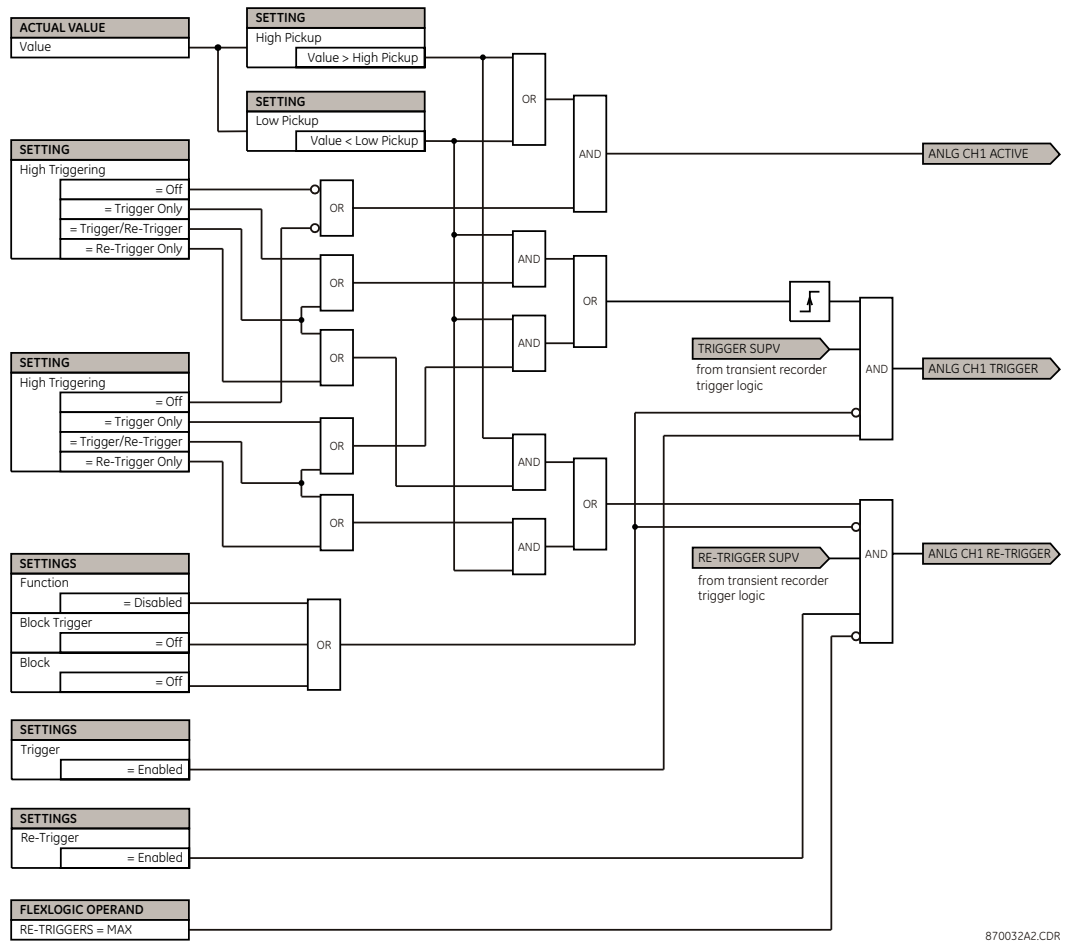
Block Trigger

Range: any FlexLogic operand or shared logic operand

Default: OFF

When the operand assigned to this setting is asserted, all high and low triggers to the specified analog channel are inhibited.

Figure 452: Analog channel trigger logic



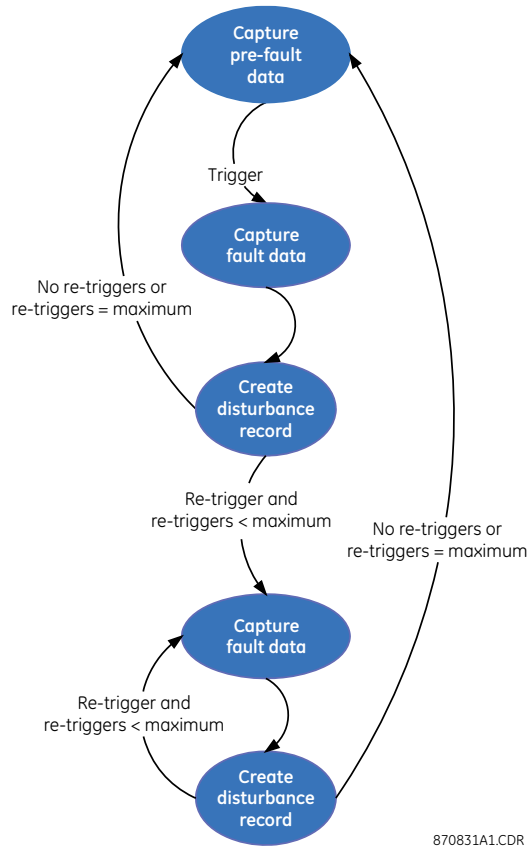
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Disturbance recorder

The disturbance recorder is designed to capture long duration events, such as power swings, at a resolution of one sample per cycle. Under normal operation, the disturbance recorder is capturing continuously the pre-event data and storing this data in memory. When a trigger is received, the disturbance recorder captures the data during the post-event period. Both the pre-event and post-event data are stored as a record in non-volatile memory within the D90^{PLUS}.

The disturbance recorder captures the user-configured digital and analog channels, each of which can be used to trigger or re-trigger the disturbance recorder. A re-trigger captures an additional record but with no pre-event data. Triggered and re-triggered records are merged into a single file, and the maximum number of re-triggers for a particular event is user-programmable.

Figure 453: Trigger and re-trigger sequence



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The number of disturbance records also is user-configurable. The length of disturbance records stored by the D90^{Plus} is a function of the number of records and the number of configured channels. The D90^{Plus} automatically calculates the record length based on user settings. The table shows the record length for some representative configurations.

Table 38: Disturbance records stored by the D90^{Plus}

Records	Digital channels	Analog channels	Record length
1	32	64	2393 cycles
5	32	64	1025 cycles
10	32	64	598 cycles
1	32	32	4520 cycles
10	32	32	1129 cycles
20	32	32	616 cycles
2	32	16	6100 cycles
5	32	16	3486 cycles
10	32	16	2033 cycles
20	32	16	1108 cycles
5	32	8	5811 cycles
10	32	8	3389 cycles
20	32	8	1848 cycles
30	32	8	1270 cycles

The recorder has two storage modes: protected and automatic overwrite. When the memory is filled, either no new records are written to memory (protected mode) or the oldest record is overwritten (automatic overwrite mode).

Front panel indications

The digital fault reporter summary screen indicates when the disturbance recorder is ready to capture data and has memory available.

In protected mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The disturbance recorder is enabled
- The block trigger input is not asserted
- Memory is available
- A record capture is not currently in progress

Otherwise the indication is red.

In automatic overwrite mode, the **Ready to Capture** indication is green when all of the following conditions hold:

- The disturbance recorder is enabled
- The block trigger input is not asserted
- A record capture is not currently in progress

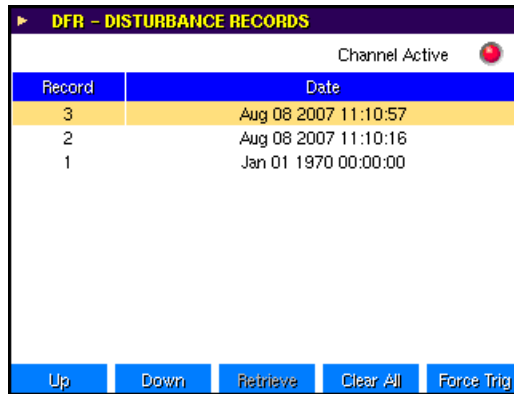
The **Memory Available** indication is green when less than 80% of the memory has been filled. It is yellow when the amount of memory filled is between 80% and 99%, and it is red if 100% of the memory is filled.

Figure 454: Digital fault reporter summary screen

Records	Latest	Total
EVENTS	2007/08/08 11:38:54	112283
FAULTS	2007/08/08 11:01:53	43640
TRANSIENTS	2007/08/08 11:01:54	8
DISTURBANCES	2007/08/08 11:10:57	3

The disturbance recorder screen shows the individual records stored on the device. This screen also indicates any active triggers (red indication) for the disturbance recorders. If a continuous trigger is active permanently, it does not fill the memory of the recorder. In this case, after the first record is generated, it is effectively disabled by the trigger logic, but its status displays on this screen. The user also can force triggering of the recorder from this screen.

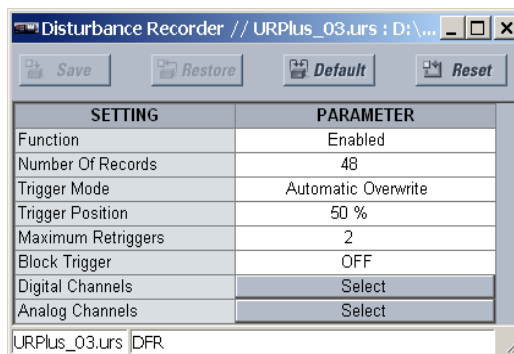
Figure 455: Disturbance recorder screen



Disturbance recorder settings

Select the **Settings > DFR > Disturbance Record** menu to open the disturbance recorder configuration window.

Figure 456: Disturbance recorder configuration settings



The following settings are available.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the disturbance recorder function.

Number of Records

Range: 1 to 64 in steps of 1

Default: 48

This setting specifies the total number of disturbance records that can be stored in the D90^{PLUS}. A larger setting results in a shorter record length, and a smaller setting results in a longer record length.

Trigger Mode

Range: Automatic Overwrite, Protected

Default: Automatic Overwrite

If this setting value is "Automatic Overwrite," then the oldest disturbance record is overwritten once the number of stored records reaches the setting value. If this value is "Protected," then no new disturbance record is stored once the number of records reaches the setting value.

Trigger Position

Range: 1 to 100% in steps of 1
 Default: 50%

This setting specifies the amount of pre-trigger data stored in a disturbance record expressed as a percentage of the disturbance record length.

Maximum Re-Triggers

Range: 1 to 4 in steps of 1
 Default: 2

This setting selects the maximum number of re-trigger records that can be generated for a disturbance event. The value is limited to one less than the number of records that can be stored (up to a maximum of four records).

Block Trigger

Range: any FlexLogic operand or shared operand
 Default: OFF

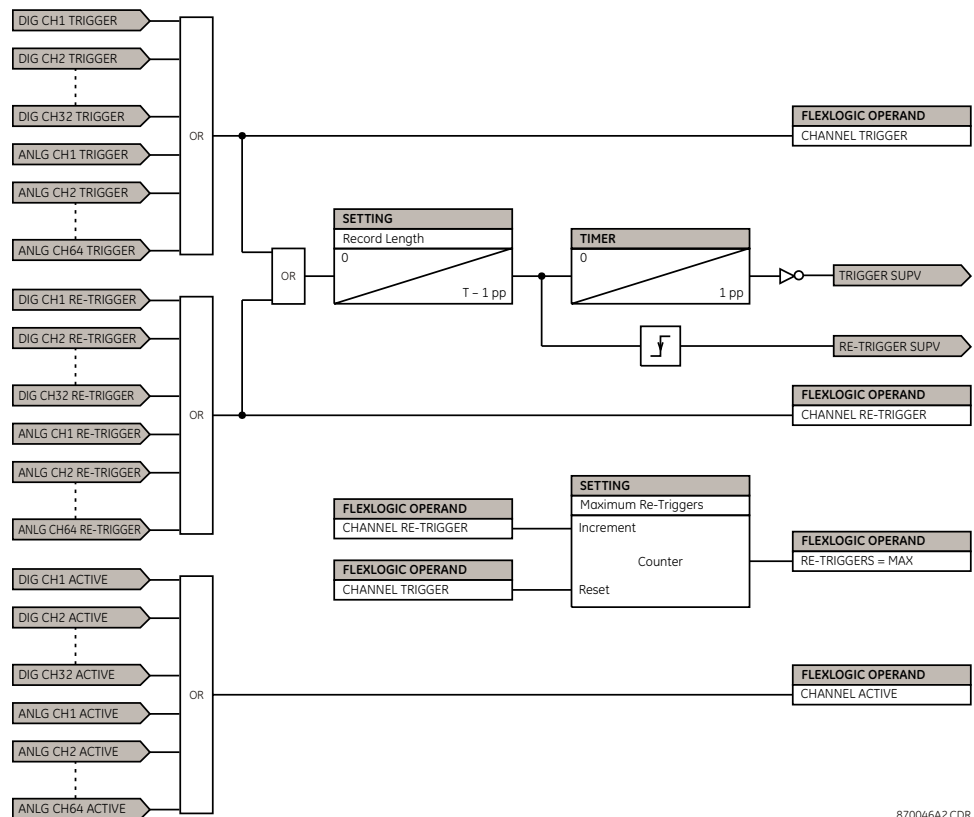
When the operand assigned to this setting is asserted, all triggers to the disturbance recorder are inhibited.



When changes are made to the disturbance recorder settings, all existing disturbance records are cleared.

The disturbance recorder starts collecting data upon power up or after the recorder is cleared. If a trigger occurs immediately after a power up or the clearing of disturbance records, and there is not enough pre-trigger data, then the pre-trigger is set to the amount of data collected and does not reflect the value specified by the user.

Figure 457: Disturbance recorder trigger logic

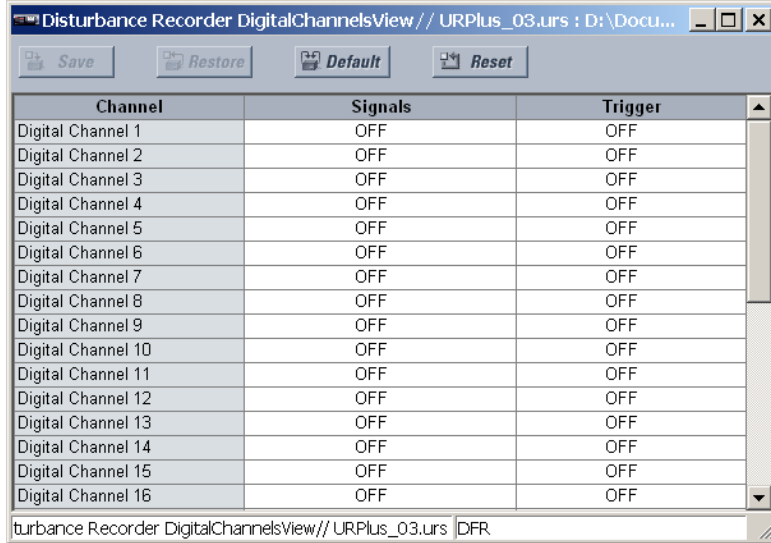


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Disturbance recorder digital channels

Up to 32 digital channels can be assigned to the disturbance recorder. Each channel can be configured individually by clicking the digital channels **Select** button in the disturbance recorder window to open the disturbance recorder digital channels window.

Figure 458: Digital channel configuration settings



The following settings are available for each disturbance recorder digital channel.

Signals

Range: any FlexLogic operand or shared operand
 Default: Off

This setting selects an operand to act as a trigger for the digital channel.

The pull-down list of available signals is populated according to the protection functions that have been enabled. Selected signals are assigned automatically as channels and as triggers according to their importance. These signals can be deactivated by the user. For example, if ground time overcurrent 1 has been enabled, then the following assignments are made.

Table 39: Example disturbance recorder signal assignment

Available signals	Assignment	
	Digital channel	Trigger
GND TOC1 DPO	Yes	No
GND TOC1 OP	Yes	Yes
GND TOC1 PKP	Yes	No

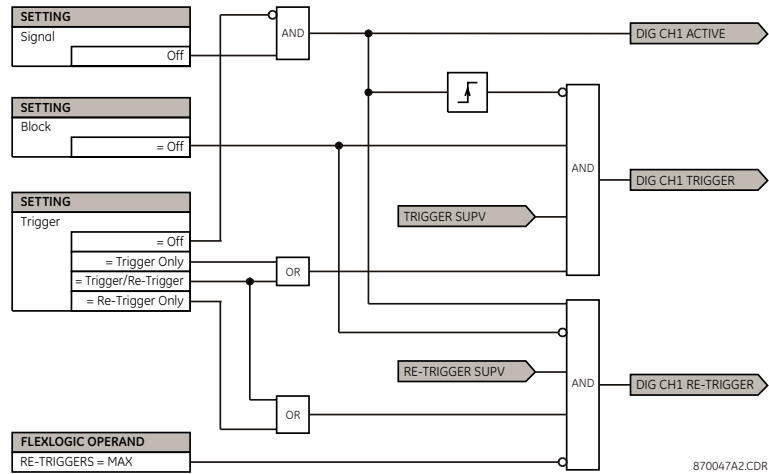
Trigger

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only
 Default: Off

This setting selects the trigger function of the digital channel. When set to “Trigger Only” or “Trigger/Re-Trigger,” the disturbance recorder initiates data capture for an OFF-ON transition of the channel signal. The resulting record contains both pre-fault and fault data and the channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Re-Trigger Only," the disturbance recorder is re-triggered if the signal is still asserted at the end of the trigger period. The resulting record contains fault data only. A re-trigger is re-generated at the end of a disturbance record if the signal is still asserted and if the number of re-triggers is less than the value specified by the **Maximum Re-Triggers** setting.

Figure 459: Disturbance recorder digital channels input logic



Disturbance recorder analog channels

Up to 64 analog channels can be assigned to the transient recorder. Each channel can be configured individually by clicking the analog channel **Select** button in the disturbance recorder window to open the disturbance recorder analog channels window.

Figure 460: Analog channel configuration settings

Channel	Available Signals	High Trigger	High Pickup	Low Trigger
Analog Channel 1	OFF	OFF	1.000	OFF
Analog Channel 2	OFF	OFF	1.000	OFF
Analog Channel 3	OFF	OFF	1.000	OFF
Analog Channel 4	OFF	OFF	1.000	OFF
Analog Channel 5	OFF	OFF	1.000	OFF
Analog Channel 6	OFF	OFF	1.000	OFF
Analog Channel 7	OFF	OFF	1.000	OFF
Analog Channel 8	OFF	OFF	1.000	OFF
Analog Channel 9	OFF	OFF	1.000	OFF
Analog Channel 10	OFF	OFF	1.000	OFF
Analog Channel 11	OFF	OFF	1.000	OFF
Analog Channel 12	OFF	OFF	1.000	OFF
Analog Channel 13	OFF	OFF	1.000	OFF
Analog Channel 14	OFF	OFF	1.000	OFF
Analog Channel 15	OFF	OFF	1.000	OFF
Analog Channel 16	OFF	OFF	1.000	OFF

The following settings are available for each disturbance recorder analog channel.

Available Signals

Range: any FlexAnalog quantity

Default: Off

This setting specifies the FlexAnalog quantity to be recorded for the channel. The size of each disturbance record depends in part on the number of parameters selected. Parameters set to "Off" are ignored.

High Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only

Default: Off

This setting selects the high triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger," the disturbance recorder initiates data capture when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record contains pre-fault and fault data. The channel must return to the OFF state before it can generate a subsequent trigger.

When set to "Re-Trigger Only" or "Trigger/Re-Trigger," the disturbance recorder is re-triggered when the magnitude of the signal is greater than the value of the **High Pickup** setting. The resulting record contains fault data only. A re-trigger is generated again at the end of a disturbance record if the magnitude is greater than the **High Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Note that only phasor magnitudes, RMS magnitudes, frequency, and power can be used as analog triggers.

High Pickup

Range: 0.0 to 1000000.0 in steps of 0.1

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units depend on the value of the **Available Signals** setting.

Low Triggering

Range: Off, Trigger Only, Trigger/Re-Trigger, Re-Trigger Only

Default: Off

This setting selects the low triggering function for the analog channel. When set to "Trigger Only" or "Trigger/Re-Trigger," the disturbance recorder initiates data capture when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting record contains both pre-fault and fault data. The channel must return to the off state before it can generate a subsequent trigger.

When set to "Trigger/Re-Trigger" or "Trigger Only," the disturbance recorder is re-triggered when the magnitude of the signal is less than the value of the **Low Pickup** setting. The resulting disturbance record contains fault data only. A re-trigger is generated again at the end of the record if the magnitude is less than the **Low Pickup** and if the number of re-triggers is less than the **Maximum Re-Trigger** setting.

Note that only phasor magnitudes, RMS magnitudes, frequency, and power can be used as analog triggers.

Low Pickup

Range: 0.0 to 1000000.0 in steps of 0.1

Default: 1000.0

This setting specifies the magnitude of the signal required to produce a trigger or re-trigger. This setting is expressed in primary values. The units depends on the value of the **Available Signals** setting.

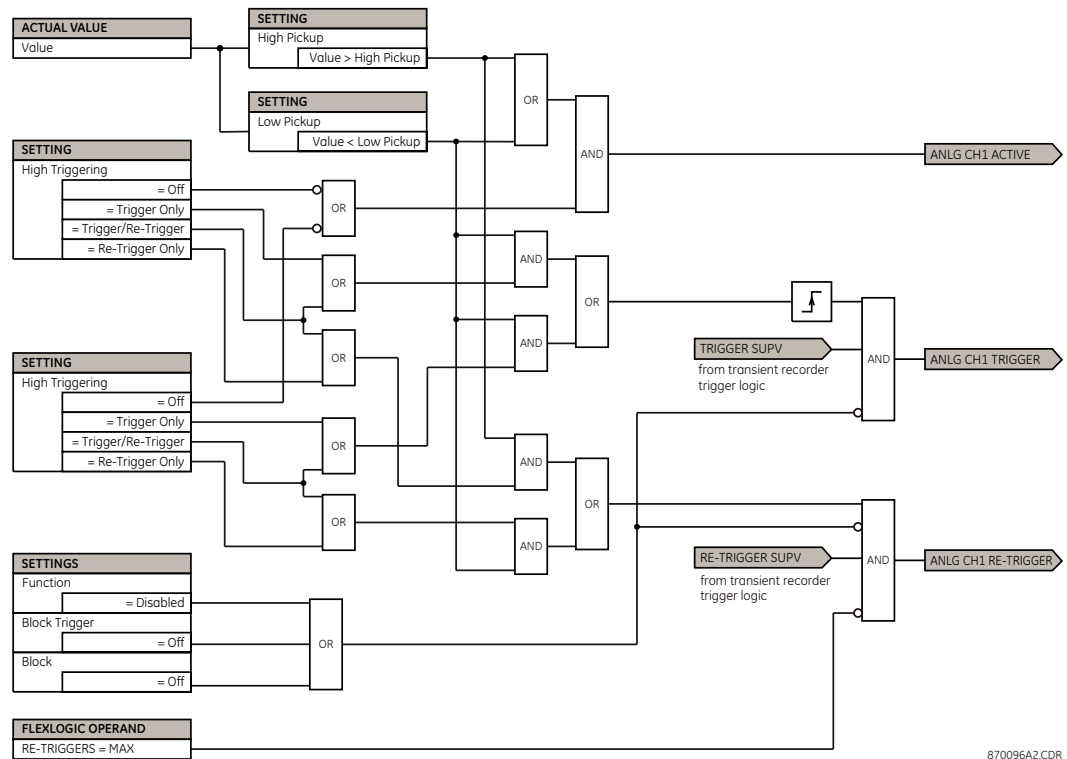
Block Trigger

Range: any FlexLogic operand

Default: Off

The FlexLogic operand assigned to this setting blocks triggering of the disturbance recorder analog channel.

Figure 461: Analog channel trigger logic



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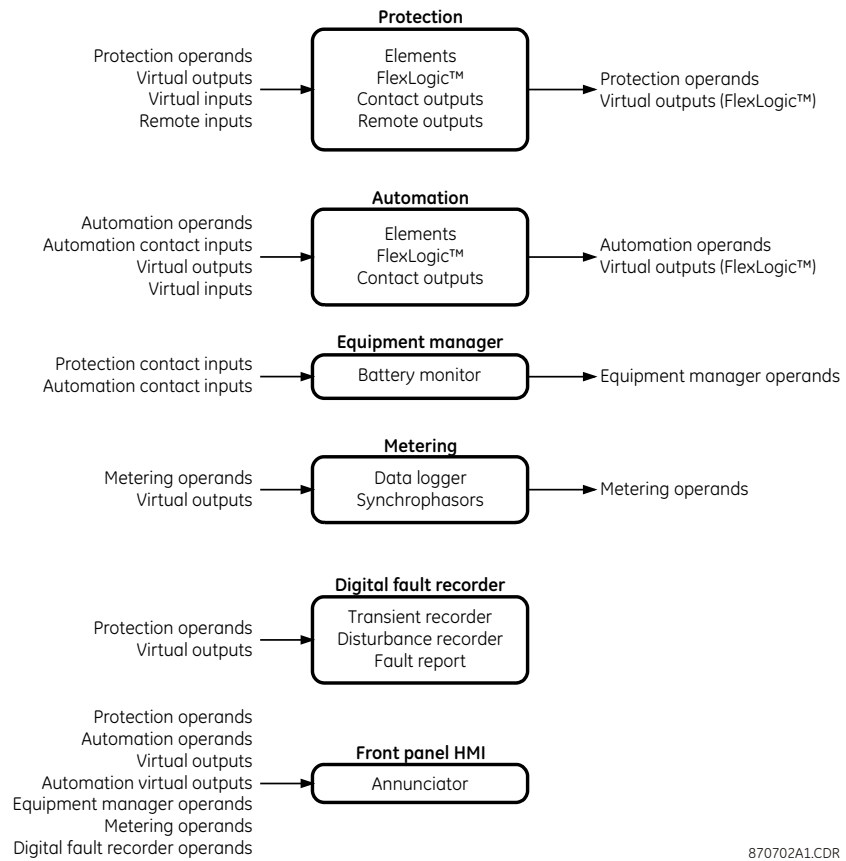
Using shared operands in digital fault recorder

The EnerVista UR^{Plus} Setup software groups the D90^{Plus} system into the following eight primary functions. Each function has its own settings and each generates its own outputs in the form of operands.

- Communications
- Protection
- Automation
- Digital fault recorder (DFR)
- Metering
- Equipment manager
- Self-tests
- Front panel interface (HMI)

It is often desirable for an output from an element within one function to be available to an element within another function. For example, it can be useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available to each function, as shown.

Figure 462: Default operand list by function



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The content of each operand list depends on the order code.

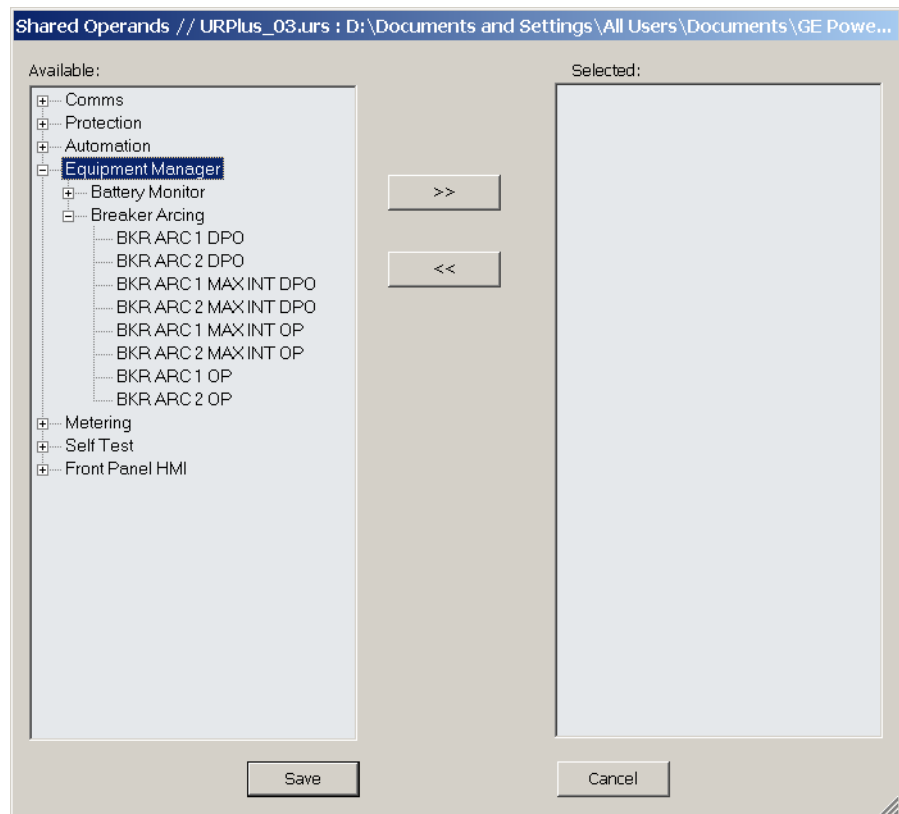
The shared operands functionality expands upon this system. An output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals then can be assigned as inputs to other functions.

For example, assume that the **GND TOC1 OP** protection operand is required as a signal within the automation function. This operand then is assigned as a shared operand and subsequently becomes available to the automation function. A total of 64 operands can be assigned as shared operands within each function.

Shared digital fault recorder operands

Select the **Settings > DFR > Shared Operands** menu to select the shared digital fault recorder operands.

Figure 463: Shared operands configuration window



The left side of this screen displays all D90^{Plus} operands that are available to the digital fault recorder function as shared operands. Select any operands from the other five primary features by clicking the >> button. Operands can be de-assigned as shared operands by clicking the << button.

Digital fault recorder FlexAnalog parameters

The following digital fault recorder FlexAnalog parameters (analog operands) are available for the D90^{Plus}. They are listed alphabetically by operand syntax.

Fault report analog operands

Fault Ia Mag [1].....	Metered phase A fault current magnitude from fault report
Fault Ia Ang [1].....	Metered phase A fault current angle from fault report
Fault Ib Mag [1].....	Metered phase B fault current magnitude from fault report
Fault Ib Ang [1].....	Metered phase B fault current angle from fault report
Fault Ic Mag [1].....	Metered phase C fault current magnitude from fault report
Fault Ic Ang [1].....	Metered phase C fault current angle from fault report
Fault Va Mag [1].....	Metered phase A fault voltage magnitude from fault report
Fault Va Ang [1].....	Metered phase A fault voltage angle from fault report
Fault Vb Mag [1].....	Metered phase B fault voltage magnitude from fault report
Fault Vb Ang [1].....	Metered phase B fault voltage angle from fault report
Fault Vc Mag [1].....	Metered phase C fault voltage magnitude from fault report
Fault Vc Ang [1].....	Metered phase C fault voltage angle from fault report
Fault Location [1].....	Metered fault location from fault report

Prefault Ia Mag [1].....	Metered phase A pre-fault current magnitude from fault report
Prefault Ia Ang [1].....	Metered phase A pre-fault current angle from fault report
Prefault Ib Mag [1].....	Metered phase B pre-fault current magnitude from fault report
Prefault Ib Ang [1].....	Metered phase B pre-fault current angle from fault report
Prefault Ic Mag [1].....	Metered phase C pre-fault current magnitude from fault report
Prefault Ic Ang [1].....	Metered phase C pre-fault current angle from fault report
Prefault Va Mag [1].....	Metered phase A pre-fault voltage magnitude from fault report
Prefault Va Ang [1].....	Metered phase A pre-fault voltage angle from fault report
Prefault Vb Mag [1].....	Metered phase B pre-fault voltage magnitude from fault report
Prefault Vb Ang [1].....	Metered phase B pre-fault voltage angle from fault report
Prefault Vc Mag [1].....	Metered phase C pre-fault voltage magnitude from fault report
Prefault Vc Ang [1].....	Metered phase C pre-fault voltage angle from fault report

D90^{Plus} Line Distance Protection System

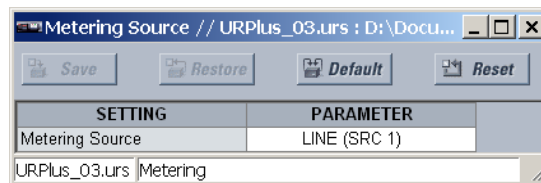
Chapter 11: Metering

This chapter outlines how to program the D90^{Plus} metering features.

Metering source

Select the **Settings > Metering > Metering Source** menu to open the metering source configuration window.

Figure 464: Metering source configuration settings



The following setting is available.

Name

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting selects the source to use for calculating metered quantities available through the front panel interface. For breaker-and-a-half schemes, select a source that sums the current from both breakers to measure the total load on the transmission line.

Phasor Measurement Unit

Phasors are used in protection relays. When these phasors are referenced to a common time base, they are referred to as synchrophasors. A vastly improved method for tracking power system dynamic phenomena for power system monitoring, protection, operation, and control can be realized when synchrophasors from different locations within the power system are networked to a central location.

The Phasor Measurement Unit (PMU) menus allow specifying basic parameters of the measurement process, such as signal source, ID, and station name, calibration data, triggering, recording, and content for transmission on each of the supported PMU ports.

The reporting ports menus allow specifying the content and rate of reporting on each of the supported ports. The PMU settings are organized in five logical groups: basic configuration, calibration, communications, triggering, and recording.

Phasor Measurement Unit configuration

Select the **Settings > Metering > Phasor Measurement Unit > Phasor Measurement Unit > Basic Configuration** menu to open the Phasor Measurement Unit configuration window.

Figure 465: Phasor Measurement Unit configuration settings

PARAMETER	PMU 1
Function	Disabled
IDcode	1
STN	GE-UR+PMU
Source	LINE (SRC 1)
Post-Filter	Symm-3-point

The settings allow for the configuration of basic synchrophasor data, such as functions, source settings, and names. The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables the Phasor Measurement Unit functionality. Any associated functions (such as the recorder or triggering comparators) do not function if this setting is "Disabled." Use the command frame to force the communication portion of the feature to start/stop transmission of data. When the transmission is turned off, the PMU is fully operational in terms of calculating and recording the phasors.

IDcode

Range: 1 to 65534 in steps of 1

Default: 1

This setting assigns a numerical ID to the PMU. It corresponds to the IDCODE field of the data, configuration, header, and command frames of the C37.118 protocol. The PMU uses this value when sending data, configuration, and header frames and responds to this value when receiving the command frame.

STN

Range: 16 alphanumeric characters

Default: GE-UR+PMU

This setting assigns an alphanumeric ID to the PMU station. It corresponds to the STN field of the configuration frame of the C37.118 protocol. This value is a 16-character ASCII string as per the C37.118 standard.

Source

Range: LINE (SRC 1), BKR 1 (SRC 2), BKR 2 (SRC 3)

Default: LINE (SRC 1)

This setting specifies one of the available D90^{Plus} signal sources for processing in the PMU. Note that any combination of voltages and currents can be configured as a source. The current channels can be configured as sums of physically connected currents. This facilitates PMU applications in breaker-and-a-half, ring-bus, and similar arrangements. The PMU feature calculates voltage phasors for actual voltage (A, B, C, and auxiliary) and current (A, B, C, and ground) channels of the source, as well as

symmetrical components (0, 1, and 2) of both voltages and currents. When configuring communication and recording features of the PMU, the user can select—from the above superset—the content to be sent out or recorded.

Post-Filter

Range: None, Symm-3-point, Symm-5-point, Symm-7-point

Default: Symm-3-point

This setting specifies amount of post-filtering applied to raw synchrophasor measurements. The raw measurements are produced at the rate of nominal system frequency using one-cycle data windows. This setting is provided to deal with interfering frequencies and to balance speed and accuracy of synchrophasor measurements for different applications. The following filtering choices are available:

- None — No post-filtering
- Symm-3-point — Symmetrical three-point filter (one historical point, one present point, one future point)
- Symm-5-point — Symmetrical five-point filter (two historical points, one present point, two future points)
- Symm-7-point — Symmetrical seven-point filter (three historical points, one present point, three future points)

This setting applies to all channels of the PMU. It is effectively for recording and transmission on all ports configured to use data for the PMU.

Phasor Measurement Unit calibration

Select the **Settings > Metering > Synchrophasors > PMU Calibration** menu to open the Phasor Measurement Unit calibration window.

Figure 466: Phasor Measurement Unit calibration settings

PARAMETER	PMU 1
Va Angle	0.00 deg
Vb Angle	0.00 deg
Vc Angle	0.00 deg
Vx Angle	0.00 deg
Ia Angle	0.00 deg
Ib Angle	0.00 deg
Ic Angle	0.00 deg
Ig Angle	0.00 deg
Sequence Voltage Shift Angle	0 deg
Sequence Current Shift Angle	0 deg

The following settings are available for each PMU. These settings specify user angle calibration data. This data is combined with the factory adjustments to shift the phasors for better accuracy.

Va Angle, Vb Angle, Vc Angle, Vx Angle

Range: -5.00 to 5.00° in steps of 0.05

Default: 0.00°

These settings recognize applications with protection class voltage and current sources, and they allow the user to calibrate each channel (phase A, B, and C voltage, as well as auxiliary voltage) individually to offset errors introduced by VTs, CTs, and cabling. The setting values are effectively added to the measured angles. Enter a positive correction if the secondary signal lags the true signal. Enter a negative value if the secondary signal leads the true signal.

Ia Angle, Ib Angle, Ic Angle, Ig Angle*Range: -5.00 to 5.00° in steps of 0.05**Default: 0.00°*

These settings recognize applications with protection class voltage and current sources, and allow the user to calibrate each channel (ground current and phase A, B, and C currents) individually to offset errors introduced by VTs, CTs, and cabling. The setting values are effectively added to the measured angles. Enter a positive correction if the secondary signal lags the true signal. Enter a negative value if the secondary signal leads the true signal.

Sequence Voltage Shift Angle*Range: -180 to 180° in steps of 30**Default: 0°*

This setting allows correcting positive and negative-sequence voltages for vector groups of power transformers located between the PMU voltage point and the reference node. This angle is effectively added to the positive-sequence voltage angle and subtracted from the negative-sequence voltage angle. Note the following:

- When this setting value is not "0°", the phase and sequence voltages do not agree. Unlike sequence voltages, the phase voltages cannot be corrected in a general case, and therefore are reported as measured.
- When receiving synchrophasor data at multiple locations, with possibly different reference nodes, it can be more beneficial to allow the central locations to perform the compensation of sequence voltages.
- This setting applies to PMU data only. The D90^{PLUS} calculates symmetrical voltages independently for protection and control purposes without applying this correction.
- When connected to line-to-line voltages, the PMU calculates symmetrical voltages with the reference to the AG voltage, and not to the physically connected AB voltage.

Sequence Current Shift Angle*Range: -180 to 180° in steps of 30**Default: 0°*

This setting allows correction of positive and negative-sequence currents for vector groups of power transformers located between the PMU current point and the reference node. The setting has the same meaning for currents as the [Sequence Voltage Shift Angle](#) setting has for voltages. Normally, the two correcting angles are set identically, except rare applications when the voltage and current measuring points are located at different windings of a power transformer.

Phasor Measurement Unit communications

Select the **Settings > Metering > Phasor Measurement Unit > Communication > Comm Port** menu to open the Phasor Measurement Unit communications window for port 1.

Figure 467: Phasor Measurement Unit communications configuration

PARAMETER	PMU 1
Type	None
PHS-1	Off
PHS-1 Name	GE-UR+PMU-PHS 1
PHS-2	Off
PHS-2 Name	GE-UR+PMU-PHS 2
PHS-3	Off
PHS-3 Name	GE-UR+PMU-PHS 3
PHS-4	Off
PHS-4 Name	GE-UR+PMU-PHS 4
PHS-5	Off
PHS-5 Name	GE-UR+PMU-PHS 5
PHS-6	Off
PHS-6 Name	GE-UR+PMU-PHS 6
PHS-7	Off
PHS-7 Name	GE-UR+PMU-PHS 7
PHS-8	Off
PHS-8 Name	GE-UR+PMU-PHS 8
PHS-9	Off
PHS-9 Name	GE-UR+PMU-PHS 9
PHS-10	Off
PHS-10 Name	GE-UR+PMU-PHS 10
PHS-11	Off
PHS-11 Name	GE-UR+PMU-PHS 11
PHS-12	Off
PHS-12 Name	GE-UR+PMU-PHS 12
PHS-13	Off
PHS-13 Name	GE-UR+PMU-PHS 13
PHS-14	Off
PHS-14 Name	GE-UR+PMU-PHS 14
A-CH-1	OFF
A-CH-1 Name	AnalogChannel 1
A-CH-2	OFF
A-CH-2 Name	AnalogChannel 2

The following settings are available for the communication port on each PMU.

Type

Range: None, Network

Default: None

This setting specifies the first communication port for transmission of the PMU data. The three ports are configured under individual menus.

PHS-1, PHS-2, PHS-3,..., PHS-14

Range: Off, Va, Vb, Vc, Vx, Ia, Ib, Ic, Ig, V1, V2, V0, I1, I2, I0

Default: Off

These settings select synchrophasors to be transmitted from the superset of all synchronized measurements. The available synchrophasor values are

- Va — The first voltage channel, either Va or Vab
- Vb — The second voltage channel, either Vb or Vbc
- Vc — The third voltage channel, either Vc or Vca
- Vx — The fourth voltage channel
- Ia — Phase A current, physical channel, or summation as per the source settings
- Ib — Phase B current, physical channel, or summation as per the source settings
- Ic — Phase C current, physical channel, or summation as per the source settings

- I_g — Fourth current channel, physical channel, or summation as per the source settings
- V₁ — Positive-sequence voltage, referenced to V_a
- V₂ — Negative-sequence voltage, referenced to V_a
- V₀ — Zero-sequence voltage
- I₁ — Positive-sequence current, referenced to I_a
- I₂ — Negative-sequence current, referenced to I_a
- I₀ — Zero-sequence current

These settings allow for optimizing the frame size and maximizing transmission channel usage, depending on a given application. Select “Off” to suppress transmission of a given value.

PHS-1 Name, PHS-2 Name, PHS-3 Name,...., PHS-14 Name

Range: 16 alphanumeric characters

Default: GE-UR+PMU1-V1, GE-UR+PMU1-V2, GE-UR-PMU1+V3,...., GE-UR+PMU1-V14

These settings allow for custom naming of the synchrophasor channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame. These names are based typically on station, bus, or breaker names.

A-CH-1, A-CH-2, A-CH-3,...., A-CH-8

Range: available FlexAnalog values

Default: Off

These settings select any analog data measured by the relay to be included as a user-selectable analog channel of the data frame. Up to eight analog channels can be configured to send any FlexAnalog value from the relay. Examples include active and reactive power, per phase or three-phase power, power factor, temperature via RTD inputs, and THD. The configured analog values are sampled concurrently with the synchrophasor instant and sent as 16-bit integer values.

A-CH-1 Name, A-CH-2 Name, A-CH-3 Name,...., A-CH-8 Name

Range: 16 alphanumeric characters

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,...., AnalogChannel8

These settings allow for custom naming of the analog channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

D-CH-1, D-CH-2, D-CH-3,...., D-CH-16

Range: any metering logic operand or shared operand

Default: Off

These settings select any digital flag measured by the relay to be included as a user-selectable digital channel of the data frame. Up to 16 analog channels can be configured to send any operand from the relay. The configured digital flags are sampled concurrently with the synchrophasor instant. The values are mapped into a two-byte integer number, with byte 1 LSB corresponding to the digital channel 1 and byte 2 MSB corresponding to digital channel 16.

D-CH-1 Name, D-CH-2 Name, D-CH-3 Name,...., D-CH-16 Name

Range: 16 alphanumeric characters

Default: DigitalChannel1, DigitalChannel2, DigitalChannel3,...., DigitalChannel16

These settings allow for custom naming of the digital channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

D-CH-1 Normal State, D-CH-2 Normal State, D-CH-3 Normal State, ..., D-CH-16 Normal State

Range: On, Off

Default: Off

These settings allow for specifying a normal state for each digital channel. These states are transmitted in configuration frames to the data concentrator.

Phasor Measurement Unit triggering

Each logical PMU contains five triggering mechanisms to facilitate triggering of the associated PMU recorder and cross-triggering of other PMUs. They are

- Overfrequency and underfrequency
- Overvoltage and undervoltage
- Overcurrent
- Overpower
- High rate of change of frequency

The pre-configured triggers can be augmented with a user-programmable trigger. This trigger can be built freely using programmable logic of the relay. The entire triggering logic is refreshed once every two power system cycles.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > User Triggering** menu to open the PMU user-programmable trigger window.

Figure 468: User-programmable trigger configuration setting



The following user-programmable trigger setting is available.

Function

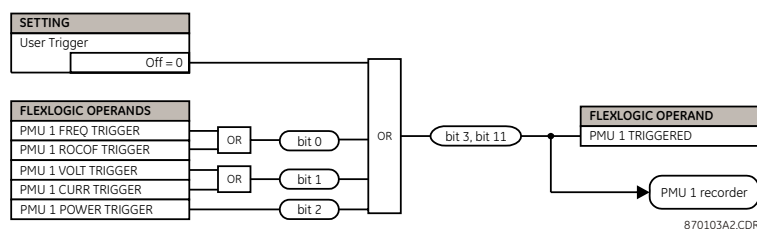
Range: any metering operand or shared operand

Default: OFF

This setting selects an operand to use as a user-specified trigger.

All five triggering functions and the user-programmable trigger are consolidated (ORed) and connected to the PMU recorder. Each trigger can be programmed to log its operation into the event recorder. The five triggers drive the STAT bits of the data frame to inform the destination of the synchrophasor data regarding the cause of trigger. The following convention is adopted to drive bits 11, 3, 2, 1, and 0 of the STAT word.

Figure 469: STAT bits logic

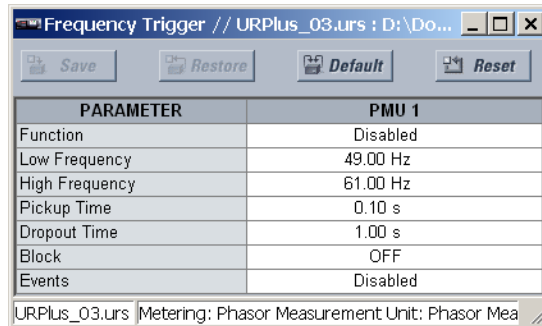


Frequency triggering

The trigger responds to the frequency signal of the Phasor Measurement Unit source. The frequency is calculated from phase voltages, auxiliary voltage, phase currents, or ground current, in this hierarchy, depending on the source configuration as per D90^{PLUS} standards. This element requires that the frequency be above the minimum measurable value. If the frequency is below this value, such as when the circuit is de-energized, the trigger drops out.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Frequency Trigger** menu to open the PMU frequency triggering window.

Figure 470: Frequency triggering configuration settings



PARAMETER	PMU 1
Function	Disabled
Low Frequency	49.00 Hz
High Frequency	61.00 Hz
Pickup Time	0.10 s
Dropout Time	1.00 s
Block	OFF
Events	Disabled

URPlus_03.urs | Metering: Phasor Measurement Unit: Phasor Mea

The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU frequency triggering function.

Low Frequency

Range: 20.00 to 70.00 Hz in steps of 0.01

Default: 49.00 Hz

This setting specifies the low threshold for the abnormal frequency trigger. The comparator applies a 0.03 Hz hysteresis.

High Frequency

Range: 20.00 to 70.00 Hz in steps of 0.01

Default: 61.00 Hz

This setting specifies the high threshold for the abnormal frequency trigger. The comparator applies a 0.03 Hz hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting is used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting is used to extend the trigger after the situation returns to normal. This setting is of importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting blocks operation of the PMU frequency triggering function.

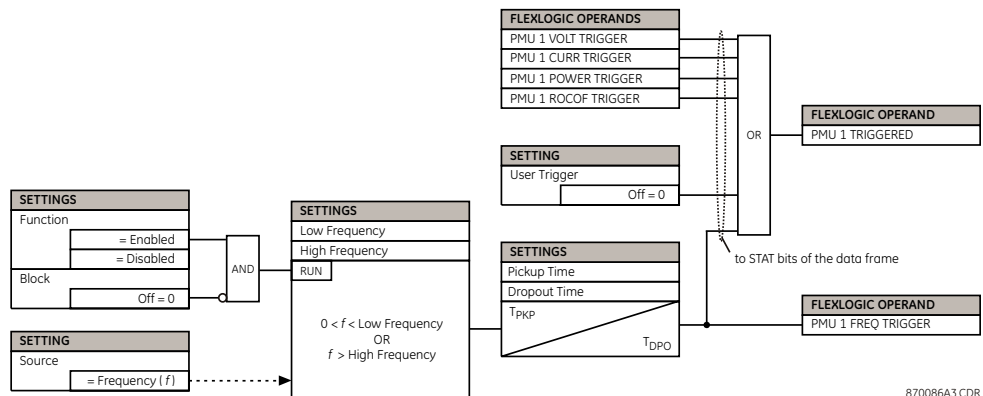
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of PMU frequency triggering events in the sequence of events recorder.

The figure shows the logic for the PMU frequency triggering function.

Figure 471: Frequency triggering logic



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Voltage triggering

This Phasor Measurement Unit voltage triggering responds to abnormal voltage. Separate thresholds are provided for low and high voltage. In terms of signaling its operation, the element does not differentiate between the undervoltage and overvoltage events. The trigger responds to the phase voltage signal of the PMU source. All voltage channels (A, B, and C or AB, BC, and CA) are processed independently and can trigger the recorder. A minimum voltage supervision of 0.1 pu is implemented to prevent pickup on a de-energized circuit, similarly to the undervoltage protection element.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Voltage Trigger** menu to open the PMU voltage triggering window.

Figure 472: Voltage triggering configuration settings

PARAMETER	PMU 1
Function	Disabled
Low Voltage	0.800 pu
High Voltage	1.200 pu
Pickup Time	0.10 s
Dropout Time	1.00 s
Block	OFF
Events	Disabled

The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU voltage triggering function.

Low Voltage

Range: 0.250 to 1.250 pu in steps of 0.001

Default: 0.800 pu

This setting specifies the low threshold for the abnormal voltage trigger, in per-unit values of the PMU source. A value of 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 3% hysteresis.

High Voltage

Range: 0.750 to 1.750 pu in steps of 0.001

Default: 1.200 pu

This setting specifies the high threshold for the abnormal voltage trigger, in per-unit values of the PMU source. A value of 1 pu is a nominal voltage value defined as the nominal secondary voltage times VT ratio. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting can be used to extend the trigger after the situation returns to normal. This setting is of importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the PMU voltage triggering function.

Events

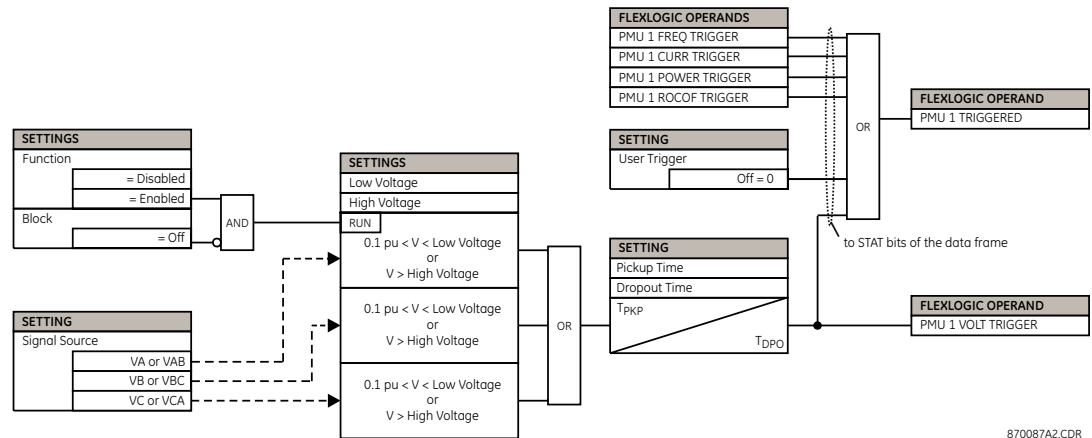
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of PMU voltage triggering events in the sequence of events recorder.

The figure shows the logic for the PMU voltage triggering function.

Figure 473: Voltage triggering logic



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Current triggering

This Phasor Measurement Unit current triggering responds to elevated current. The trigger responds to the phase current signal of the PMU source. All current channel (A, B, and C) are processed independently and can trigger the recorder.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Current Trigger** menu to open the PMU current triggering window.

Figure 474: Current triggering configuration settings

PARAMETER	PMU 1
Function	Disabled
Pickup	1.800 pu
Pickup Time	0.10 s
Dropout Time	1.00 s
Block	OFF
Events	Disabled

The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU current triggering function.

Pickup

Range: 0.100 to 30.000 pu in steps of 0.001

Default: 1.800 pu

This setting specifies the pickup threshold for the overcurrent trigger, in per-unit values of the PMU source. A value of 1 pu is a nominal primary current. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting is used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01
 Default: 1.00 seconds

This setting is used to extend the trigger after the situation returns to normal. This setting is of particular importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
 Default: Off

Assertion of the operand assigned to this setting blocks operation of the PMU current triggering function.

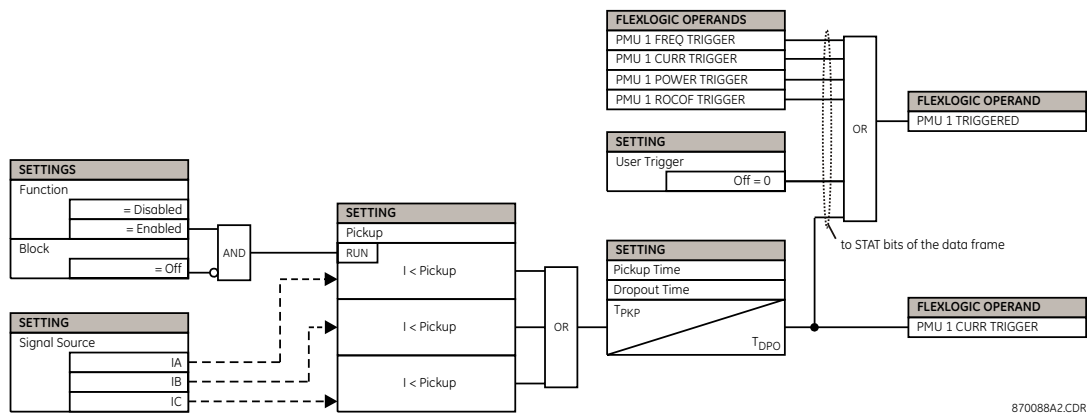
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of PMU current triggering events in the sequence of events recorder.

The figure shows the logic for the PMU current triggering function.

Figure 475: Current triggering logic



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Power triggering

The Phasor Measurement Unit power triggering responds to abnormal power. Separate thresholds are provided for active, reactive, and apparent powers. In terms of signaling its operation, the element does not differentiate between the three types of power. The trigger responds to the single-phase and three-phase power signals of the PMU source.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > Power Trigger** menu to open the PMU power triggering window.

Figure 476: Power triggering configuration settings

PARAMETER	PMU 1
Function	Disabled
Active	1.250 pu
Reactive	1.250 pu
Apparent	1.250 pu
Pickup Time	0.10 s
Dropout Time	1.00 s
Block	OFF
Events	Disabled

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The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU power triggering function.

Active

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the active power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio, and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Reactive

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the reactive power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Apparent

Range: 0.250 to 3.000 pu in steps of 0.001

Default: 1.250 pu

This setting specifies the pickup threshold for the apparent power of the source. For single-phase power, 1 pu represents the product of 1 pu voltage and 1 pu current, or the product of nominal secondary voltage, the VT ratio and the nominal primary current. For the three-phase power, 1 pu is three times the value for single-phase power. The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting is used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01
 Default: 1.00 seconds

This setting is used to extend the trigger after the situation returns to normal. This setting is of importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand
 Default: OFF

Assertion of the operand assigned to this setting blocks operation of the PMU power triggering function.

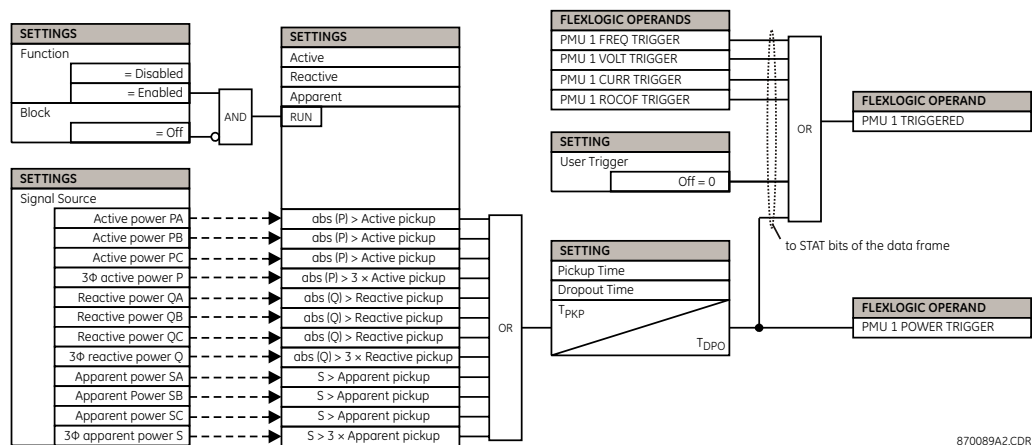
Events

Range: Enabled, Disabled
 Default: Disabled

This setting enables and disables the logging of PMU power triggering events in the sequence of events recorder.

The figure shows the logic for the PMU power triggering function.

Figure 477: Power triggering logic



Frequency rate of change triggering

This Phasor Measurement Unit triggering responds to the rate of change of frequency. Separate thresholds are provided for rising and falling frequency. The trigger responds to the rate of change of frequency (df/dt) of the PMU source.

Select the **Settings > Metering > Phasor Measurement Unit > Triggering > df/dt Trigger** menu to open the PMU frequency rate of change triggering window.

Figure 478: Frequency rate of change triggering configuration settings

PARAMETER	PMU 1
Function	Disabled
Raise	0.25 Hz/s
Fall	0.25 Hz/s
Pickup Time	0.10 s
Dropout Time	1.00 s
Block	OFF
Events	Disabled

The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU frequency rate of change triggering function.

Raise

Range: 0.10 to 15.00 Hz/s in steps of 0.01

Default: 0.25 Hz/s

This setting specifies the pickup threshold for the rate of change of frequency in the rising direction (positive df/dt). The comparator applies a 3% hysteresis.

Fall

Range: 0.10 to 15.00 Hz/s in steps of 0.01

Default: 0.25 Hz/s

This setting specifies the pickup threshold for the rate of change of frequency in the falling direction (negative df/dt). The comparator applies a 3% hysteresis.

Pickup Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 0.10 seconds

This setting can be used to filter out spurious conditions and avoid unnecessary triggering of the recorder.

Dropout Time

Range: 0.00 to 600.00 seconds in steps of 0.01

Default: 1.00 seconds

This setting can be used to extend the trigger after the situation returns to normal. This setting is of importance when using the recorder in the forced mode (recording as long as the triggering condition is asserted).

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks operation of the PMU frequency rate of change triggering function.

Events

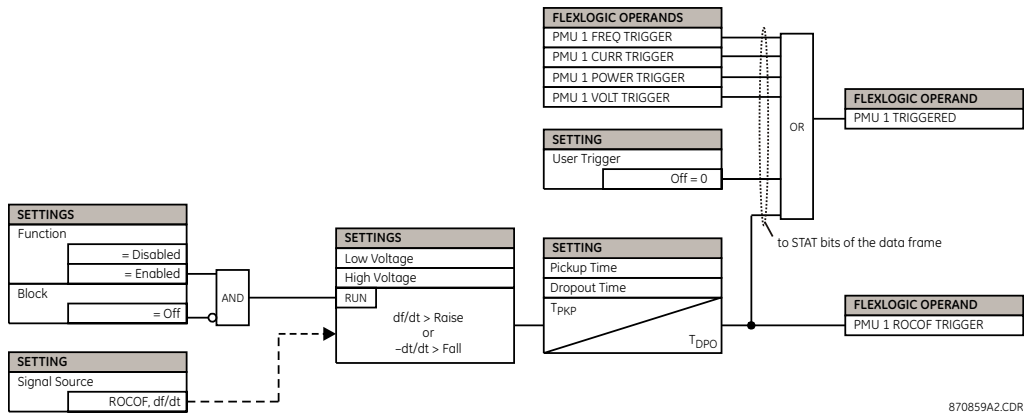
Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of PMU frequency rate of change triggering events in the sequence of events recorder.

The figure shows the logic for the PMU frequency rate of change triggering function.

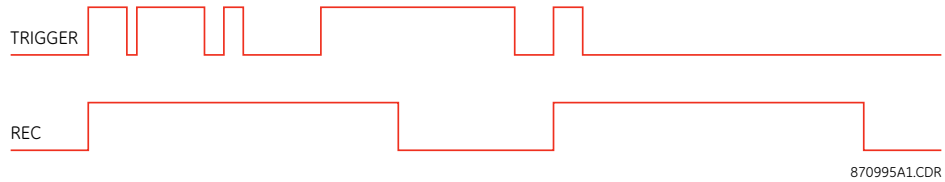
Figure 479: Frequency rate of change triggering logic



Phasor Measurement Unit recording

Each logical Phasor Measurement Unit is associated with a recorder. The triggering condition is programmed via the **Settings > Metering > Phasor Measurement Unit > Triggering** menu. The recorder works with polar values using resolution as in the PMU actual values.

Figure 480: Phasor Measurement Unit recording



Select the **Settings > Metering > Phasor Measurement Unit > Recording** menu to open the PMU recording window.

Figure 481: Phasor Measurement Unit recording configuration settings

PARAMETER	PMU 1
Recording Rate	10/sec
Number of Timed Records	3
Trigger Mode	Automatic Overwrite
Timed Trigger Position	10 %
Rec PHS-1	Off
Rec PHS-1 Name	GE-UR+PMU-PHS 1
Rec PHS-2	Off
Rec PHS-2 Name	GE-UR+PMU-PHS 2
Rec PHS-3	Off
Rec PHS-3 Name	GE-UR+PMU-PHS 3
Rec PHS-4	Off
Rec PHS-4 Name	GE-UR+PMU-PHS 4
Rec PHS-5	Off
Rec PHS-5 Name	GE-UR+PMU-PHS 5
Rec PHS-6	Off
Rec PHS-6 Name	GE-UR+PMU-PHS 6
Rec PHS-7	Off
Rec PHS-7 Name	GE-UR+PMU-PHS 7
Rec PHS-8	Off
Rec PHS-8 Name	GE-UR+PMU-PHS 8
Rec PHS-9	Off
Rec PHS-9 Name	GE-UR+PMU-PHS 9
Rec PHS-10	Off
Rec PHS-10 Name	GE-UR+PMU-PHS 10
Rec PHS-11	Off
Rec PHS-11 Name	GE-UR+PMU-PHS 11
Rec PHS-12	Off
Rec PHS-12 Name	GE-UR+PMU-PHS 12
Rec PHS-13	Off
Rec PHS-13 Name	GE-UR+PMU-PHS 13
Rec PHS-14	Off
Rec PHS-14 Name	GE-UR+PMU-PHS 14
Rec A-CH-1	OFF
Rec A-CH-1 Name	AnalogChannel 1

The following settings are available for each PMU.

Recording Rate

Range: 1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second

Default: 10 times per second

This setting specifies the recording rate for the record content. Not all recording rates are applicable to either 50 or 60 Hz systems (for example, recording at 25 phasors a second in a 60 Hz system). The relay supports decimation by integer number of phasors from the nominal system frequency. If the rate of 25 is selected for the 60 Hz system, the relay decimates the rate of 60 phasors a second by round $(60 / 25) = 2$; that is, it records at $60 / 2 = 30$ phasors a second.

Number of Timed Records

Range: 1 to 128 in steps of 1

Default: 3

This setting specifies how many timed records are available for a given logical PMU. The length of each record equals available memory divided by the content size and number of records. The higher the number of records, the shorter each record. The relay supports a maximum of 128 records.

Trigger Mode

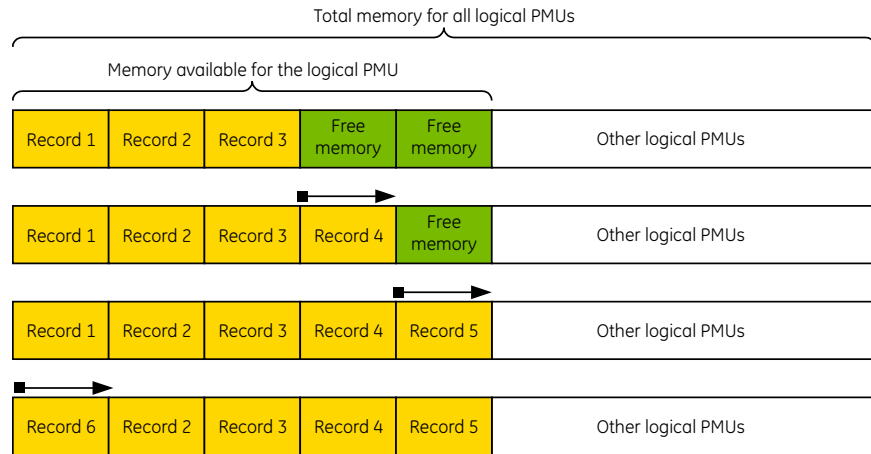
Range: Automatic Overwrite, Protected

Default: Automatic Overwrite

This setting specifies what happens when the recorder uses its entire available memory storage. If set to “Automatic Overwrite,” the last record is erased to facilitate new recording, when triggered. If set to “Protected,” the recorder stops creating new records when the entire memory is used by the old, uncleared records.

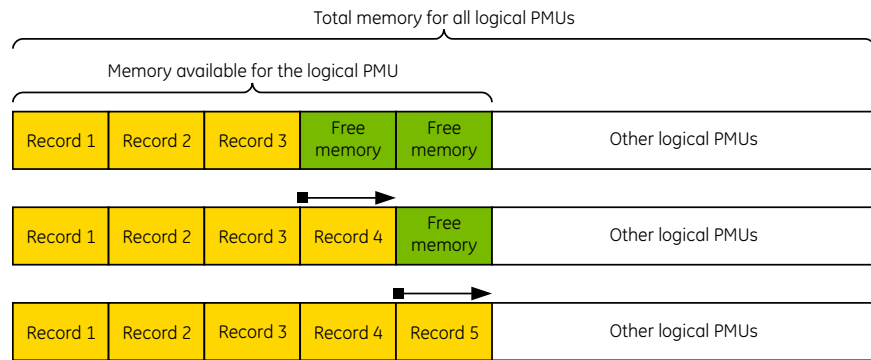
The following set of figures illustrate the concept of memory management via the **Trigger Mode** setting.

Figure 482: Memory management in automatic overwrite mode



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Figure 483: Memory management in protected mode



No further recording after all allocated memory is used

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Timed Trigger Position

Range: 1 to 50% in steps of 1

Default: 10%

This setting specifies the amount of pre-trigger data in percent of the entire record. This setting applies only to the timed mode of recording.

Rec PHS-1, Rec PHS-2, Rec PHS-3,..., Rec PHS-14

Range: available synchrophasor values

Default: Off

These settings specify synchrophasors to be recorded from the superset of all synchronized measurements as indicated in the following table. These settings allow for optimizing the record size and content depending on a given application. Select “Off” to suppress recording of a given value.

Table 40: Available synchrophasor values

Value	Description
Va	First voltage channel, either Va or Vab
Vb	Second voltage channel, either Vb or Vbc
Vc	Third voltage channel, either Vc or Vca
Vx	Fourth voltage channel
Ia	Phase A current, physical channel, or summation as per the source settings
Ib	Phase B current, physical channel, or summation as per the source settings
Ic	Phase C current, physical channel, or summation as per the source settings
Ig	Fourth current channel, physical channel, or summation as per the source settings
V1	Positive-sequence voltage, referenced to Va
V2	Negative-sequence voltage, referenced to Va
V0	Zero-sequence voltage, referenced to Va
I1	Positive-sequence current, referenced to Ia
I2	Negative-sequence current, referenced to Ia
I0	Zero-sequence current

Rec PHS-1 Name, Rec PHS-2 Name, Rec PHS-3 Name,...., Rec PHS-14 Name

Range: 16 character ASCII string

Default: GE-UR+PMU-PHS1, GE-UR+PMU-PHS2, GE-UR+PMU-PHS3,...., GE-UR+PMU-PHS14

These settings allow for custom naming of the synchrophasor channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame. Typically these names are based on station, bus, or breaker names.

Rec A-CH-1, Rec A-CH-2, Rec A-CH-3,...., Rec A-CH-8

Range: available FlexAnalog values

Default: OFF

These settings specify analog data measured by the relay to be included as a user-selectable analog channel of the record. Up to eight analog channels can be configured to record any FlexAnalog value from the relay. Examples include active and reactive power, per phase or three-phase power, power factor, and THD. The configured analogs are sampled concurrently with the synchrophasor instance.

Rec A-CH-1 Name, Rec A-CH-2 Name, Rec A-CH-3 Name,...., Rec A-CH-8 Name

Range: 16 character ASCII string

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,...., AnalogChannel8

These settings allow for custom naming of the analog channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

Rec D-CH-1, Rec D-CH-2, Rec D-CH-3,...., Rec D-CH-16

Range: any metering logic operand or shared operand

Default: OFF

These settings specify any digital flag measured by the relay to be included as a user-selectable digital channel in the record. Up to 16 digital channels can be configured to record any operand from the relay. The configured digital flags are sampled concurrently with the synchrophasor instance.

Rec D-CH-1 Name, Rec D-CH-2 Name, Rec D-CH-3 Name,...., Rec D-CH-16 Name

Range: 16 character ASCII string

Default: AnalogChannel1, AnalogChannel2, AnalogChannel3,...., AnalogChannel16

This setting allows custom naming of the digital channels. Sixteen-character ASCII strings are allowed as in the CHNAM field of the configuration frame.

Phasor Measurement Unit reporting over network

The Phasor Measurement Unit Ethernet connection works simultaneously with other communication means over Ethernet. The network reporting feature is programmed via the **Settings > Metering > Phasor Measurement Unit > Reporting Over Network** menu.

Figure 484: Phasor Measurement Unit reporting over network configuration settings

SETTING	PARAMETER
Function	Disabled
ID Code	1
Rate	10/sec
Style	Polar
Format	Integer
PDC Control	Disabled
TCP Port Number	4712
UDP Port Number	4713

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The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU reporting over network feature.

ID Code

Range: 1 to 65534 in steps of 1

Default: 1

This setting specifies an IDCODE for the entire port. Individual PMU streams transmitted over this port are identified via their own IDCODEs as per the PMU IDCODE settings. This IDCODE is to be used by the command frame to start and stop transmission, and request configuration or header frames.

Rate

Range: 1, 2, 5, 10, 12, 15, 20, 25, 30, 50, or 60 times per second

Default: 10 times per second

This setting specifies the reporting rate for the network (Ethernet) port. This value applies to all PMU streams of the device that are assigned to transmit over this port.

Style

Range: Polar, Rectangular

Default: Polar

This setting selects between reporting synchrophasors in rectangular (real and imaginary) or in polar (magnitude and angle) coordinates. This setting complies with bit-0 of the format field of the C37.118 configuration frame.

Format

Range: Integer, Floating

Default: Integer

This setting selects between reporting synchrophasors as 16-bit integer or 32-bit IEEE floating point numbers. This setting complies with bit 1 of the format field of the C37.118 configuration frame. Note that this setting applies to synchrophasors only—the user-selectable FlexAnalog channels are always transmitted as 32-bit floating point numbers.

PDC Control

Range: Enabled, Disabled

Default: Disabled

The synchrophasor standard allows for user-defined controls originating at the PDC, to be executed on the PMU. The control is accomplished via an extended command frame. The relay decodes the first word of the extended field, EXTFRAME, to drive 16 dedicated FlexLogic operands: **PDC NETWORK CNTRL 1** (from the least significant bit) to **PDC NETWORK CNTRL 16** (from the most significant bit). Other words, if any, in the EXTFRAME are ignored. The operands are asserted for five seconds following reception of the command frame. If the new command frame arrives within the five-second period, the FlexLogic operands are updated, and the five-second timer restarts.

This setting enables or disables the control. When enabled, all 16 operands are active; when disabled, all 16 operands remain reset.

TCP Port Number

Range: 1 to 65535 in steps of 1

Default: 4712

This setting selects the TCP port number to use for network reporting.

UDP Port Number

Range: 1 to 65535 in steps of 1

Default: 4713

This setting selects the UDP port number to use for network reporting.

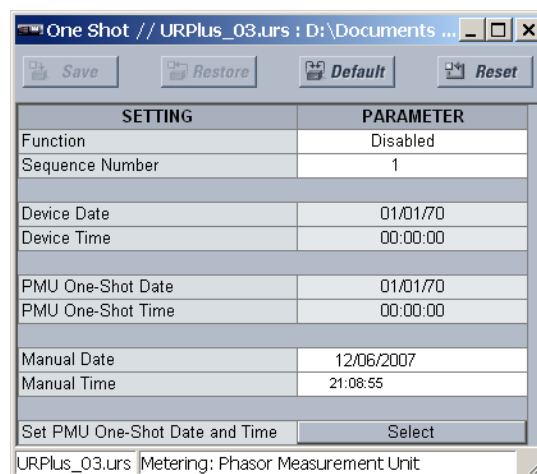
Phasor Measurement Unit one-shot

The one-shot feature allows pre-scheduling of a PMU measurement. This functionality can be used to test for accuracy of the PMU and for manual collection of synchronized measurements through the system.

Phasor Measurement Unit one-shot settings

Select the **Settings > Metering > Phasor Measurement Unit > One-Shot** menu to open the PMU one-shot window.

Figure 485: Phasor Measurement Unit one-shot configuration settings



The following settings are available for each PMU.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the PMU one-shot feature.

Sequence Number

Range: 0 to nominal frequency - 1, in steps of 1

Default: 1

When the **Device Date** and **Device Time** match the **PMU One-Shot Date** and **PMU One-Shot Time**, the D90^{PLUS} compares the present sequence number of the measured synchrophasors with this setting value. When the two numbers match, the function saves the actual values as the one-shot actual values. This allows manual read-out of the synchrophasor values for the pre-set time and pre-set sequence number (via supported communication protocols, such as Modbus or DNP, and the EnerVista UR^{PLUS} Setup software).

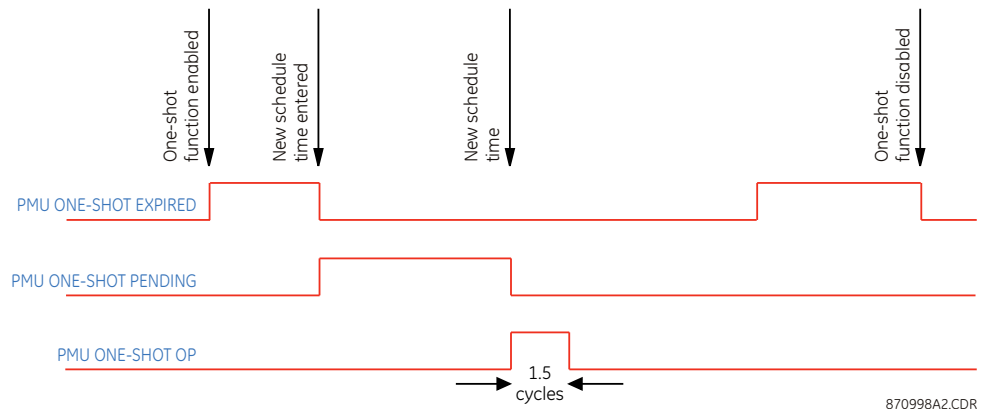
When the values are saved as one-shot values, the function also asserts a **PMU ONE-SHOT OP** metering logic operand. This operand can be configured to drive an output contact and trigger an external measuring device, such as a digital scope with the intent to verify the accuracy of the PMU under test.

With reference to the following figure, the PMU one-shot function (when enabled) controls the following three metering logic operands:

- The **PMU ONE-SHOT EXPIRED** operand indicates that the one-shot operation has been executed.
- The **PMU ONE-SHOT PENDING** operand indicates that the one-shot operation is pending; that is, the present time is before the scheduled one-shot time.
- The **PMU ONE-SHOT OP** operand indicates the one-shot operation.

When the PMU one-shot function is disabled, all three operands are de-asserted. The one-shot function applies to all logical PMUs of a given D90^{PLUS} relay.

Figure 486: Phasor Measurement Unit one-shot operands



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Device Date

Range: date in MM/DD/YYYY format

Default: 01/01/1970

This value reflects the date programmed in the D90^{PLUS}. This date cannot be modified from this window.

Device Time

Range: time in HH:MM:SS format

Default: 00:00:00

This value reflects the time programmed in the D90^{PLUS}. This time cannot be modified from this window.

PMU One-Shot Date

Range: date in MM/DD/YYYY format

Default: 01/01/2007

When the PMU unit one-shot feature is enabled, the D90^{PLUS} continuously compares the device date with this value.

PMU One-Shot Time

Range: time in HH:MM:SS format

Default: 00:00:00

When the PMU one-shot feature is enabled, the D90^{PLUS} continuously compares the device date with this value.

Manual Date

Range: date in MM/DD/YYYY format

Default: 01/01/2007

The **PMU One-Shot Date** is updated to the value specified by this setting when the **Set PMU One-Shot Date and Time** command is executed.

Manual Time

Range: time in HH:MM:SS format

Default: 00:00:00

The **PMU One-Shot Time** is updated to the value specified by this setting when the **Set PMU One-Shot Date and Time** command is executed.

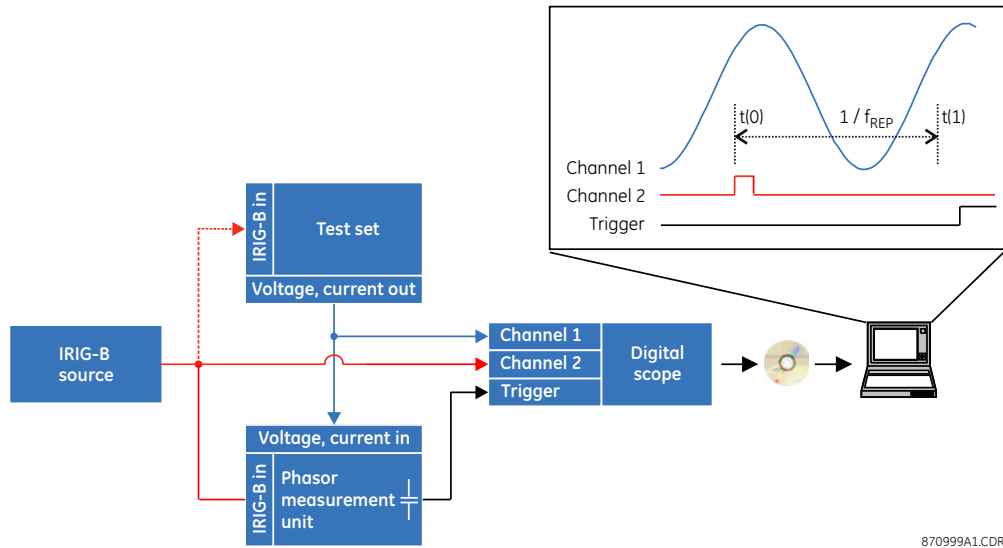
Testing accuracy of the Phasor Measurement Unit

The Phasor Measurement Unit one-shot feature can be used to test accuracy of the synchrophasor measurement. GPS-synchronized test sets perform a similar function; instead of measuring the phasor from physical signals with respect to the externally provided time reference, they produce the physical signals with respect to the externally provided time reference, given the desired phasor values. Therefore the GPS-synchronized test sets cannot be assumed more accurate than the PMUs under test. This calls for a method to verify both the measuring device (PMU) and the source of signal (test set).

With reference to the following figure, the one-shot feature can be configured to trigger a high-accuracy scope to capture both the time reference signal (rising edge of the 1 pps signal of the IRIG-B time reference), and the measured waveform. The high-accuracy high-sampling rate record of the two signals captured by the scope can be processed using digital tools to verify the magnitude and phase angle with respect to the time reference signal. As both the time reference and the measured signals are raw inputs to the PMU under test, their independently captured record, processed using third-party software, is a good reference point for accuracy calculations. Such a record proves useful when discussing the test results, and can be retained as a part of the testing documentation.

Note that the PMU under test does not have to be connected to a real GPS receiver as the accuracy is measured with respect to the timing reference provided to the PMU and not to the absolute UTC time. A simple IRIG-B generator can be used instead. Also, the test set does not have to support GPS synchronization. Any stable signal source can be used. If both the PMU under test and the test set use the timing reference, they need to be driven from the same IRIG-B signal: either the same GPS receiver or IRIG-B generator. Otherwise, do not compare the setpoints of the test set and the PMU measurements because they are referenced to different time scales.

Figure 487: Testing synchrophasor measurement accuracy



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Collecting synchronized measurements *ad hoc*

The Phasor Measurement Unit one-shot feature can be used for *ad hoc* collection of synchronized measurements in the network. Two or more PMUs can be pre-scheduled to freeze their measurements at the same time. When frozen, the measurements can be collected using the EnerVista software or a protocol client.

Data logger

The data logger samples and records up to 16 analog parameters at a user-defined sampling rate. This recorded data can be downloaded to the EnerVista software and displayed with parameters on the vertical axis and time on the horizontal axis. All data is stored in non-volatile memory, meaning that it is retained when power to the relay is off.

For a fixed sampling rate, the data logger can be configured with a few channels over a long period or a larger number of channels for a shorter period. The relay automatically partitions the available memory for the channels in use.

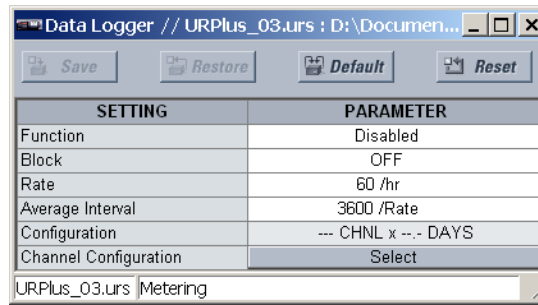
Between the recording intervals, the data logger calculates the maximum, minimum, and the average value of each channel. At the end of the interval either the maximum, minimum, or average value is written to the data logger depending on the mode setting. This ensures that data is not missed if a low rate setting is selected.

In addition, the maximum value, timestamp of maximum, minimum value, and time stamp of minimum are calculated for the channel for the duration of recording since the start of recording. A high, low, high-high, and low-low alarm can be configured for each channel.

Data logger function configuration

Select the **Settings > Metering > Data Logger > Function** menu to open the data logger configuration window.

Figure 488: Data logger configuration settings



The following settings are available for the data logger.

Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the data logger.

Block

Range: any metering logic operand or shared operand

Default: OFF

Assertion of the operand assigned to this setting blocks data logger functionality.

Rate

Range: 1 to 3600 samples per hour in steps of 1

Default: 60 samples per hour

This setting determines how often data is written to the data log.

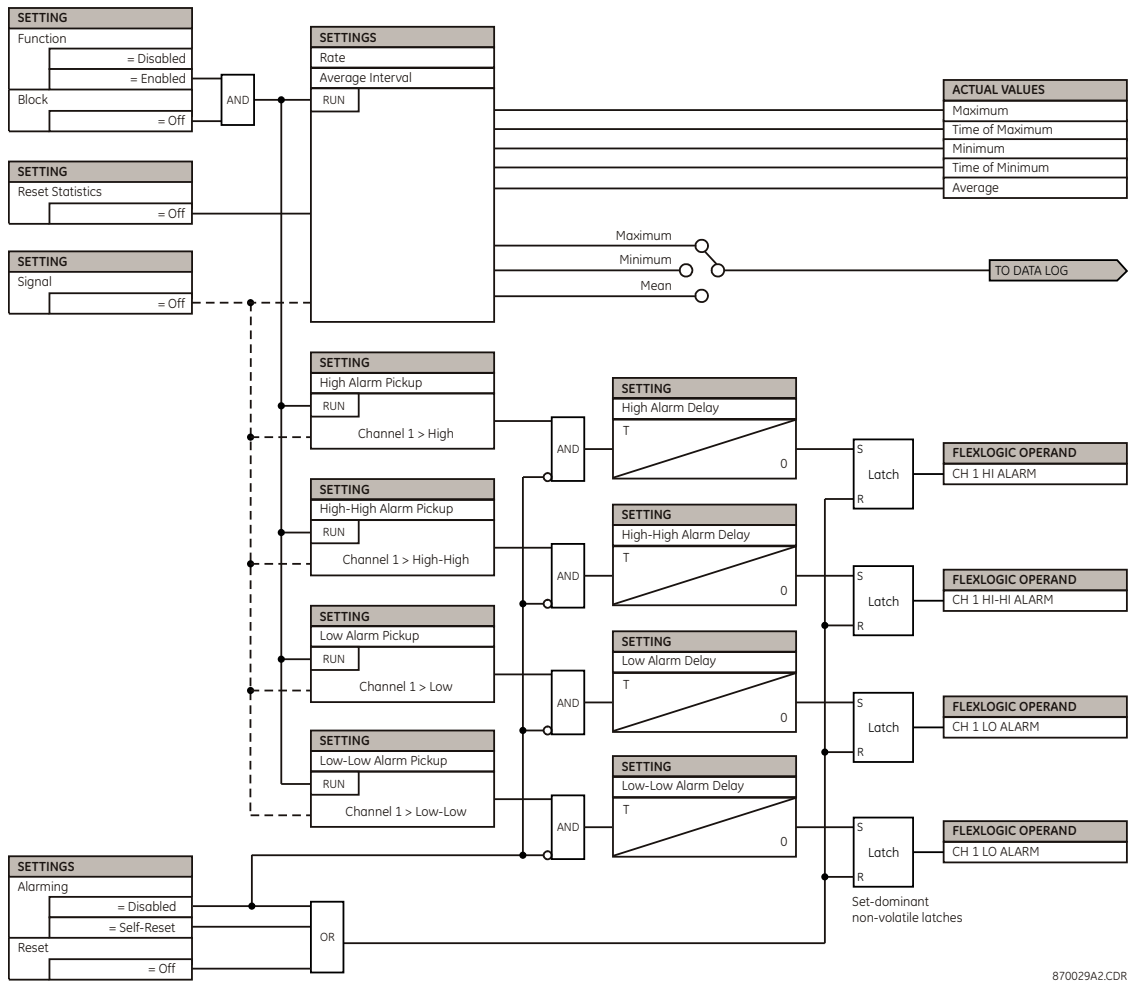
Average Interval

Range: 1/rate to 86400/rate in steps of 1/rate

Default: 3600/rate

This setting selects the time interval for which the average value is calculated. This number is expressed as a multiple of the **Rate** setting. For instance, if the **Rate** is set to "60/hr" and the **Average Interval** is "1440/rate" then a 24-hour average is calculated.

Figure 489: Data logger logic



Data logger channel configuration

Select the **Settings > Metering > Data Logger > Channel Configuration** menu to open the data logger configuration window.

Figure 490: Data logger channel configuration settings

PARAMETER	CHANNEL 1	CHANNEL 2
Signal	OFF	OFF
Name	Channel 1	Channel 2
Mode	Mean	Mean
Alarming	Disabled	Disabled
Reset Alarms	OFF	OFF
Reset Statistics	OFF	OFF
Hi-Hi Alarm Pickup	1.00 pu	1.00 pu
Hi-Hi Alarm Delay	1.0 s	1.0 s
Hi Alarm Pickup	1.00 pu	1.00 pu
Hi Alarm Delay	1.0 s	1.0 s
Lo Alarm Pickup	1.00 pu	1.00 pu
Lo Alarm Delay	1.0 s	1.0 s
Lo-Lo Alarm Pickup	1.00 pu	1.00 pu
Lo-Lo Alarm Delay	1.0 s	1.0 s

The following settings are available for all 16 data logger channels.

Signal

Range: any FlexAnalog parameter

Default: Off

This setting selects the metering value to be recorded for the data logger channel.

Name

Range: up to 12 alphanumeric characters

Default: Channel 1

This setting specifies the name of the data logger channel.

Mode

Range: Max, Min, Mean

Default: Mean

This setting defines which value (maximum, minimum, or mean) is written to the data logger.

Alarming

Range: Disabled, Self-Reset, Latched

Default: Disabled

When this setting is "Disabled," alarming is inhibited. When set to "Self-Reset," alarms are reset as soon as the signal drops below the pickup value. When set to "Latched," the alarms remain active until the reset input is asserted.

Reset Alarms

Range: any metering logic operand or shared operand

Default: OFF

The alarms are reset when the operand assigned to this setting is asserted and the **Alarming** setting is selected as "Latched."

Reset Statistics

Range: any metering logic operand or shared operand

Default: OFF

The maximum, minimum, time of maximum, and time of minimum statistics are reset when the operand assigned to this setting is asserted.

High Alarm Pickup, Low Alarm Pickup, High-High Alarm Pickup, Low-Low Alarm Pickup

Range: -90.00 to 90.00 pu in steps of 0.01

Default: 1.00 pu

These settings specify the pickup thresholds for the alarm in per-unit values. A fixed hysteresis of 3% is applied.

High Alarm Delay, Low Alarm Delay, High-High Alarm Delay, Low-Low Alarm Delay

Range: 1.0 to 300.0 seconds in steps of 0.1

Default: 1.0 seconds

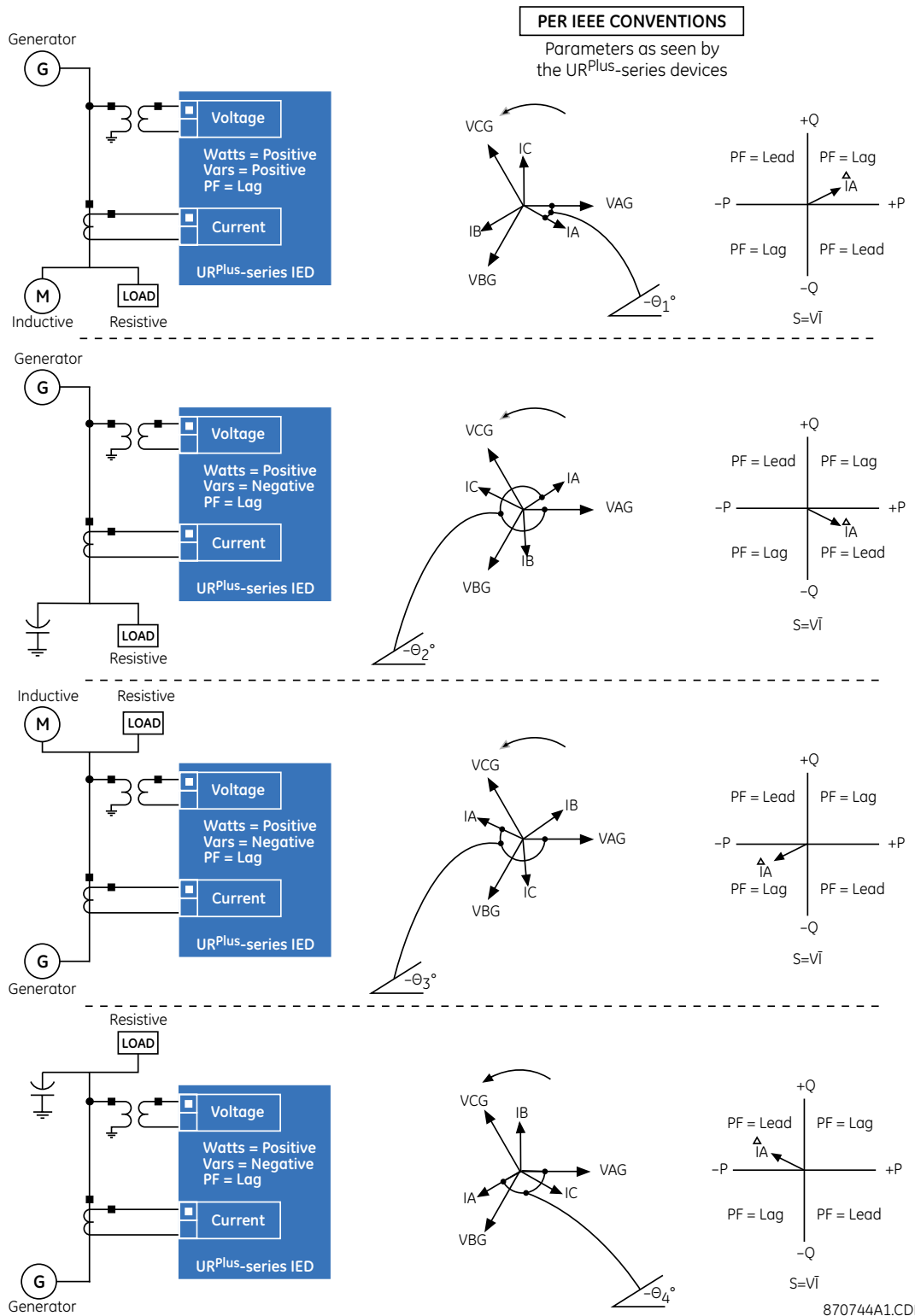
These settings specify the time delays for the four alarm pickup types.

Metered values

This section describes the metered values available for each source. Metered values presented for each source depend on the phase and auxiliary VTs and phase and ground CTs assignments for the particular source. For example, if no phase VT is assigned to a particular source, then no voltage, energy, and power values are available.

The figure illustrates the metering conventions for measuring power and energy established for use in D90^{PLUS} devices.

Figure 491: Flow direction of signed values for watts and vars



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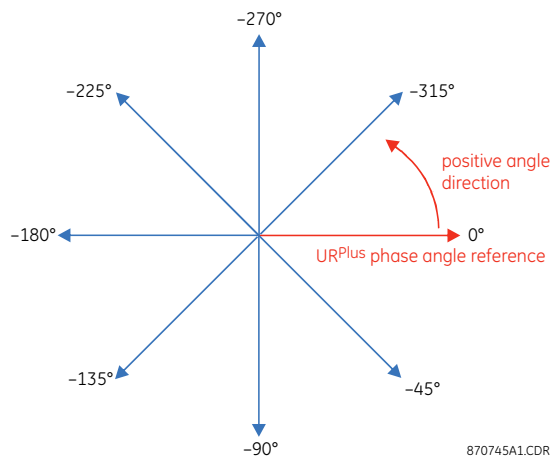
All phasors calculated by the D90^{PLUS} and used for protection, control, and metering functions are rotating phasors that maintain the correct phase angle relationships with each other at all times.

For display and oscillography purposes, all phasor angles in a given device are referred to an AC input channel pre-selected by the **Frequency and Phase Reference** setting in the **Settings > Protection > Power System > Frequency** menu. This setting defines a particular AC signal source to be used as the reference.

The D90^{Plus} first determines if any phase VT bank is indicated in the source. If it is, voltage channel VA of that bank is used as the angle reference. Otherwise, the D90^{Plus} determines if any auxiliary VT bank is indicated. If it is, the auxiliary voltage channel of that bank is used as the angle reference. If neither of these two conditions are satisfied, then two more steps of this hierarchical procedure to determine the reference signal include the phase CT bank and the ground CT bank.

If the AC signal pre-selected by the D90^{Plus} upon configuration is not measurable, then the phase angles are not referenced. The phase angles are assigned as positive in the leading direction and negative in the lagging direction to more closely align with power system metering conventions. The figure illustrates these.

Figure 492: D90^{Plus} phase angle measurement convention



The D90^{Plus} calculates voltage symmetrical components for the power system phase A line-to-neutral voltage, and it calculates symmetrical components of the currents for the power system phase A current. Owing to the above definition, phase angle relations between the symmetrical currents and voltages stay the same irrespective of the connection of instrument transformers. This is important for setting directional protection elements that use symmetrical voltages.

For display and oscillography purposes, the phase angles of symmetrical components are referenced to a common value specified by the **Frequency and Phase Reference** setting.

The following voltages and currents are measured for wye-connected instrument transformers in the ABC phase rotation:

$$V_{-0} = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}); \quad I_{-0} = \frac{1}{3}(I_A + I_B + I_C) \tag{Eq. 54}$$

$$V_{-1} = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG}); \quad I_{-1} = \frac{1}{3}(I_A + aI_B + a^2I_C) \tag{Eq. 55}$$

$$V_{-2} = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG}); \quad I_{-2} = \frac{1}{3}(I_A + a^2I_B + aI_C) \tag{Eq. 56}$$

The following voltages and currents are measured for wye-connected instrument transformers in the ACB phase rotation:

$$V_{-0} = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}); \quad I_{-0} = \frac{1}{3}(I_A + I_B + I_C) \quad \text{Eq. 57}$$

$$V_{-1} = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG}); \quad I_{-1} = \frac{1}{3}(I_A + a^2I_B + aI_C) \quad \text{Eq. 58}$$

$$V_{-2} = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG}); \quad I_{-2} = \frac{1}{3}(I_A + aI_B + a^2I_C) \quad \text{Eq. 59}$$

The following voltages and currents are measured for delta-connected instrument transformers in the ABC phase rotation. The zero-sequence voltage (V_{-0}) is not measurable under the delta connection of instrument transformers and is defaulted to zero.

$$V_{-1} = \frac{1\angle-30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA}); \quad I_{-1} = \frac{1\angle-30^\circ}{3\sqrt{3}}(I_A + aI_B + a^2I_C) \quad \text{Eq. 60}$$

$$V_{-2} = \frac{1\angle30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA}); \quad I_{-2} = \frac{1\angle30^\circ}{3\sqrt{3}}(I_A + a^2I_B + aI_C) \quad \text{Eq. 61}$$

The following voltages and currents are measured for delta-connected instrument transformers in the ACB phase rotation. The zero-sequence voltage (V_{-0}) is not measurable under the delta connection of instrument transformers and is defaulted to zero.

$$V_{-1} = \frac{1\angle30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA}); \quad I_{-1} = \frac{1\angle30^\circ}{3\sqrt{3}}(I_A + a^2I_B + aI_C) \quad \text{Eq. 62}$$

$$V_{-2} = \frac{1\angle-30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA}); \quad I_{-2} = \frac{1\angle-30^\circ}{3\sqrt{3}}(I_A + aI_B + a^2I_C) \quad \text{Eq. 63}$$

In these equations, a represents phase rotation operator that rotates a phasor vector forward by 120° ($a = 1\angle120^\circ$).

As an example, consider a wye connected VT with the following system voltages (in secondary volts): $V_{AG} = 13.9 \text{ V}\angle0^\circ$, $V_{BG} = 76.2 \text{ V}\angle-125^\circ$, $V_{CG} = 79.7 \text{ V}\angle-250^\circ$, $V_{AB} = 84.9 \text{ V}\angle-313^\circ$, $V_{BC} = 138.3 \text{ V}\angle-97^\circ$, and $V_{CA} = 85.4 \text{ V}\angle-241^\circ$. For simplicity, the power system voltages are phase-referenced to V_{AG} . However, any value can be chosen as a reference. It is important to remember that displayed values are always referenced as to the voltage specified by the [Frequency and Phase Reference](#) setting.

$$\begin{aligned} V_{-0} &= \frac{1}{3}(V_{AG} + V_{BG} + V_{CG}) \\ &= \frac{1}{3}(13.9\angle0^\circ + 76.2\angle-125^\circ + 79.7\angle-250^\circ) \\ &= 19.5\angle-192^\circ \end{aligned} \quad \text{Eq. 64}$$

$$\begin{aligned} V_{-1} &= \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG}) \\ &= \frac{1}{3}(13.9\angle0^\circ + 1\angle120^\circ \times 76.2\angle-125^\circ + 1\angle240^\circ \times 79.7\angle-250^\circ) \\ &= 56.5\angle-7^\circ \end{aligned} \quad \text{Eq. 65}$$

$$\begin{aligned} V_{-2} &= \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG}) \\ &= \frac{1}{3}(13.9\angle0^\circ + 1\angle240^\circ \times 76.2\angle-125^\circ + 1\angle120^\circ \times 79.7\angle-250^\circ) \\ &= 23.3\angle-187^\circ \end{aligned} \quad \text{Eq. 66}$$

As another example, consider a delta connected VT with the following system voltages (in secondary volts): $V_{AB} = 84.9 \text{ V}\angle0^\circ$, $V_{BC} = 138.3 \text{ V}\angle-144^\circ$, and $V_{CA} = 85.4 \text{ V}\angle-288^\circ$. For simplicity, the power system voltages are phase-referenced to V_{AB} . However, any value

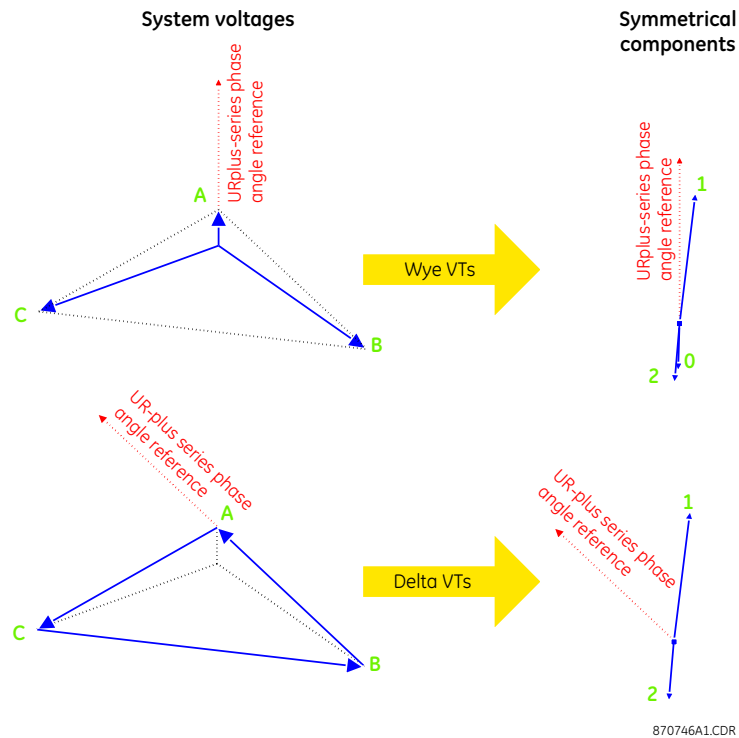
can be chosen as a reference. It is important to remember that displayed values are always referenced as to the voltage specified by the **Frequency and Phase Reference** setting.

$$\begin{aligned}
 V_{-1} &= \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA}) \\
 &= \frac{1\angle -30^\circ}{3\sqrt{3}}(84.9\angle 0^\circ + 1\angle 240^\circ \times 138.3\angle -144^\circ + 1\angle 120^\circ \times 85.4\angle -288^\circ) \\
 &= 56.5\angle -54^\circ
 \end{aligned}
 \tag{Eq. 67}$$

$$\begin{aligned}
 V_{-2} &= \frac{1\angle -30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA}) \\
 &= \frac{1\angle -30^\circ}{3\sqrt{3}}(84.9\angle 0^\circ + 1\angle 120^\circ \times 138.3\angle -144^\circ + 1\angle 240^\circ \times 85.4\angle -288^\circ) \\
 &= 23.3\angle -234^\circ
 \end{aligned}
 \tag{Eq. 68}$$

The figure illustrates the examples.

Figure 493: Measurement convention for symmetrical components



Phase current metering

Select the **Actual Values > Metering > Phase Current** menu to open the metered phase current window.

Figure 494: Phase current metering window

PARAMETER	SOURCE 1	SOURCE 2	SOURCE 3
Name	LINE	BKR 1	BKR 2
PHASORS	View	View	View
RMS Ia	0.000 A	0.000 A	0.000 A
RMS Ib	0.000 A	0.000 A	0.000 A
RMS Ic	0.000 A	0.000 A	0.000 A
RMS In	0.000 A	0.000 A	0.000 A
Phasor Ia	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Phasor Ib	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Phasor Ic	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Phasor In	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Zero Seq I0	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Positive Seq I1	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg
Negative Seq I2	0.000 A 0.0 deg	0.000 A 0.0 deg	0.000 A 0.0 deg

The following actual values display for each source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Phasors

Clicking the **View** button for this value allows the user to configure and display a graphical representation of selected current and voltage phasors. For details, see [Observing current and voltage phasors](#) on page 571.

RMS Ia, RMS Ib, RMS Ic, RMS In

Range: 0 to 999999.999 A in steps of 0.001

These values display the phase A, phase B, phase C, and neutral RMS current on each source.

Phasor Ia, Phasor Ib, Phasor Ic, Phasor In

Range: 0 to 999999.999 A in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

These values display the magnitude and phase angles for phase A, phase B, phase C, and neutral current on each source.

Zero Seq I0

Range: 0 to 999999.999 A in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the zero-sequence current (I₀) on each source.

Positive Seq I1

Range: 0 to 999999.999 A in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the positive-sequence current (I₁) on each source.

Negative Seq I2

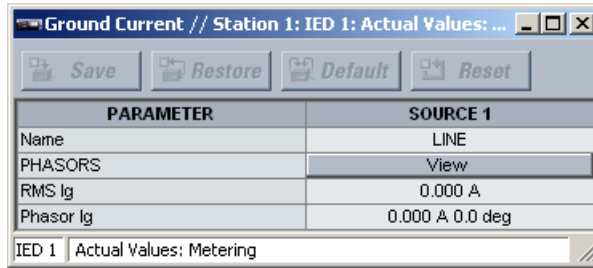
Range: 0 to 999999.999 A in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the negative-sequence current (I₂) on each source.

Ground current metering

Select the **Actual Values > Metering > Ground Current** menu to open the metered ground current window.

Figure 495: Ground current metering window



The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Phasors

Clicking the **View** button for this value allows the user to configure and display a graphical representation of selected current and voltage phasors. For details, see [Observing current and voltage phasors](#) on page 571.

RMS Ig

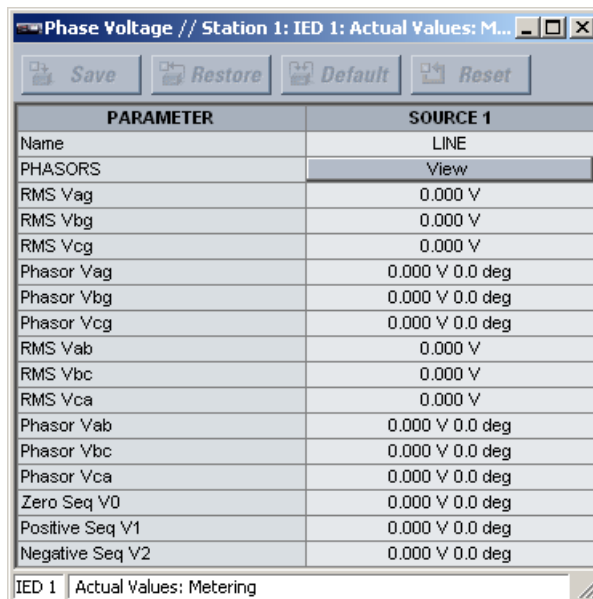
Range: 0 to 999999.999 A in steps of 0.001

This actual value displays the ground current RMS for each source.

Phase voltage metering

Select the **Actual Values > Metering > Phase Voltage** menu to open the metered phase voltage window.

Figure 496: Phase voltage metering window



The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Phasors

Clicking the **View** button for this value allows the user to configure and display a graphical representation of selected current and voltage phasors. For details, see [Observing current and voltage phasors](#) on page 571.

RMS Vag, RMS Vbg, RMS Vcg

Range: 0 to 999999.999 V in steps of 0.001

These values display the phase A to ground, phase B to ground, and phase C to ground RMS voltage values for each source.

Phasor Vag, Phasor Vbg, Phasor Vcg

Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

These values display the magnitude and phase angles for the phase A to ground, phase B to ground, and phase C to ground voltage phasors for each source.

RMS Vab, RMS Vbc, RMS Vca

Range: 0 to 999999.999 V in steps of 0.001

These values display the phase AB, phase BC, and phase CA RMS voltage values for each source.

Phasor Vab, Phasor Vbc, Phasor Vca

Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

These values display the magnitude and phase angles for the phase AB, phase BC, and phase CA voltage phasors for each source.

Zero Seq V0

Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the zero-sequence voltage (V_0) on each source.

Positive Seq V1

Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the positive-sequence voltage (V_1) on each source.

Negative Seq V2

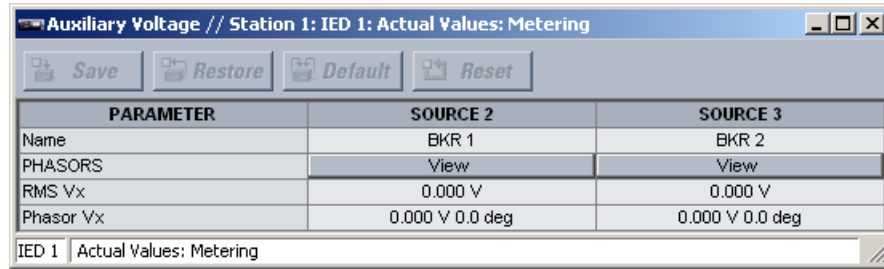
Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This value displays the magnitude and phase angle for the negative-sequence voltage (V_2) on each source.

Auxiliary voltage metering

Select the **Actual Values > Metering > Auxiliary Voltage** menu to open the metered auxiliary voltage window.

Figure 497: Auxiliary voltage metering window



The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Phasors

Clicking the **View** button for this value allows the user to configure and display a graphical representation of selected current and voltage phasors. For details, see [Observing current and voltage phasors](#) on page 571.

RMS Vx

Range: 0 to 999999.999 V in steps of 0.001

This actual value displays the auxiliary RMS voltage value for each source.

Phasor Vx

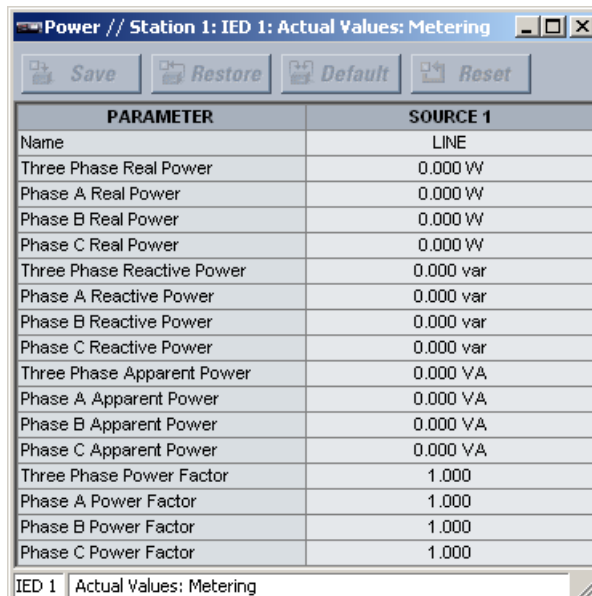
Range: 0 to 999999.999 V in steps of 0.001; -359.0° to 0.0° in steps of 0.1°

This actual value displays the magnitude and phase angle for the auxiliary voltage phasor for each source.

Power metering

Select the **Actual Values > Metering > Power** menu to open the metered power window. The metered values for real power, apparent power, reactive power, and power factor display.

Figure 498: Power metering window



The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Three Phase Real Power, Phase A Real Power, Phase B Real Power, Phase C Real Power

Range: -1000000000.000 to 1000000000.000 W in steps of 0.001

These actual values display the metered real power for phase A, B, and C, as well as the three-phase real power, for each applicable source.

Three Phase Reactive Power, Phase A Reactive Power, Phase B Reactive Power, Phase C Reactive Power

Range: -1000000000.000 to 1000000000.000 W in steps of 0.001

These actual values display the metered reactive power for phase A, B, and C, as well as the three-phase reactive power, for each applicable source.

Three Phase Apparent Power, Phase A Apparent Power, Phase B Apparent Power, Phase C Apparent Power

Range: -1000000000.000 to 1000000000.000 W in steps of 0.001

These actual values display the metered apparent power for phase A, B, and C, as well as the three-phase apparent power, for each applicable source.

Three Phase Power Factor, Phase A Power Factor, Phase B Power Factor, Phase C Power Factor

Range: -0.999 to 1.000 in steps of 0.001

These actual values display the metered power factor for phase A, B, and C, as well as the three-phase power factor, for each applicable source.

Energy metering

Select the **Actual Values > Metering > Energy** menu to open the metered energy window. The metered values for real energy and reactive energy display. Because energy values are accumulated, record these values and then reset immediately prior to changing CT or VT characteristics.

Figure 499: Energy metering window

PARAMETER	SOURCE 1
Name	LINE
Positive Watthour	0.000 Wh
Negative Watthour	0.000 Wh
Positive varhour	0.000 varh
Negative varhour	0.000 varh

IED 1 | Actual Values: Metering

The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Positive Watthour, Negative Watthour

Range: 0.000 to 100000000000.000 Wh in steps of 0.001

These actual values display the metered real energy for each applicable source.

Positive varhour, Negative varhour

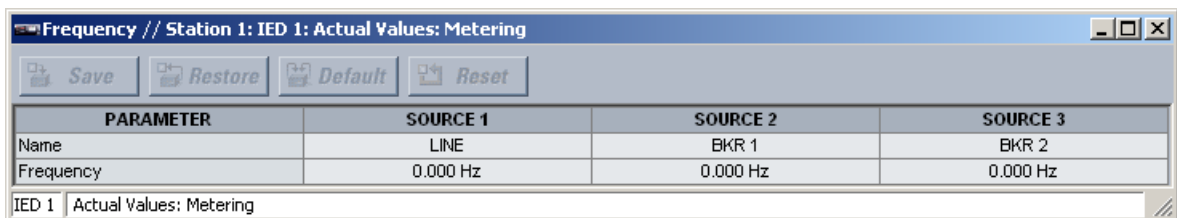
Range: 0.000 to 1000000000000.000 varh in steps of 0.001

These actual values display the metered reactive energy for each applicable source.

Frequency metering

Select the **Actual Values > Metering > Frequency** menu to open the metered frequency window. Source frequency is measured via software-implemented zero-crossing detection of an AC signal. The signal is either a Clarke transformation of three-phase voltages or currents, auxiliary voltage, or ground current as per the source configuration. The signal used for frequency estimation is low-pass filtered. The final frequency measurement is passed through a validation filter that eliminates false readings due to signal distortions and transients.

Figure 500: Frequency metering window



The following actual values display for each applicable source.

Name

Range: up to 20 alphanumeric characters

This value displays the user-programmed name for each source.

Frequency

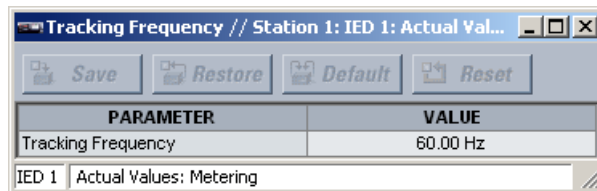
Range: 0.000 to 90.000 Hz in steps of 0.001

These actual values display the metered frequency for each applicable source.

Tracking frequency

Select the **Actual Values > Metering > Tracking Frequency** menu to open the tracking frequency window.

Figure 501: Tracking frequency window



The following actual value displays.

Tracking Frequency

Range: 0.00 to 90.00 Hz in steps of 0.01

This actual value displays the tracking frequency. The frequency is tracked based on the selection of the reference source with the **Frequency And Phase Reference** setting in the **Settings > Protection > Power System > Frequency** menu.

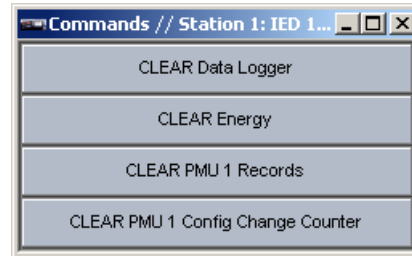
For additional information, refer to:

[Power system frequency](#) on page 177

Clearing metered values

Select the **Actual Values > Metering > Commands** menu to open the metering commands menu. The commands allow the user to clear accumulated metering values.

Figure 502: Metering commands window



The following commands are available.

Clear Data Logger

Click this button to clear the accumulated data logger actual values.

Clear Energy

Click this button to clear the accumulated energy actual values.

Clear PMU 1 Records

Click this button to clear the Phasor Measurement Unit records.

Clear PMU 1 Config Change Counter

Click this button to clear the Phasor Measurement Unit configuration change counter records.

Observing current and voltage phasors

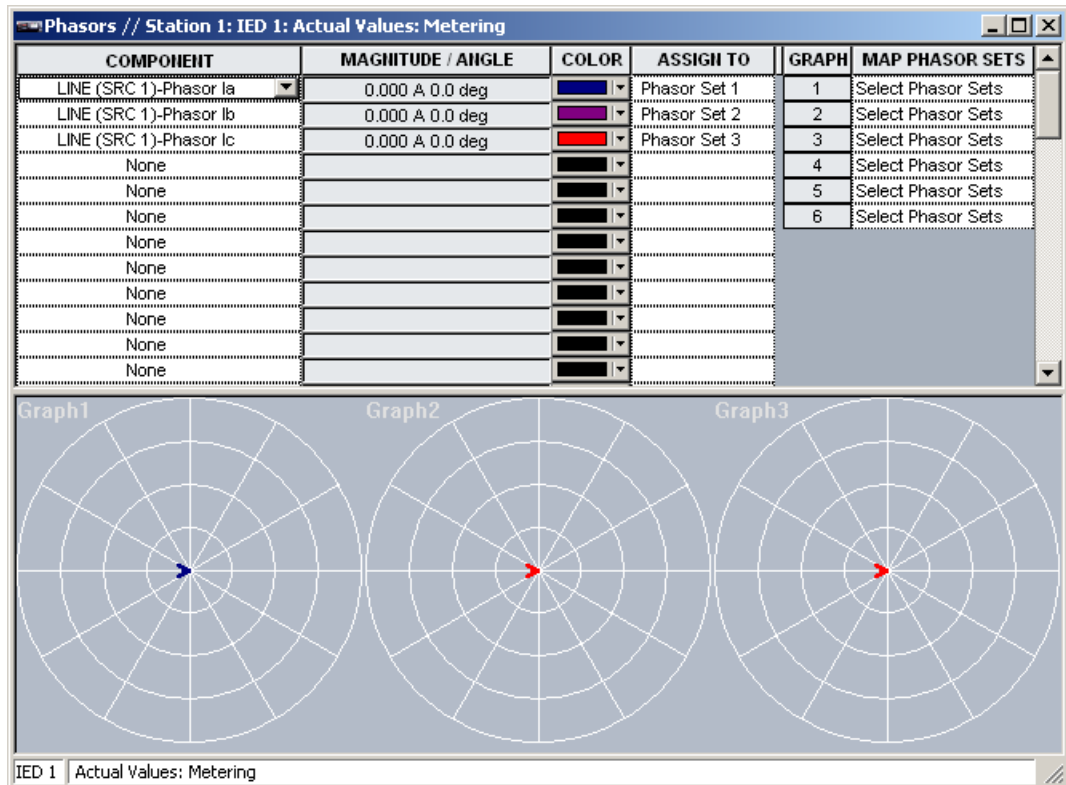
The D90^{PLUS} can graphically display phasor information for metered currents and voltages. Click the **Phasors** button in any metered current or voltage window to open the phasor configuration window. Up to six phasor diagrams can be displayed that indicate the rotation, magnitude, and angle of metered current and voltage phasors.



NOTE

Phasor representations are calculated on a per-cycle basis.

Figure 503: Example of phasor configuration window with three phasor graphs



The following options are available to configure the phasor graphs.

Component

Range: None, Phasor Ia, Phasor Ib, Phasor Ic, Phasor In, Zero Seq I0, Positive Seq I1, Negative Seq I2, Phasor Ig, Phasor Igd, Phasor Vag, Phasor Vbg, Phasor Vcg, Phasor Vab, Phasor Vbc, Phasor Vca, Zero Seq V0, Positive Seq V1, Negative Seq V2, Phasor Vx (phasor options are available for each signal source)

Default: None

This option selects the current or voltage phasor to configure for graphical display. Up to 50 phasors can be configured. The magnitude and angle actual value of each phasor component also displays in the adjacent column.

Color

Range: pre-selected colors and user-configurable colors

Default: Black

This option allows the user to configure the display color for the specified phasor component.

Assign to

Range: Phasor Set 1, Phasor Set 2, Phasor Set 3,..., Phasor Set 12

Default: <Empty>

This option assigns the specified phasor component to one of 12 phasor sets. The use of phasor sets allows phasors to be viewed with respect to a common phasor signal. Phasor signals grouped together display in relation to the other phasors in their set. The phasor with the largest amplitude is taken as the reference phasor, and other phasors in the set display in their proper ratios with respect to this phasor.

Map Phasor Sets

Range: Show Graph, Phasor Set 1, Phasor Set 2, Phasor Set 3,..., Phasor Set 12

Default: <Empty>

This option selects the phasor sets to display on each of the six available phasor graphs. The “Show Graph” option must be selected for each of the six graphs to display the specified phasors. Single or multiple phasor sets can be displayed on each graph as per user preferences.

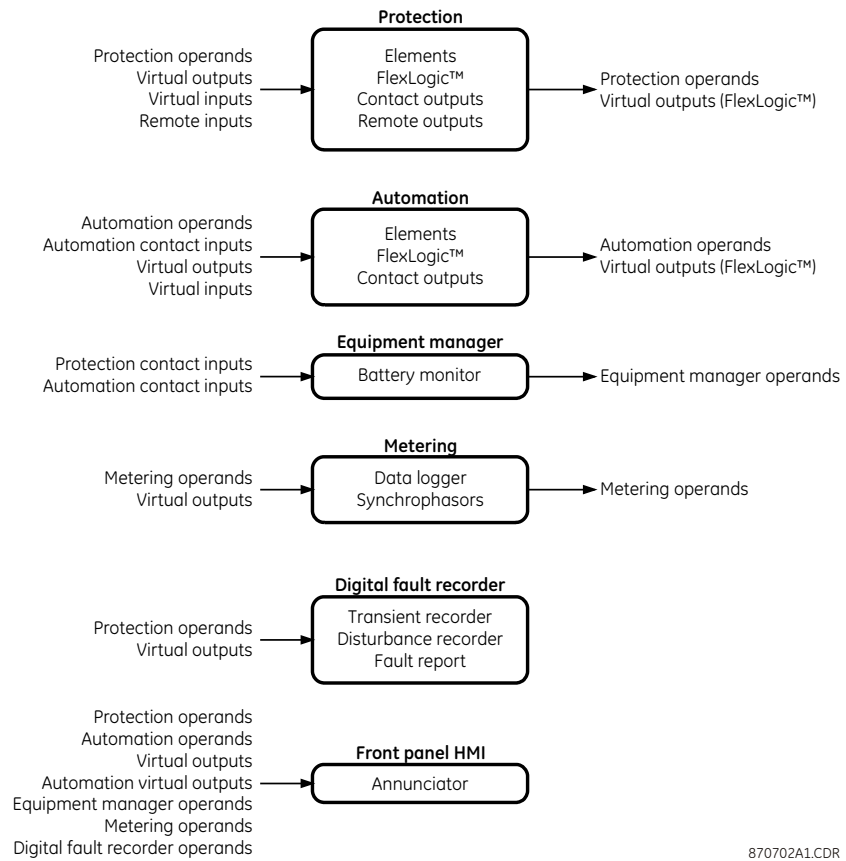
Using shared operands in metering

The EnerVista UR^{Plus} Setup software groups the D90^{Plus} system into the following eight primary functions. Each function has its own settings and each generates its own outputs in the form of operands.

- Communications
- Protection
- Automation
- Digital fault recorder (DFR)
- Metering
- Equipment manager
- Self-tests
- Front panel interface (HMI)

It is often desirable for an output from an element within one function to be available to an element within another function. For example, it can be useful for the digital fault recorder to record the output operands of any protection element. Consequently a fixed, predetermined set of operands is available to each function, as shown.

Figure 504: Default operand list by function



870702A1.CDR

The content of each operand list depends on the order code.

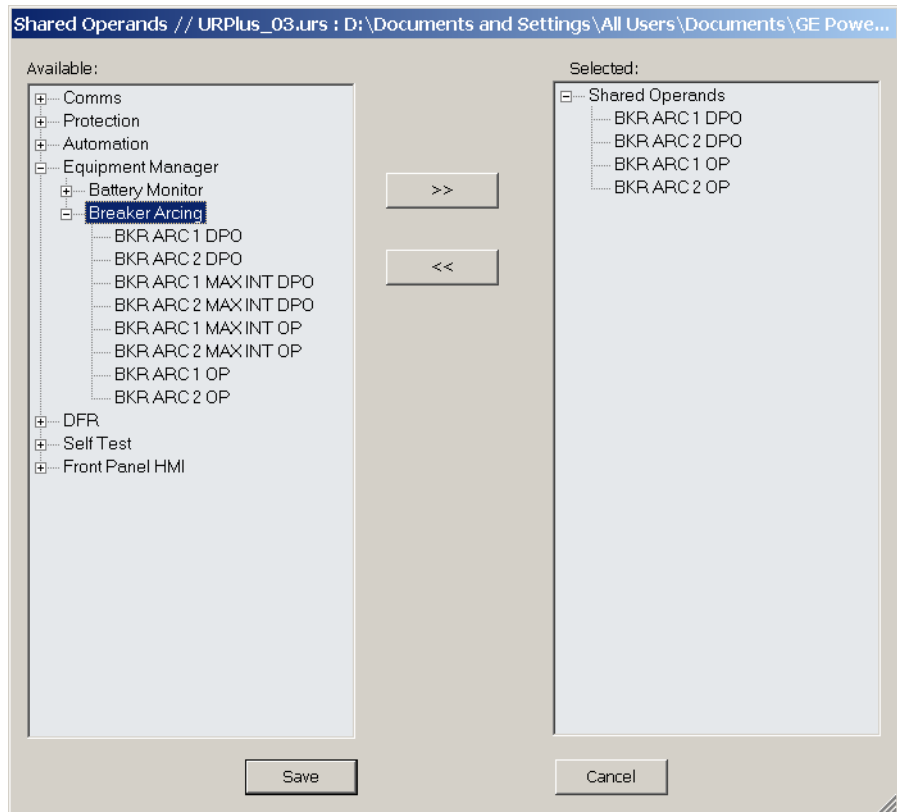
The shared operands functionality expands upon this system. An output from any element can be assigned as a shared operand within the EnerVista UR^{Plus} Setup software. These signals then can be assigned as inputs to other functions.

For example, assume that the [GND TOC1 OP](#) protection operand is required as a signal within the automation function. This operand then is assigned as a shared operand and subsequently becomes available to the automation function. A total of 64 operands can be assigned as shared operands within each function.

Shared metering operands

Select the **Settings > Metering > Shared Operands** menu to select the shared metering operands.

Figure 505: Shared operands configuration window

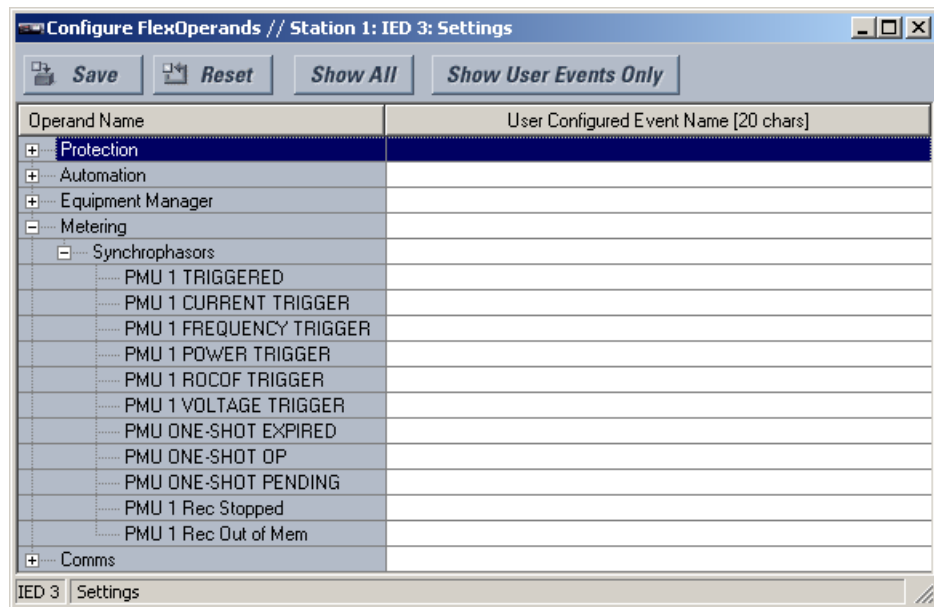


The left side of this screen displays all D90^{Plus} operands that are available to the metering function as shared operands. Select any operands from the other five primary features by clicking the >> button. Operands can be de-assigned as shared operands by clicking the << button.

Customizing the metering logic operands

Select the **Settings > Configure FlexOperands** menu to open the user-configurable operands window.

Figure 506: User-configurable metering logic operands window



The left side of this screen displays all operands that are currently available to the D90^{Plus}. The metering logic operands are displayed by expanding the **Metering** entry. Each operand can be renamed with a user-specified value to provide additional information or match specific applications.

User Configured Event Name

Range: up to 20 alphanumeric characters

Default: ---

Each available metering logic operand can be renamed. This feature allows users to rename operands to allow for clearer identification or to match specific applications. The new operand name appears in protection and automation logic, in settings that take operands as their value, and in event reports.

Metering logic operands

The following metering logic operands are available for the D90^{Plus}. They are listed alphabetically by operand syntax. If required, these operands can be assigned user-defined names through the **Settings > Configure FlexOperands** menu.

Data logger operands

- D LOG CH1 HI ALM Asserted while the data logger channel 1 high alarm is active.
- D LOG CH1 HI-HI ALM..... Asserted while the data logger channel 1 high-high alarm is active.
- D LOG CH1 LO ALM Asserted while the data logger channel 1 low alarm is active.
- D LOG CH1 LO-LO ALM..... Asserted while the data logger channel 1 low-low alarm is active.
- D LOG CH2 The operands listed above are also available for data loggers 2 through 16.

Phasor Measurement Unit operands

- PMU 1 CURR TRIGGER..... Asserted when the overcurrent trigger of Phasor Measurement Unit 1 operates.
- PMU 1 FREQ TRIGGER..... Asserted when the abnormal frequency trigger of Phasor Measurement Unit 1 operates.

PMU 1 POWER TRIGGER.....	Asserted when the overpower trigger of Phasor Measurement Unit 1 operates.
PMU 1 ROCOF TRIGGER.....	Asserted when the rate of change of frequency trigger of Phasor Measurement Unit 1 operates.
PMU 1 TRIGGERED	Asserted when the Phasor Measurement Unit 1 triggers. No events or targets are generated by this operand.
PMU 1 VOLT TRIGGER.....	Asserted when the abnormal voltage trigger of Phasor Measurement Unit 1 operates.

Phasor Measurement Unit one-shot operands

PMU ONE-SHOT EXPIRED	Asserted after the one-shot operation executes.
PMU ONE-SHOT OP	Asserted upon one-shot operation.
PMU ONE-SHOT PENDING.....	Asserted while the one-shot operation is pending. That is, while the present time is before the scheduled one-shot time.

Metering FlexAnalog parameters

The following metering FlexAnalog parameters (analog operands) are available for the D90^{PLUS}. They are listed alphabetically by operand syntax.

Phasor Measurement Unit analog operands

PMU 1 Conf Ch.....	Metered configuration change counter value for Phasor Measurement Unit 1
PMU 1 df dt.....	Metered frequency rate of change value for Phasor Measurement Unit 1
PMU 1 Freq.....	Metered frequency value for Phasor Measurement Unit 1
PMU 1 Num Triggers	Metered number of triggers for Phasor Measurement Unit 1
PMU 1 Ia Mag.....	Metered phase A current magnitude for Phasor Measurement Unit 1
PMU 1 Ia Ang.....	Metered phase A current angle for Phasor Measurement Unit 1
PMU 1 Ib Mag.....	Metered phase B current magnitude for Phasor Measurement Unit 1
PMU 1 Ib Ang.....	Metered phase B current angle for Phasor Measurement Unit 1
PMU 1 Ic Mag.....	Metered phase C current magnitude for Phasor Measurement Unit 1
PMU 1 Ic Ang.....	Metered phase C current angle for Phasor Measurement Unit 1
PMU 1 Ig Mag.....	Metered ground current magnitude for Phasor Measurement Unit 1
PMU 1 Ig Ang.....	Metered ground current angle for Phasor Measurement Unit 1
PMU 1 I0 Mag.....	Metered zero-sequence current magnitude for Phasor Measurement Unit 1
PMU 1 I0 Ang.....	Metered zero-sequence current angle for Phasor Measurement Unit 1
PMU 1 I1 Mag.....	Metered positive-sequence current magnitude for Phasor Measurement Unit 1
PMU 1 I1 Ang.....	Metered positive-sequence current angle for Phasor Measurement Unit 1
PMU 1 I2 Mag.....	Metered negative-sequence current magnitude for Phasor Measurement Unit 1
PMU 1 I2 Ang.....	Metered negative-sequence current angle for Phasor Measurement Unit 1

PMU 1 Va Mag.....	Metered phase A voltage magnitude for Phasor Measurement Unit 1
PMU 1 Va Ang.....	Metered phase A voltage angle for Phasor Measurement Unit 1
PMU 1 Vb Mag.....	Metered phase B voltage magnitude for Phasor Measurement Unit 1
PMU 1 Vb Ang.....	Metered phase B voltage angle for Phasor Measurement Unit 1
PMU 1 Vc Mag.....	Metered phase C voltage magnitude for Phasor Measurement Unit 1
PMU 1 Vc Ang.....	Metered phase C voltage angle for Phasor Measurement Unit 1
PMU 1 Vx Mag.....	Metered auxiliary voltage magnitude for Phasor Measurement Unit 1
PMU 1 Vx Ang.....	Metered auxiliary voltage angle for Phasor Measurement Unit 1
PMU 1 V0 Mag.....	Metered zero-sequence voltage magnitude for Phasor Measurement Unit 1
PMU 1 V0 Ang.....	Metered zero-sequence voltage angle for Phasor Measurement Unit 1
PMU 1 V1 Mag.....	Metered positive-sequence voltage magnitude for Phasor Measurement Unit 1
PMU 1 V1 Ang.....	Metered positive-sequence voltage angle for Phasor Measurement Unit 1
PMU 1 V2 Mag.....	Metered negative-sequence voltage magnitude for Phasor Measurement Unit 1
PMU 1 V2 Ang.....	Metered negative-sequence voltage angle for Phasor Measurement Unit 1

Frequency metering analog operands

SRC 1 Frequency.....	Metered frequency for source 1
SRC 2 Frequency.....	Metered frequency for source 2
SRC 3 Frequency.....	Metered frequency for source 3
SRC 4 Frequency.....	Metered frequency for source 4

Current metering analog operands

SRC 1 Ia RMS.....	Metered RMS phase A current for source 1
SRC 1 Ib RMS.....	Metered RMS phase B current for source 1
SRC 1 Ic RMS.....	Metered RMS phase C current for source 1
SRC 1 In RMS.....	Metered RMS neutral current for source 1
SRC 1 Ia Angle.....	Metered phase A current angle for source 1
SRC 1 Ia Mag.....	Metered phase A current magnitude for source 1
SRC 1 Ib Angle.....	Metered phase B current angle for source 1
SRC 1 Ib Mag.....	Metered phase B current magnitude for source 1
SRC 1 Ic Angle.....	Metered phase C current angle for source 1
SRC 1 Ic Mag.....	Metered phase C current magnitude for source 1
SRC 1 In Angle.....	Metered neutral current angle for source 1
SRC 1 In Mag.....	Metered neutral current magnitude for source 1
SRC 1 Ig Angle.....	Metered ground current angle for source 1
SRC 1 Ig Mag.....	Metered ground current magnitude for source 1
SRC 1 I0 Angle.....	Metered zero-sequence current angle for source 1
SRC 1 I0 Mag.....	Metered zero-sequence current magnitude for source 1
SRC 1 I1 Angle.....	Metered positive-sequence current angle for source 1
SRC 1 I1 Mag.....	Metered positive-sequence current magnitude for source 1
SRC 1 I2 Angle.....	Metered negative-sequence current angle for source 1

SRC 1 I2 Mag.....Metered negative-sequence current magnitude for source 1
 SRC 2.....The analog parameters shown above are available for sources 2 and above.

Power metering analog operands

SRC 1 P.....Metered three-phase real power for source 1
 SRC 1 Pa.....Metered phase A real power for source 1
 SRC 1 Pb.....Metered phase B real power for source 1
 SRC 1 Pc.....Metered phase C real power for source 1
 SRC 1 Q.....Metered three-phase reactive power for source 1
 SRC 1 Qa.....Metered phase A reactive power for source 1
 SRC 1 Qb.....Metered phase B reactive power for source 1
 SRC 1 Qc.....Metered phase C reactive power for source 1
 SRC 1 S.....Metered three-phase apparent power for source 1
 SRC 1 Sa.....Metered phase A apparent power for source 1
 SRC 1 Sb.....Metered phase B apparent power for source 1
 SRC 1 Sc.....Metered phase C apparent power for source 1
 SRC 1 PF.....Metered three-phase power factor for source 1
 SRC 1 PF A.....Metered phase A power factor for source 1
 SRC 1 PF B.....Metered phase B power factor for source 1
 SRC 1 PF C.....Metered phase C power factor for source 1
 SRC 2.....The analog parameters shown above are available for sources 2 and above.

Energy metering analog operands

SRC 1 Pos Watth.....Metered three-phase real power for source 1
 SRC 1 Neg Watth.....Metered phase A real power for source 1
 SRC 1 Pos Varh.....Metered phase B real power for source 1
 SRC 1 Neg Varh.....Metered phase C real power for source 1
 SRC 2.....The analog parameters shown above are available for sources 2 and above.

Voltage metering analog operands

SRC 1 Vag RMS.....Metered RMS phase A to ground voltage for source 1
 SRC 1 Vbg RMS.....Metered RMS phase B to ground voltage for source 1
 SRC 1 Vcg RMS.....Metered RMS phase C to ground voltage for source 1
 SRC 1 Vag Angle.....Metered phase A to ground voltage angle for source 1
 SRC 1 Vag Mag.....Metered phase A to ground voltage magnitude for source 1
 SRC 1 Vbg Angle.....Metered phase B to ground voltage angle for source 1
 SRC 1 Vbg Mag.....Metered phase B to ground voltage magnitude for source 1
 SRC 1 Vcg Angle.....Metered phase C to ground voltage angle for source 1
 SRC 1 Vcg Mag.....Metered phase C to ground voltage magnitude for source 1
 SRC 1 Vab RMS.....Metered RMS phase A to B voltage for source 1
 SRC 1 Vbc RMS.....Metered RMS phase B to C voltage for source 1
 SRC 1 Vca RMS.....Metered RMS phase C to A voltage for source 1
 SRC 1 Vab Angle.....Metered phase A to B voltage angle for source 1
 SRC 1 Vab Mag.....Metered phase A to B voltage magnitude for source 1
 SRC 1 Vbc Angle.....Metered phase B to C voltage angle for source 1
 SRC 1 Vbc Mag.....Metered phase B to C voltage magnitude for source 1
 SRC 1 Vca Angle.....Metered phase C to A voltage angle for source 1
 SRC 1 Vca Mag.....Metered phase A to A voltage magnitude for source 1

SRC 1 Vx RMS.....	Metered RMS auxiliary voltage for source 1
SRC 1 Vx Angle.....	Metered auxiliary voltage angle for source 1
SRC 1 Vx Mag	Metered auxiliary voltage magnitude for source 1
SRC 1 V0 Angle.....	Metered zero-sequence voltage angle for source 1
SRC 1 V0 Mag	Metered zero-sequence voltage magnitude for source 1
SRC 1 V1 Angle.....	Metered positive-sequence voltage angle for source 1
SRC 1 V1 Mag	Metered positive-sequence voltage magnitude for source 1
SRC 1 V2 Angle.....	Metered negative-sequence voltage angle for source 1
SRC 1 V2 Mag	Metered negative-sequence voltage magnitude for source 1
SRC 2	The analog parameters shown above are available for sources 2 and above.

Tracking frequency analog operand

Tracking frequency.....	Metered tracking frequency
-------------------------	----------------------------

D90^{Plus} Line Distance Protection System

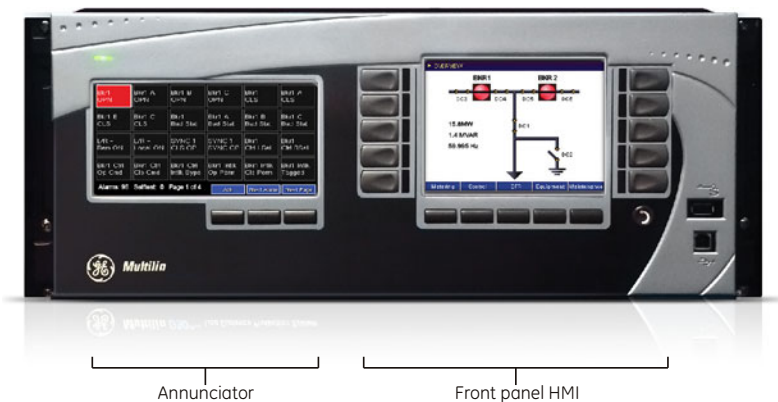
Chapter 12: Local interface

This section outlines how to program the D90^{Plus} local interface features.

Local interface overview

The front panel of the D90^{Plus} provides a color LCD annunciator alarm panel with an optional second LCD display for human-machine interface (HMI) functions that include user-configurable metering and control pages, access to the digital fault recorder, physical input/output status, and equipment maintenance functions. Keys are provided at the bottom of each display for navigation and at both sides of the front panel HMI display for assigned user control actions. These control actions can include selection of a breaker or a disconnect switch in a select-before-operate sequence, or direct operation of a user definable push-button or selector switch element. Up to 30 pushbutton instances, 10 selector switch instances, 6 disconnect switches, and six breakers are supported on the D90^{Plus}.

Figure 507: Front panel interface



Annunciator panel

The annunciator indicates the status of system alarm points and actual values. It displays self-test messages and product information for the unit.

Annunciator operation

The annunciator supports three types of alarms: self-reset, latched, and acknowledgeable. Each location in an annunciator display page can be configured to be one of the three alarm types and can also display an optional metered value. The value of each self-reset alarm is refreshed approximately every half second.

Alarms are organized in a table and numbered increasing from left to right horizontally and then top to bottom. The first alarm in the top left corner of the first page is denoted as indicator 1 by the EnerVista UR^{Plus} Setup software. The top left location of the next page is the bottom right alarm number on the previous page plus one. Up to 288 individual alarms or metered values can be configured.

Each location in the alarm table can be configured as an alarm only, metering only, or mixed content. With the exception of metering only table entries, a FlexLogic alarm input operand is required for each alarm table location. Selecting an operand of “None” hides the entry from view.

Alarms can display up to three lines of text using specified foreground and background colors. A configured metering value replaces the specified line of text. The figure shows a typical annunciator display.

Figure 508: Typical annunciator display

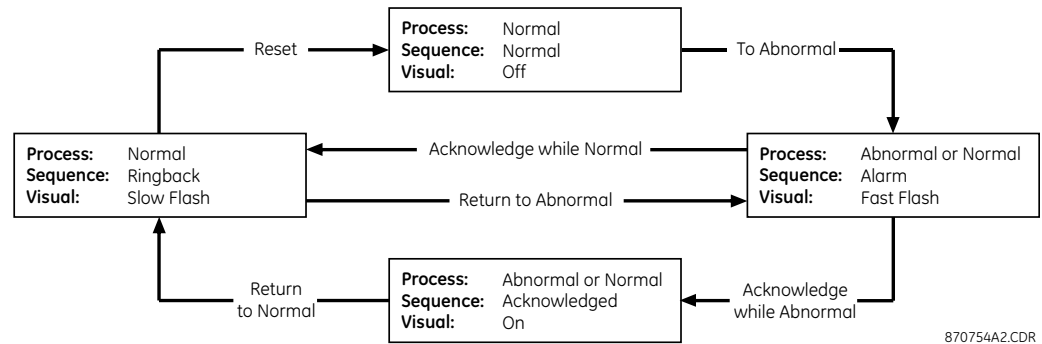
Phase Distance Zone 1	Phase Distance Zone 2	Ground Distance Zone 1	Ground Distance Zone 2
Line Pickup	Pilot Scheme	Breaker 1 Failure	Breaker 2 Failure
Autoreclose Lockout	Fuse Failure	Setting Group 2 Active	Fault Report
Alarms: 6 Selftest: 1 Page 1 of 1			
		Ack	Next Alarm
			Next Page

There are three control buttons at the bottom of the display.

- The Next Page button navigates through the configured alarm, self-test, and product information pages. Pages that contain no configured alarms are not displayed.
- The Next Alarm button navigates horizontally through the current alarms that are active, from left-to-right, starting with the first row of alarms. A border is drawn around the current alarm.
- The Ack/Reset button is used to acknowledge alarms or reset latched and acknowledgeable alarms that are in the ringback state.

The annunciator alarm sequence conforms to ISA 18.1-1979 (R1992) standard, type R.

Figure 509: Annunciator alarm sequence



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The table outlines annunciator states.

Table 41: Acknowledgeable alarm states

Sequence (initial state)	Process (status)	Pushbutton (input)	Sequence (final state)	Visual indication
Normal	Normal	N/A	N/A	Off
Normal	Abnormal	N/A	Alarm	Fast flash
Alarm	Normal	N/A	Alarm	Fast flash
Alarm	Normal	Acknowledged	Normal	Off
Alarm	Abnormal	Acknowledged	Acknowledged	On
Acknowledged	Abnormal	N/A	Acknowledged	On
Acknowledged	Normal	N/A	Ringback	Slow flash
Ringback	Normal	Reset	Normal	Off
Ringback	Abnormal	N/A	Acknowledged	On

The visual indications display as follows:

- Off – Grey text on a darker grey background
- On – User-configurable
- Fast flash – Alternating between off and on state two times per second
- Slow flash – Alternating between off and on state one time per second

In the event of an alarm, the page containing the alarm is promoted to active page. If there are multiple pages with alarms, the page with the lowest page number is promoted.

If there are alarms on multiple pages, and alarms on some pages have already been acknowledged (but not cleared) by the user, then the pages with active alarms move ahead of the pages that have acknowledged alarms. The user always has to navigate through the pages of alarms to view them.

Display of alarm pages is prioritized according to active window (unacknowledged or flashing alarm) and page number (for example, if two pages have an unacknowledged alarm, the page with the lowest number is promoted automatically as the displayed page).

Annunciator configuration

Select the **Settings > Local HMI > Annunciator Panel** menu to open the annunciator configuration window.

Figure 510: Annunciator configuration settings

SETTING	PARAMETER	LAYOUT AND NAVIGATION							
Clear Latched	OFF			3x4	Preview	Navigation			
PARAMETER	CONTENT	ALARM INPUT	ALARM TYPE	TEXT (LINE 1)	TEXT (LINE 2)	TEXT (LINE 3)	TEXT COLOR	BACK COLOR	ACTUAL
Indicator 1	Alarm	OFF	Acknowledgeable	New	Transient	Record	White	Red	Configure
Indicator 2	Alarm	OFF	Acknowledgeable	Bkr 1	Arcing	Operated	White	Red	Configure
Indicator 3	Alarm	OFF	Acknowledgeable	Bkr 2	Arcing	Operated	White	Red	Configure
Indicator 4	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 5	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 6	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 7	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 8	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 9	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 10	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 11	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 12	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 13	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 14	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 15	Alarm	OFF	Acknowledgeable				White	Red	Configure
Indicator 16	Alarm	OFF	Acknowledgeable				White	Red	Configure

The following settings are available. The setting descriptions apply to all 288 alarms, with different default values.

Clear Latched

Range: any FlexLogic operand or shared operand

Default: OFF

This setting allows the user to designate a FlexLogic operand to clear all latched alarms when the operand transitions to an active state. For example, a central station HMI can simultaneously clear all IED alarms remotely by assigning this value to a virtual input.

Page Layout

Range: 3 × 4, 4 × 6, 6 × 8

Default: 3 × 4

This setting specifies the number of alarms shown per page. This setting applies globally to all alarm pages. For example if “4 × 6” is selected, then 288 alarms can be displayed on 12 pages. Note that annunciator pages that do not contain at least one configured alarm are hidden.

Content

Range: Actual, Alarm, Mixed

Default: Alarm

This setting specifies if the corresponding alarm consists of a single metered value (set to “Actual”), contains a single alarm indication (set to “Alarm”), or contains both a metered value and an alarm indication (set to “Mixed”).

For information on configuring the alarm when **Content** is set to “Actual,” see [Configuring metering values](#) on page 586.

Alarm Input

Range: any FlexLogic operand or shared operand

Default: see above

This setting specifies the input signal connected to the alarm.

Alarm Type

Range: Acknowledgeable, Latched, Self-Reset

Default: Acknowledgeable

This setting specifies the alarm type. Self-reset alarms track the state of the corresponding input operand. Latched alarms can be reset using the Ack/Reset button at the bottom of the display. Acknowledgeable alarms follow the state transitions listed in the previous section.

Text (Line 1), Text (Line 2), Text (Line 3)

Range: up to ten alphanumeric characters

Default: product-specific defaults or blank

These settings specify the displayed text on the corresponding line in the alarm indicator. Three lines can be displayed if the page layout is 3 × 4 or 4 × 6. For 6 × 8 layouts, only the first two lines are displayed. Note that a specified metering value replaces the text for the selected line.

Text Color

Range: Black, Red, Yellow, Blue, Green, Teal, Purple, White, Dark Red, Dark Yellow, Dark Blue, Dark Green, Dark Teal, Dark Purple, Grey

Default: White

This setting specifies the color of the alarm indicator text.

Back Color

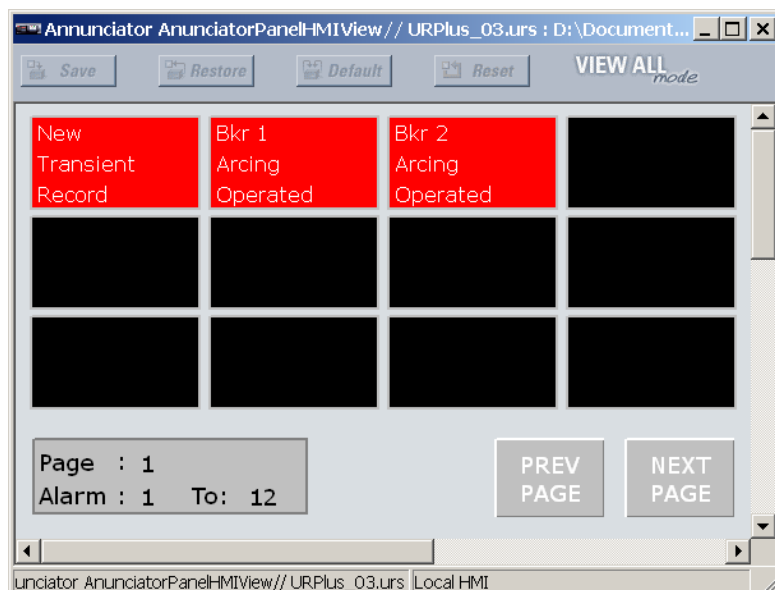
Range: Black, Red, Yellow, Blue, Green, Teal, Purple, White, Dark Red, Dark Yellow, Dark Blue, Dark Green, Dark Teal, Dark Purple, Grey

Default: Red

This setting specifies the color of the alarm indicator text.

The **Preview** button displays a static image of the front panel alarm page (as it appears when active) so that the user can verify the layout and color of the indicators.

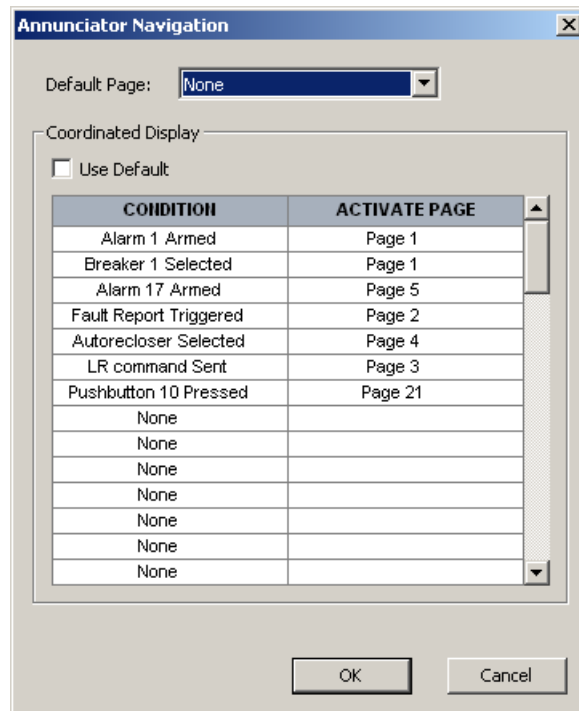
Figure 511: Annunciator preview window



The **Navigation** button allows the user can specify which annunciator alarm page displays under various conditions, including selection of a breaker or disconnect switch from a user-configurable line diagram, any configured alarm becoming active, any user-

programmable pushbutton or selector switch button being activated, a new fault report being triggered, selection of the autorecloser in the single line diagram, or toggling of the local/remote status.

Figure 512: Annunciator navigation window



If the **Use Default** check box is selected and the **Default Page** is set to “None,” selection of the alarm page to display follows the following sequence:

- In the event of a new alarm, the page containing the alarm is promoted to the active page. If there are multiple pages with alarms, the lowest numbered page is promoted.
- If there are alarms on multiple pages, and alarms on some pages have already been acknowledged but not reset by the user, then the lowest numbered page with an alarm is promoted above any page that has an acknowledged alarm.

The **Default Page** field selects the page that is displayed after the user-specified period of inactivity has elapsed.

The D90^{PLUS} is shipped with a complete range of default annunciator settings. These can be modified according to the specific applications.

Configuring metering values

The following window displays when the **Configure** button is clicked for metered value indicators. This window allows the user to configure metering values.

Figure 513: Metering value properties window

The following parameters are available.

Parameter

Range: any FlexAnalog parameter

Default: Digital Counter 1 Value

This setting selects a FlexAnalog parameter that specifies the metered value to display in the annunciator alarm.

Units

Range: up to 4 alphanumeric characters

Default: ---

This setting specifies a four-character alphanumeric string that is used in the annunciator display of the corresponding metered value.

Scale Factor

Range: None, k (kilo), M (Mega), G (Giga)

Default: None

This setting allows the user to specify the scaling factor for the metering units value.

Multiplier

Range: dependent on selected analog value

Default: 1.0

This setting allows the user to specify a multiplier for the metering parameter value. The range is restricted to correspond to the selected actual value parameter.

Number of Integers

Range: 1 to 12 in steps of 1

Default: 1

This setting specifies the number of integers in the displayed analog value. It can be used to provide for leading character spacing of the display value.

Number of Decimals

Range: 1 to 10 in steps of 1

Default: 3

This setting specifies the number of decimal places in the displayed analog value.

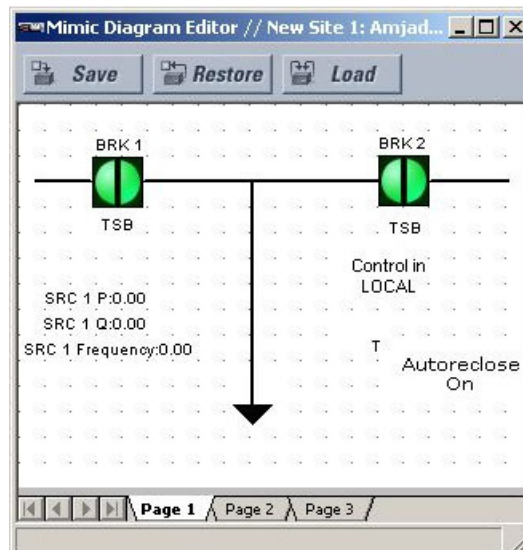
Display in Line*Range: 1, 2, 3**Default: 1*

This setting specifies the line in the annunciator alarm to display the metered value. It can be displayed in lines 1, 2, or 3 if the page layout is 3 × 4 or 4 × 6. For 6 × 8 layouts, it can be displayed in lines 1 or 2.

Mimic diagram editor

The mimic diagram editor allows users to create customized single line diagrams (mimic diagrams) for the front panel display. Select the **Settings > Local HMI > Mimic Diagram Editor** menu to open the editor.

Figure 514: Mimic diagram editor with example of diagram



There is one top level page in the mimic diagram editor.

Each top level diagram has up to 10 sub-level diagrams corresponding to each of the active components. The sub-level diagram is rendered when the corresponding active component is selected for operation. To create a sub-level diagram, right-click the breaker or switch instance in the diagram editor and select the **GoTo SLD** item. A new diagram is created and populated with the selected active component and a new tab is added to the diagram editor.

A components library is included on the upper-right side of the EnerVista software. Options include dynamic power components, static power components, and text blocks. To create the single line diagram, select a component, then click the drawing pane to place the component. Once on the drawing plane, the component can be positioned accordingly.

Figure 515: Mimic diagram components library



The following functions are available for the mimic diagram editor:

- Circuit breakers
- Disconnect and earthing switches
- Busbars
- Transformers
- Capacitor banks
- Reactors
- CTs and VTs
- Transmission lines
- Grounding









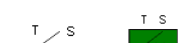






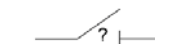

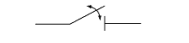


The circuit breakers, disconnects, and earthing switches can be configured to display automatically the actual status of these devices. All other devices are static. As such, they are used for information only and cannot dynamically change states.

The following sections outline the diagram options and use.

Dynamic symbols

The following dynamic symbols are available. The symbols can be displayed in the standard UR^{PLUS}-series format or as IEC style symbols.

Figure 516: Mimic diagram editor dynamic symbols

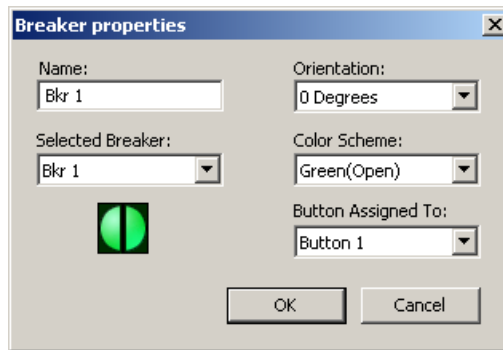
Components	Symbols		Notes
	Standard	IEC	
Circuit breakers in the open position			 : Only this symbol is defined in the IEC standard; the others are created
Circuit breakers in the closed position			Created symbols
Circuit breakers with bad status			Created symbols
Tagged circuit breakers			Device is tagged (T); status is substituted (S). Created symbols
Switches in the open position			 : Only this symbol is defined in the IEC standard; the others are created
Switches in the closed position			Created symbols
Switches with bad status			Created symbols
Switches in the intermediate position			Created symbols
Tagged switches			Device is tagged (T); status is substituted (S). Created symbols

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A maximum of 10 dynamic components is allowed for each mimic diagram.

When a dynamic symbol is selected and added to the diagram, a window appears to configure the device. This allows the user to specify the name and orientation of the device. For example, the figure shows the breaker properties device configuration window.

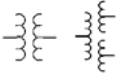
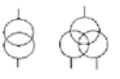
















Figure 517: Breaker properties device configuration



Static symbols

The following static symbols are available. The symbols can be displayed in the standard UR^{PLUS}-series format or as IEC symbols.

Figure 518: Mimic diagram editor static symbols

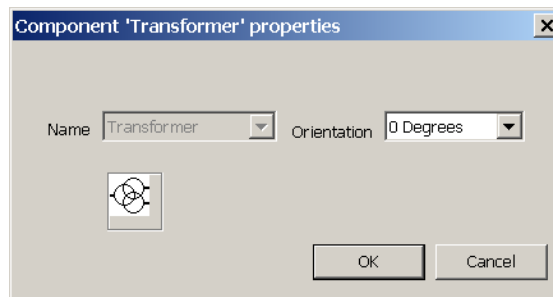
Components	Symbols	
	Standard	IEC
Transformer		
Autotransformer		
Transformer with tap changer		
Autotransformer with tap changer		
Capacitor bank		
Reactor		
VT		
CT		
Grounding		
Busbar and transmission lines		

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For more information on these symbols, see the ANSI/IEEE 315A and IEC 617 standards. There is no limit on the number of static symbols per screen, provided that they fit within the screen dimensions.

When a static symbol is selected and added to the diagram, a window appears to configure the device. This allows the user to specify the orientation of the device; the name of a static device cannot be changed. The figure shows the transformer properties device configuration window.


Figure 519: Transformer properties device configuration window



Metering blocks

Metering blocks can display various metered quantities. They allow the user to display specific analog values in the mimic diagram. The table outlines the metered text block type. A maximum of six metering blocks can be used per mimic diagram page.

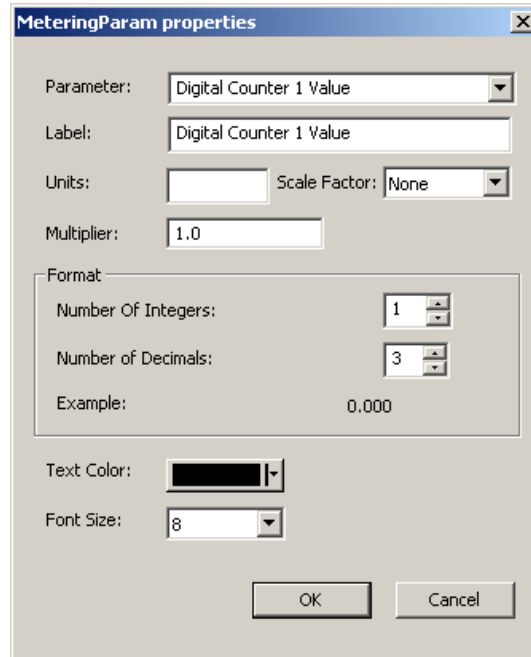
Figure 520: Mimic diagram metering block symbol

Text block type	Interface symbols	
	Button	Example display
Metered text block		-63.6 W -2.9 VAR 59.962 Hz

870870A1.CDR

The properties of a metering block can be configured by right-clicking the box and selecting **Properties** to open the Metering Properties configuration window.

Figure 521: Metering properties configuration window



The following parameters are available.

Parameter

Range: any analog actual value

Default: Analog 1 (VA1)

This setting selects the actual value to be displayed in the metering block.

Label

Range: up to 40 ASCII characters

Default: Analog 1 (VA1)

This setting allows the user to specify a custom label for the metering block if the actual value name is insufficient.

Units

Range: up to 4 ASCII characters

Default: ---

This setting allows the user to specify a custom units value for the metering block if the actual value unit designation is insufficient.

Scale Factor

Range: G (Giga), M (Mega), k (kilo), None

Default: None

This setting allows the user to select a scaling factor for the metering units value. The range is restricted to correspond to the selected analog value parameter.

Multiplier

Range: dependent on the selected analog value

Default: None

This setting allows the user to specify the multiplier for the metering units value if the scaling factor is set to "None."

Number of Integers

Range: 1 to 12 in steps of 1

Default: 1

This setting selects the number of integer places displayed for the metering block.

Number of Decimals

Range: 0 to 10 in steps of 1

Default: 3

This setting selects the number of decimal places displayed for the metering block.

Text Color

Range: available system colors

Default: Black

This setting specifies the displayed text color for the metering block.

Font Size

Range: 8, 10, 12




Default: 8

This setting specifies the displayed font size for the metering block.

Text blocks

Text blocks display various control quantities. They allow the user to display specified control states in the mimic diagram. The table outlines the three types of text blocks available. A maximum of three text blocks can be used per mimic diagram.

Figure 522: Mimic diagram text block symbols

Text block type	Interface symbols	
	Button	Example display
Local/remote text block		Control in LOCAL
Autoreclose text block		T Autoreclose On
Select-to-operate text block		SELECT TO OPERATE

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View modes

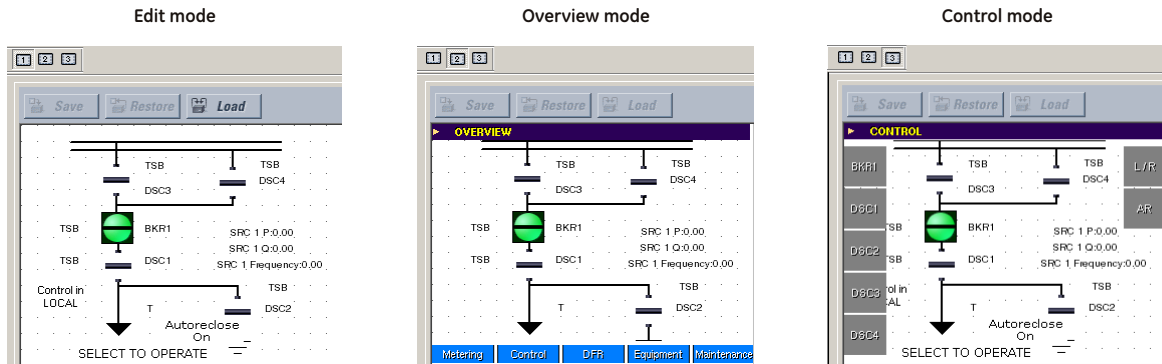
The mimic diagram editor has three viewing modes: edit mode, overview mode, and control mode. These modes are toggled via the three mode buttons on menu bar.

- **Edit mode** — Used when creating and modifying mimic diagrams with the editor

- **Overview mode** — Provides a preview of how the mimic diagram appears on the overview screen of the front panel interface
- **Control mode** — Provides a preview of how the mimic diagram appears on the control screen of the front panel interface

These modes allow the user to ensure that the mimic diagram displays appropriately in all display screens. The following figure illustrates the viewing modes.

Figure 523: Mimic diagram view modes



Pre-configured mimic diagrams

The EnerVista UR^{plus} Setup software contains a library of 12 pre-configured mimic diagrams that can be loaded into the mimic diagram editor. Click the **Load** button to load a pre-configured mimic diagram from the library. User-created mimic diagrams can also be saved into this library. The following pre-configured diagrams are available:

- Breaker-and-a-half scheme
- Breaker-and-a-half scheme with breaker disconnects
- Breaker-and-a-half scheme with breaker and line disconnects
- Breaker-and-a-half scheme with breaker, line, and ground disconnects
- Breaker-and-a-half scheme with line disconnect
- Breaker-and-a-half scheme with line and ground disconnects
- Double-bus bypass scheme 1
- Double-bus bypass scheme 2
- Double-bus bypass scheme with line and ground disconnects
- Single-bus scheme
- Single-bus scheme with line disconnect
- Single-bus scheme with line and ground disconnects

Breakers and disconnect switches are pre-assigned to 12 diagrams shown in the following figures. If a breaker or disconnect switch has not been enabled, then the device displays as a solid block.

Figure 524: Pre-configured mimic diagram 1 (breaker-and-a-half scheme)

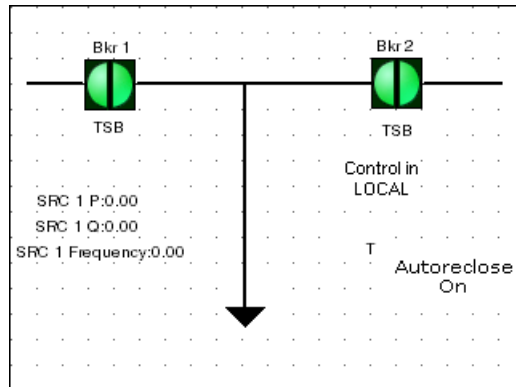


Figure 525: Pre-configured mimic diagram 2 (breaker-and-a-half scheme with breaker disconnects)

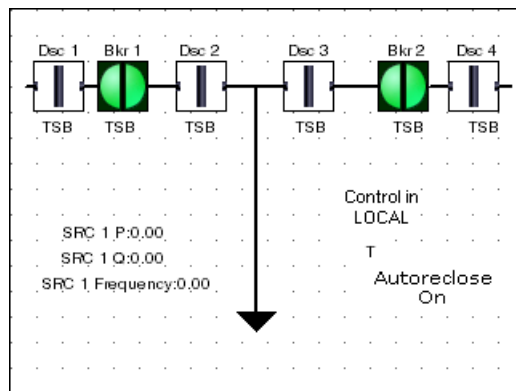


Figure 526: Pre-configured mimic diagram 3 (breaker-and-a-half scheme, with breaker and line disconnects)

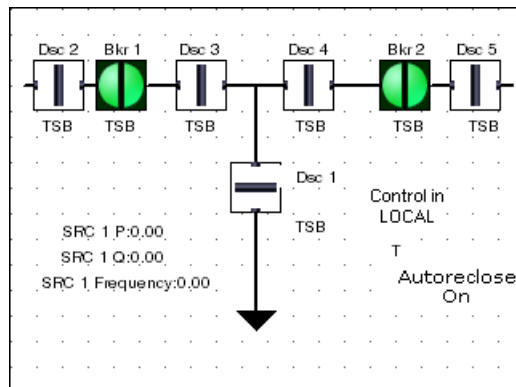


Figure 527: Pre-configured mimic diagram 4 (breaker-and-a-half scheme, with breaker,

line, and ground disconnects)

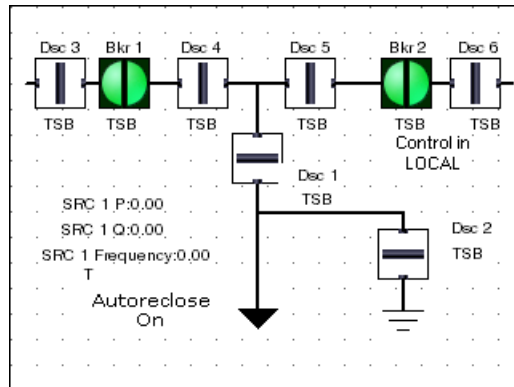


Figure 528: Pre-configured mimic diagram 5 (breaker-and-a-half scheme with line disconnect)

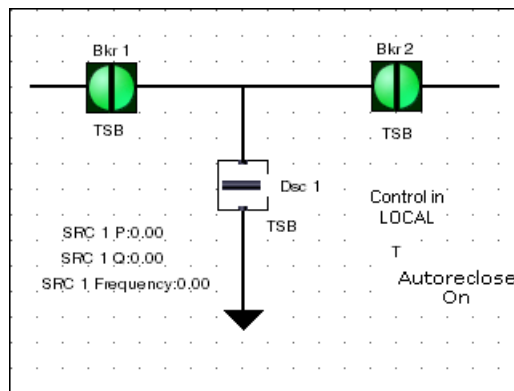


Figure 529: Pre-configured mimic diagram 6 (breaker-and-a-half scheme with line and ground disconnects)

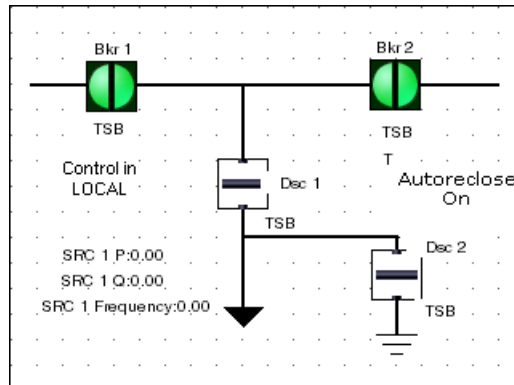


Figure 530: Pre-configured mimic diagram 7 (double-bus bypass scheme 1)

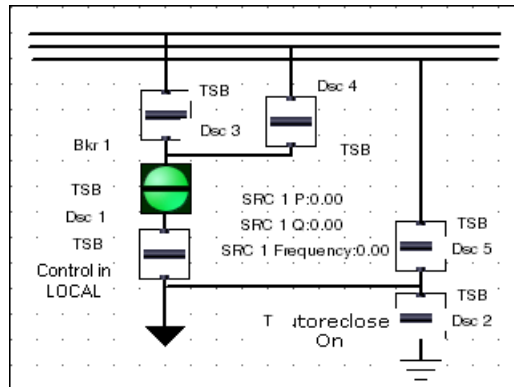


Figure 531: Pre-configured mimic diagram 8 (double-bus bypass scheme 2)

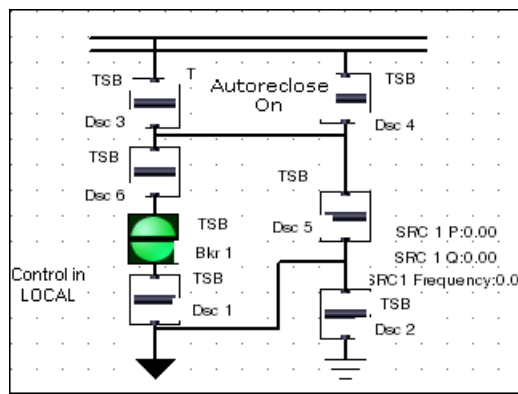


Figure 532: Pre-configured mimic diagram 9 (double-bus bypass scheme with line and ground disconnects)

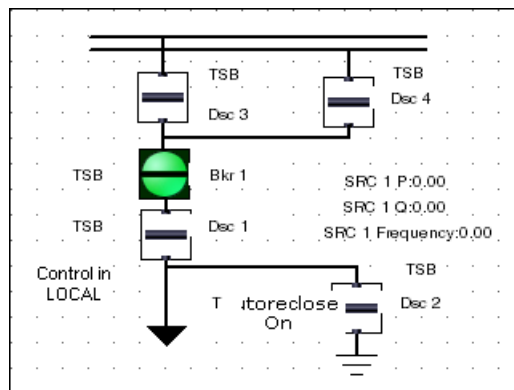


Figure 533: Pre-configured mimic diagram 10 (single-bus scheme)

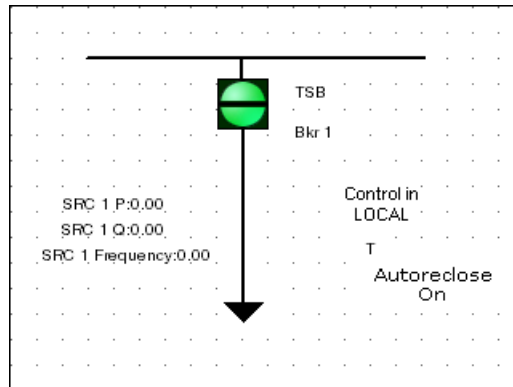


Figure 534: Pre-configured mimic diagram 11 (single-bus scheme with line disconnect)

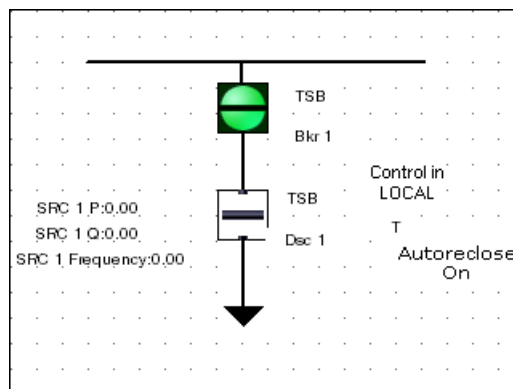
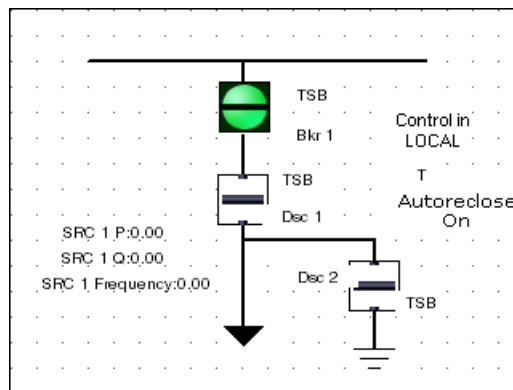


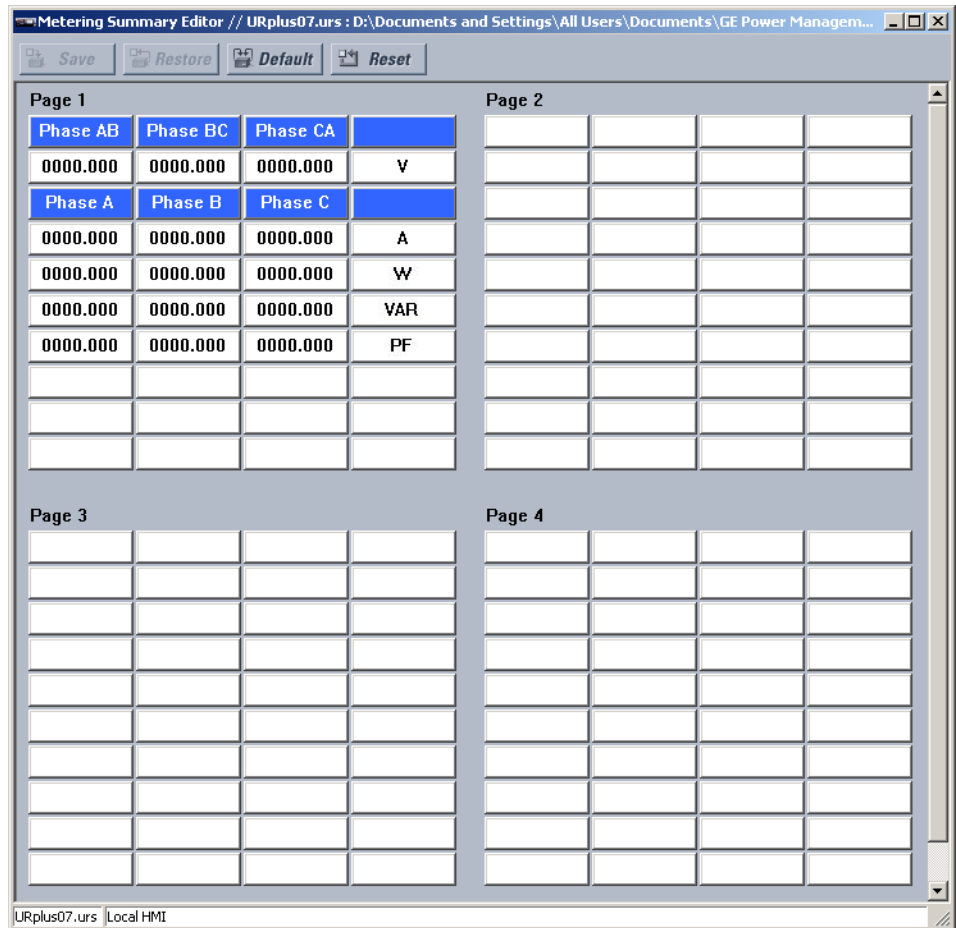
Figure 535: Pre-configured mimic diagram 12 (single-bus scheme with line and ground disconnects)



Metering summary editor

Select the **Settings > Local HMI > Metering Summary Editor** menu to open the metering configuration window.

Figure 536: Metering summary editor window



A click of the left mouse button in a metering location opens the following window. You enter header text of a selected font size and color, or select a metered quantity from the drop-down list. A metered quantity can be a system voltage, current, real or reactive power on a per-phase basis, for any configured source.

Figure 537: Metering configuration window

Text

Range: up to 20 alphanumeric characters

Default: ---

This setting defines the selected metering cell as a text box. These are used typically as headings. Specify up to 10 alphanumeric characters.

Parameter

Range: any FlexAnalog parameter

Default: Digital Counter 1 Value

This setting selects a FlexAnalog parameter that specifies the metered value to display in the metering cell.

Units

Range: up to 4 alphanumeric characters

Default: ---

This setting specifies a four-character alphanumeric string that is used in the metering cell display for the corresponding metered value.

Scale Factor

Range: G (Giga), M (Mega), k (kilo), None

Default: None

This setting allows the user to select a scaling factor for a displayed metered value. The range is restricted to correspond to the selected analog value parameter.

Multiplier

Range: dependent on selected analog value

Default: ---

This setting allows the user to specify a multiplier for the metering parameter value if the scaling factor is set to "None." The range is restricted to correspond to the selected actual value parameter.

Number of Integers*Range: 1 to 6 in steps of 1**Default: 1*

This setting specifies the number of integers in the displayed metering cell. It can be used to provide for leading character spacing of the resultant display value.

Number of Decimals*Range: 1 to 6 in steps of 1**Default: 3*

This setting specifies the number of decimal places in the displayed metering cell.

Font Size*Range: 8, 10, 12**Default: 10*

This setting specifies the font size to use for the displayed metering cell.

Text Color*Range: available system colors**Default: Black*

This setting specifies the text color to use for the foreground text in the displayed metering cell.

Background Color*Range: available system colors**Default: White*

This setting specifies the color to use in the background for the displayed metering cell.

User-programmable pushbuttons

The D90^{Plus} supports 30 user-programmable pushbuttons and 10 selector switches. Each of the selector switch instances can be assigned to one of the available HMI control keys on the three pushbutton screens. The mapping of pushbutton instances to control keys is fixed. Pushbuttons 1 through 10 are on the first screen, 11 through 20 on the second screen, and 21 through 30 on the third screen. Pushbuttons are numbered starting with the top-left control key, increasing from top-to-bottom on the left side of the display and then from top-to-bottom on the right side of the display.

The user can specify the text for the navigation menu entry for each pushbutton page. If a page does not contain any configured pushbutton or selector switch instances, the navigation menu is disabled and the menu text is grayed out.

For each pushbutton and selector switch instance, the user supplies the text that is drawn in the rectangle adjacent to the control key for each switch position. For pushbuttons, text can be specified for both the ON and OFF states.

The pushbutton configuration is started when the user clicks the **Configure** setting in the user-programmable pushbutton settings window.

**NOTE**

The D90^{Plus} must be in the programmed state and the corresponding selector switch or pushbutton element must be enabled before the control keys affect a change to the element state.

User-programmable pushbutton operation

User-programmable pushbuttons provide a simple and error-free way to enter digital state (on, off) information. The digital state can be entered locally (by directly pressing the front panel pushbutton) or remotely (via operands) into logic equations, protection elements, and control elements. Typical applications include breaker control, autorecloser blocking, setting group changes, and the control of selector switches.

Each pushbutton asserts its own on-state and off-state operands (for example, **PUSHBUTTON 1 ON** and **PUSHBUTTON 1 OFF**). These operands are available for each pushbutton and are used to program specific actions. If any pushbutton is active, the **ANY PB ON** operand asserts.

The pushbuttons can be controlled automatically by asserting user-specified operands. The pushbutton reset status is declared when the **PUSHBUTTON 1 OFF** operand is asserted. The activation and deactivation of user-programmable pushbuttons depends on whether latched or self-reset mode is selected.

In latched mode, a pushbutton can be set (activated) by asserting the set operand or by pressing the pushbutton. The pushbutton maintains the set state until deactivated by the reset command or after a user-specified time delay. The state of each pushbutton is stored in non-volatile memory and maintained through a loss of control power. The pushbutton is reset (deactivated) in latched mode by asserting the reset operand or by pressing the pushbutton. The pushbutton can also be programmed to reset automatically through settings. These settings enable the autoreset timer and specify the associated time delay. The autoreset timer can be used in select-before-operate (SBO) breaker control applications, where the command type (close/open) or breaker location (feeder number) must be selected prior to command execution. The selection must reset automatically if control is not executed within a specified time period.

In self-reset mode, a pushbutton remains active for the time it is pressed (the pulse duration) plus a user-specified dropout time. If the pushbutton is activated via logic equations, the pulse duration is specified by only the user-specified dropout time. The time that the set operand remains assigned has no effect on the pulse duration. The pushbutton is reset (deactivated) in self-reset mode when a user-specified dropout delay expires.



The pulse duration of the remote set, remote reset, or local pushbutton must be at least 50 ms to operate the pushbutton. This allows the user-programmable pushbuttons to operate during power cycling events and various system disturbances that can cause transient assertion of the operating signals.

The local and remote operation of each user-programmable pushbutton can be inhibited through user settings. If local locking is applied, the pushbutton ignores set and reset commands executed through the front panel pushbuttons. If remote locking is applied, the pushbutton ignores set and reset commands executed through logic operands.

The locking functions are not applied to the autorestart feature. In this case, the inhibit function can be used in SBO control operations to prevent the pushbutton function from being activated and ensuring *one-at-a-time* select operation. The locking functions also can be used to prevent the accidental pressing of the front panel pushbuttons. The separate inhibit of the local and remote operation simplifies the implementation of local/remote control supervision.

Pushbutton states can be logged by the sequence of events recorder. In latched mode, user-defined messages also can be associated with each pushbutton and displayed when the pushbutton is on or changing to off.

User-programmable pushbutton settings

Select the **Settings > Local HMI > User-Programmable Pushbuttons** menu to open the user-programmable pushbuttons settings window.

Figure 538: User-programmable pushbutton configuration settings

PARAMETER	PB 1	PB 2	PB 3
Function	Disabled	Disabled	Disabled
Set	OFF	OFF	OFF
Reset	OFF	OFF	OFF
Autoreset	Disabled	Disabled	Disabled
Autoreset Delay	1.0 s	1.0 s	1.0 s
Remote Lock	OFF	OFF	OFF
Local Lock	OFF	OFF	OFF
Dropout Time	0.0 s	0.0 s	0.0 s
Events	Enabled	Enabled	Enabled

The following settings are available for each user-programmable pushbutton.

Function

Range: Disabled, Latched, Self-Reset

Default: Disabled

This setting selects the pushbutton operating characteristic. If set to “Disabled,” the pushbutton is not active and the corresponding operands (both on-state and off-state operands) are de-asserted. If set to “Self-Reset,” the control logic is activated by the pulse (longer than 100 ms) issued when the pushbutton is initiated physically via the front panel interface or initiated virtually via logic.

When in “Self-Reset” mode and activated locally, the pushbutton control logic asserts the corresponding on-state operand as long as the pushbutton remains physically initiated. After the pushbutton is released, the de-assertion of the operand is delayed by the drop out timer. The off-state operand is asserted when the pushbutton element is deactivated. If the pushbutton is activated remotely, the pushbutton control logic asserts the corresponding on-state operand only for the time specified by the **Dropout Time** setting.

If set to “Latched,” the pushbutton control logic alternates the state of the corresponding operand between the on-state and off-state on each button press or by virtually activating the pushbutton (assigning set and reset operands). In latched mode, the operand states are stored in non-volatile memory. If the power supply goes off, the correct state of the pushbutton is retained upon subsequent power-up.

Set

Range: any FlexLogic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, the pushbutton operates and the **PUSHBUTTON 1 ON** operand asserts. The duration of the incoming set signal must be at least 100 ms.

Reset

Range: any FlexLogic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, the pushbutton resets and the **PUSHBUTTON 1 OFF** operand asserts. This setting applies when the pushbutton is in latched mode. The duration of the incoming set signal must be at least 100 ms.

Autoreset

Range: Disabled, Enabled

Default: Disabled

This setting enables the user-programmable pushbutton autoreset feature. This setting applies when the pushbutton is in latched mode.

Autoreset Delay

Range: 0.2 to 600.0 seconds in steps of 0.1

Default: 1.0 seconds

This setting specifies the time delay for automatic reset of the pushbutton when in latched mode.

Remote Lock

Range: any FlexLogic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, pushbutton operation from operands assigned to the **Set** or **Reset** settings is inhibited.

Local Lock

Range: any FlexLogic operand or shared operand

Default: OFF

When the operand assigned to this setting is asserted, pushbutton operation from the front panel interface is inhibited. This locking functionality does not apply to pushbutton autoreset.

Dropout Time

Range: 0.0 to 60.0 seconds in steps of 0.1

Default: 0.0 seconds

This setting specifies the duration of the pushbutton active status after the pushbutton has been released. This setting applies to self-reset mode and is required to set the duration of the pushbutton operating pulse.

Events

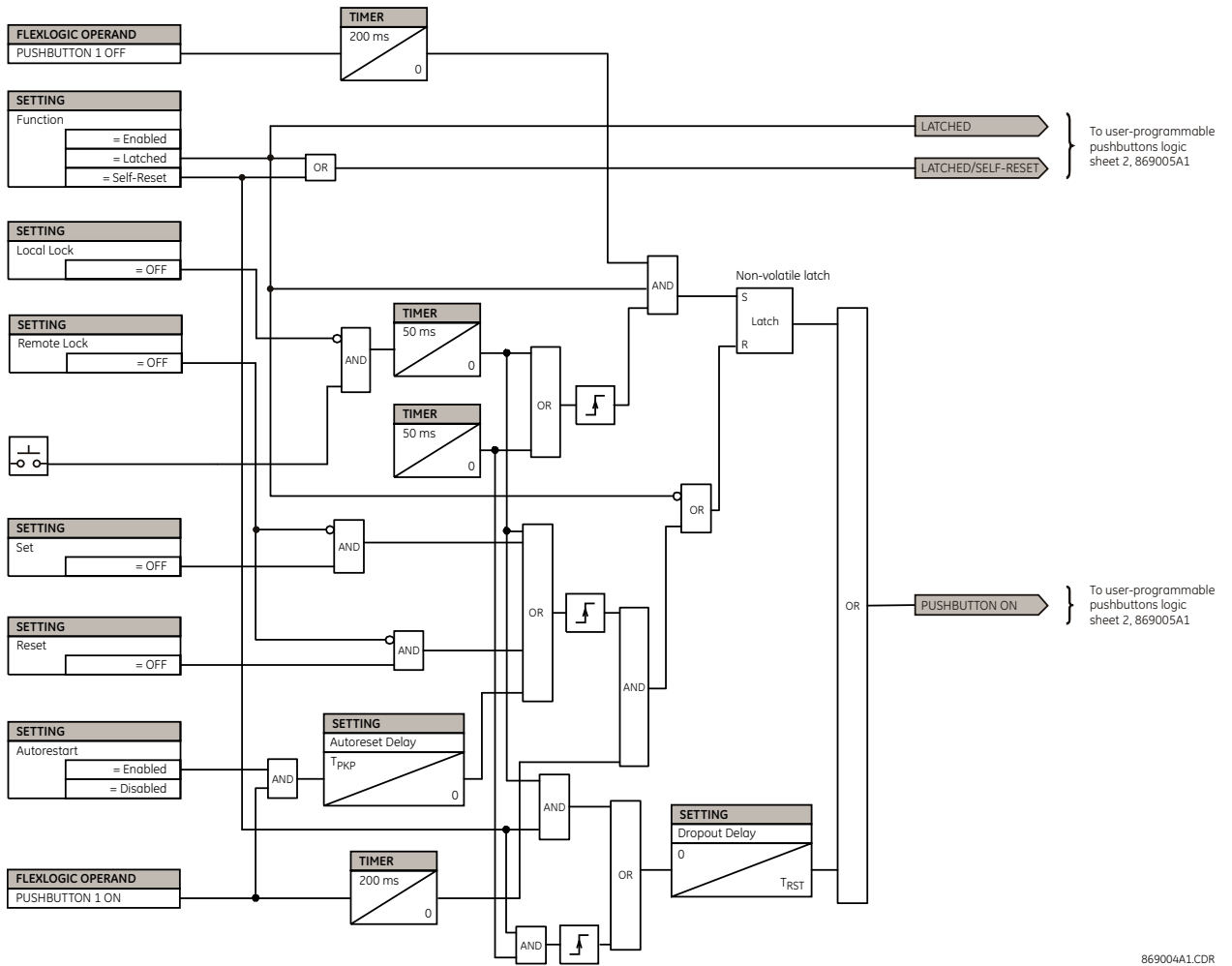
Range: Disabled, Enabled

Default: Enabled

This setting enables and disables the logging of user-programmable pushbutton events in the sequence of events recorder.

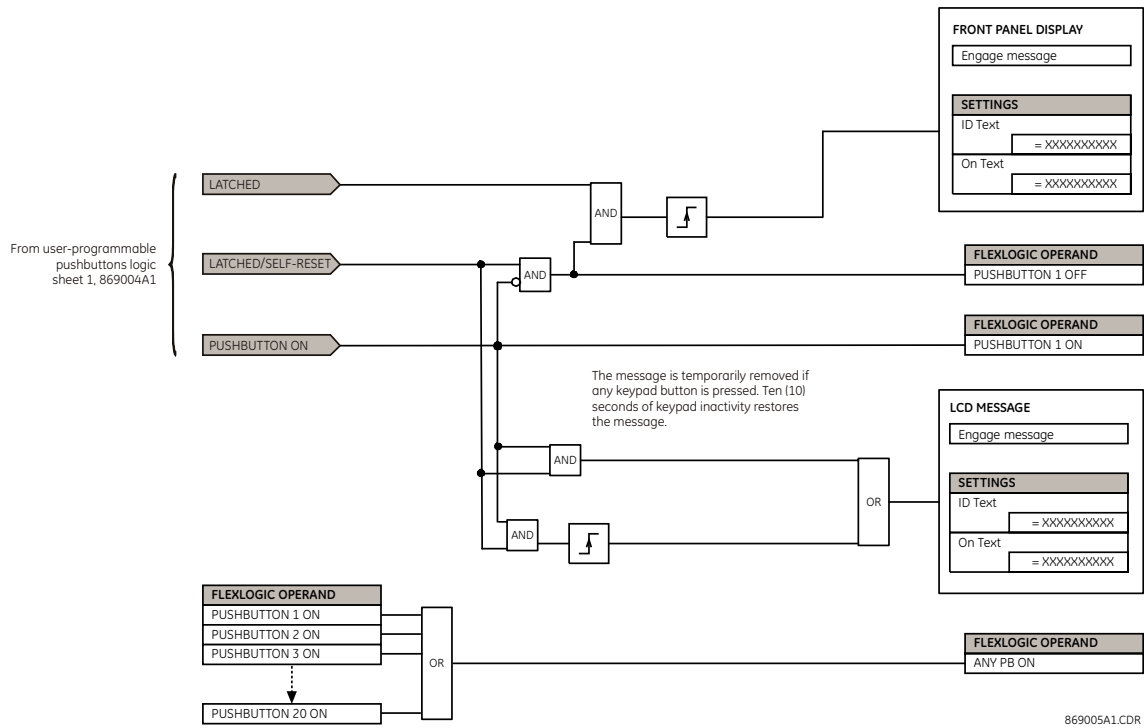
The figures show the user-programmable pushbutton 1 logic. The logic is functionally identical for all user-programmable pushbuttons.

Figure 539: User-programmable pushbutton logic, sheet 1 of 2



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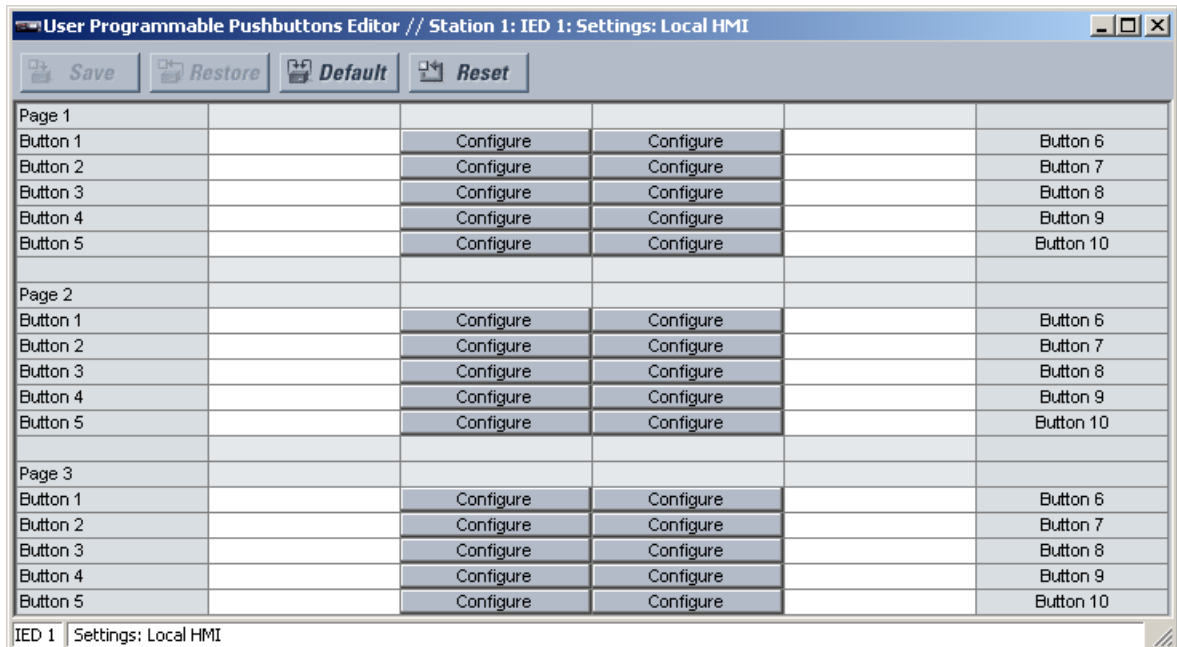
Figure 540: User-programmable pushbutton logic, sheet 2 of 2



User-programmable pushbutton editor

Select the **Settings > Local HMI > User-Programmable Pushbuttons Editor** menu to open the user-programmable pushbuttons editor window.

Figure 541: User-programmable pushbuttons editor settings



Click the **Configure** button to access the settings. The following window displays for each user-programmable pushbutton.

Figure 542: Pushbutton configuration window

The following settings are available.

Button Name

Range: up to 20 alphanumeric characters

Default: ---

This setting allows the user to assign a pushbutton or selector switch name that appears on the user-programmable pushbutton window and on the display page when the corresponding pushbutton element or selector switch element is disabled.

Button Type

Range: Pushbutton, Selector Switch

Default: Pushbutton

This setting defines the type of switch associated with each control key.

State OFF Text

Range: up to 20 alphanumeric characters

Default: ---

This setting specifies the text to display under the button name when the pushbutton is in the OFF state.

State ON Text

Range: up to 20 alphanumeric characters

Default: ---

This setting specifies the text to display under the button name when the pushbutton is in the ON state.

Choose Selector

Range: 1 to 10 in steps of 1

Default: 1

This setting selects the selector switch number to associate with the current control key. This setting is available when the **Button Type** is "Selector Switch."

State 1 Text, State 2 Text, ..., State 10 Text

Range: up to 19 alphanumeric characters

Default: ---

These settings specify the text to display under the selector switch name for each switch position. These settings are available when the **Button Type** is "Selector Switch."

D90^{Plus} Line Distance Protection System

Chapter 13: Security

This section outlines how to program the D90^{Plus} security features.

Password security

It is recommended that passwords be programmed for each security level and assigned to specific personnel. There are two password security access levels: command and setting. The command access level restricts the user from making any settings changes, but allows the user to perform the following operations:

- Operate breakers via the front panel interface
- Change the state of virtual inputs
- Clear event records
- Clear oscillography records
- Clear fault reports
- Change the system date and time
- Clear energy records
- Operate control pushbuttons

The setting access level allows the user to make any changes to any of the setting values and operate in test mode.

The command and setting passwords are not programmed when the device is shipped from the factory. When a command or setting password is set to null/not programmed, the password security feature is disabled.

The D90^{Plus} supports password entry from a local or remote connection. This means that four password types are possible: a local command password, remote command password, local settings password, and remote settings password.

Local access is access to settings or commands via the faceplate interface. This includes both keypad entry and the faceplate serial USB connection. Remote access is access to settings or commands via any rear Ethernet port. Any changes to local or remote passwords enables this functionality.

The rear RS485 port can be configured as either a local or remote connection through the serial port **Connection** setting.

When entering a settings or command password via Ethernet or the serial USB interface, you must enter the corresponding password level shown in the following table.

Table 42: Required password levels for various connection types

Connection type	Password required
Front panel USB	Local
Rear Ethernet port	Remote
Rear RS485 port, with Connection setting as "Local"	Local
Rear RS485 port, with Connection setting as "Remote"	Remote

Password security operation

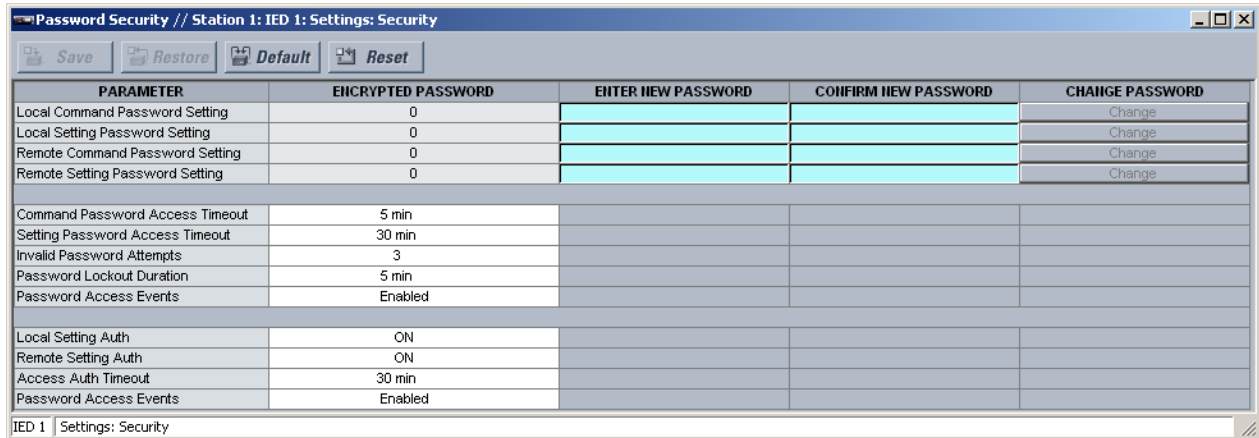
By default, when an incorrect command or setting password is entered three times within a three-minute time span, the **ACCESS DENIED** operand asserts and the D90^{PLUS} does not allow setting or command access for the next five minutes. The operand de-asserts after expiry of the five minute timeout.

The D90^{PLUS} provides a means to raise an alarm upon failed password entry. When password verification fails while accessing a password-protected level of the relay (either settings or commands), the **UNAUTHORIZED ACCESS** operand asserts. The operand can be programmed to raise an alarm via contact outputs or communications. This feature can be used to protect against both unauthorized and accidental access attempts. Therefore, to apply this feature with security, password-protect the command level. The operand does not generate events.

Password security settings

Select the **Settings > Security > Password Security** menu to open the password security settings window.

Figure 543: Password security configuration settings



Passwords can consist of up to 12 alphanumeric characters, excluding all non-printing characters as well as the "space" character (ASCII code 32), "`" (ASCII code 60), "\" (ASCII code 92), "/" (ASCII code 47), and "|" (ASCII code 124). Also, the password cannot be programmed as "0."

The settings are arranged into three groups: password settings, access supervision, and dual-permission security access.

The following password settings are available.

Local Command Password

Range: up to 12 visible ASCII characters (see restrictions outlined)

Default: null

The value of the local command password is specified here. For the password to be successfully entered, the values in the [Enter New Password](#) and [Confirm New Password](#) fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding [Encrypted Password](#) value.

Local Setting Password

Range: up to 12 visible ASCII characters (see restrictions outlined)

Default: null

The value of the local setting password is specified here. For the password to be successfully entered, the values in the [Enter New Password](#) and [Confirm New Password](#) fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding [Encrypted Password](#) value.

Remote Command Password

Range: up to 12 visible ASCII characters (see restrictions outlined)

Default: null

The value of the remote command password is specified here. For the password to be successfully entered, the values in the [Enter New Password](#) and [Confirm New Password](#) fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding [Encrypted Password](#) value.

Remote Setting Password

Range: up to 12 visible ASCII characters (see restrictions outlined)

Default: null

The value of the remote setting password is specified here. For the password to be successfully entered, the values in the [Enter New Password](#) and [Confirm New Password](#) fields must be identical.

If an entered password is lost (or forgotten), consult the factory with the corresponding [Encrypted Password](#) value.

The following access supervision settings allow the user to specify the length of inactivity required before returning to the restricted access level.

Command Password Access Timeout

Range: 5 to 480 minutes in steps of 1

Default: 5 minutes

This setting specifies the length of inactivity (no local or remote access) required to return to restricted access from the command password level.

Setting Password Access Timeout

Range: 5 to 480 minutes in steps of 1

Default: 30 minutes

This setting specifies the length of inactivity (no local or remote access) required to return to restricted access from the setting password level.

Invalid Password Attempts*Range: 2 to 5 in steps of 1**Default: 3*

This setting specifies the number of times an incorrect password can be entered within a three-minute time span before lockout occurs and applies to both the setting and command passwords.

When lockout occurs for the command password level, the [ACCESS LOC CMND DENY](#) and [ACCESS REM CMND DENY](#) communication operands are set to "On." These operands are returned to the "Off" state upon expiration of the lockout. Likewise, when lockout occurs for the setting password level, the [ACCESS LOC SETG DENY](#) and [ACCESS REM SETG DENY](#) communication operands are set to "On." These operands are also returned to the "Off" state upon expiration of the lockout.

Password Lockout Duration*Range: 5 to 60 minutes in steps of 1**Default: 5 minutes*

This setting specifies the time that the D90^{PLUS} locks out command password access after the number of invalid password entries specified by the [Invalid Password Attempts](#) setting has occurred.

Password Access Events*Range: Enabled, Disabled**Default: Disabled*

This setting enables and disables the logging of password access supervision events in the sequence of events recorder.

The following dual-permission security access settings prevent unauthorized or unintended upload of settings to a device through the local or remote interfaces.

Local Setting Authorization*Range: selected operands (see description below)**Default: ON*

This setting is used for local (front panel USB and RS485 interface) setting access supervision. Valid operand values are either "ON" (default) or any physical contact input value.

If this setting is "ON," then local setting access functions as normal; that is, a local setting password is required. If this setting value is any contact input operand, then the operand must be asserted (set as on) prior to providing the local setting password to gain setting access.

Remote Setting Authorization*Range: any communications operand or shared operand**Default: ON*

This setting is used for remote (Ethernet and RS485) setting access supervision.

If this setting is "ON" (the default setting), then remote setting access functions as normal; that is, a remote password is required. If this setting is "OFF," then remote setting access is blocked even if the correct remote setting password is provided. If this setting is any other operand, then the operand must be asserted (set as on) prior to providing the remote setting password to gain setting access.

Access Authorization Timeout

Range: 5 to 480 minutes in steps of 1

Default: 30 minutes

This setting specifies the timeout delay for setting access. This setting applies when the **Local Setting Authorization** or **Remote Setting Authorization** settings are programmed to any operand except "ON" or "OFF." The states of any selected operands are continuously monitored for an off-to-on transition. When this occurs, setting access is permitted and the timer programmed with this setting value is started. When this timer expires, setting access is immediately denied. If access is permitted and an off-to-on transition of the selected operand is detected, the timeout restarts. The status of this timer is updated every five seconds.

Password Access Events

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the logging of dual-permission security access events in the event recorder.

EnerVista security management system

The EnerVista security management system is a role-based access control (RBAC) system that allows a security administrator to manage the security privileges of multiple users. This allows for access control of UR^{Plus}-series devices by multiple personnel within a substation and conforms to the principles of RBAC as defined in ANSI INCITS 359-2004.

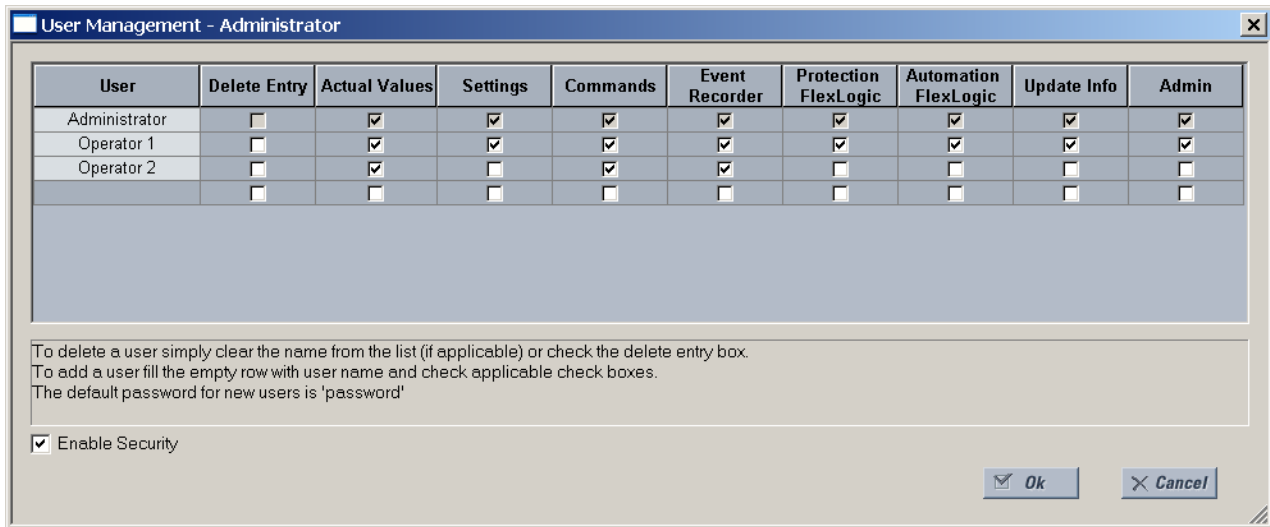
Enable the security management system

The EnerVista security system allows an administrator to manage access privileges of multiple users of EnerVista.

It is disabled by default to allow access to the device immediately after installation. When security is disabled, all users have administrator access. GE recommends enabling the EnerVista security before placing the device in service.

To enable the security system and require password use:

1. Select the **Security > User Management** menu to open the user management configuration window.



2. Enable the **Enable Security** check box in the lower-left corner to enable the security management system.
3. Click the **Ok** button.

Security is now enabled for the EnerVista software. Upon starting the software, users are now required to enter a username and password.



If you force password entry by using this feature, ensure that you know the Administrator password. If you do not know the password and are locked out of the software, contact GE Grid Solutions for the default password.

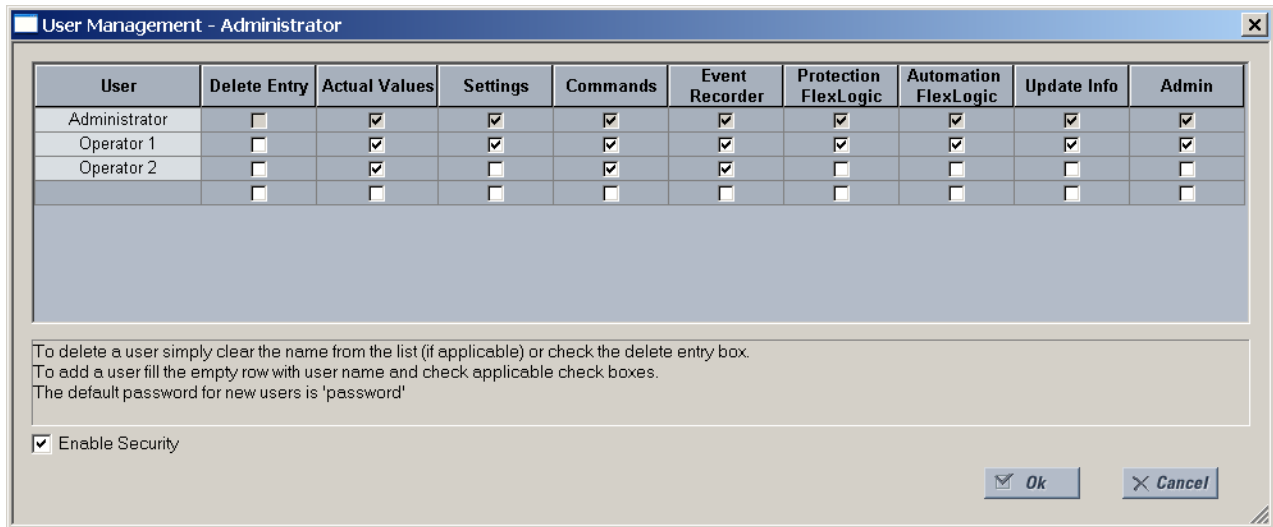
Add a new user

The following pre-requisites are required to add user accounts to the EnerVista security management system:

- The user adding the account must have administrator rights
- The EnerVista security management system must be enabled (previous section)

To add a user account:

1. Select the **Security > User Management** menu from the top menu to open the user management window.



2. Enter a username in the **User** field. The username must be four to 20 characters in length.
3. Select the user access rights by enabling the check box of one or more fields.

Table 43: Access rights summary

Field	Description
Delete Entry	Deletes the user account when exiting the user management window
Actual Values	Allows the user to read actual values
Settings	Allows the user to read setting values
Commands	Allows the user to execute commands
Event Recorder	Allows the user to use the digital fault recorder
Protection FlexLogic	Allows the user to read protection FlexLogic values
Automation Logic	Allows the user to read automation logic values
Update Info	Allows the user to write to any function to which they have read privileges. When any of the Settings , Event Recorder , Protection FlexLogic , and Automation Logic check boxes are enabled by themselves, the user is granted read access. When any of them are enabled in conjunction with the Update Info box, they are granted read and write access. The user is not granted write access to functions that are not enabled, even if the Update Info field is enabled.
Admin	When this check box is enabled, the user becomes an EnerVista UR ^{PLUS} Setup administrator and has all administrative rights. Exercise caution when granting administrator rights.

4. Click **OK** to add the user account to the system.

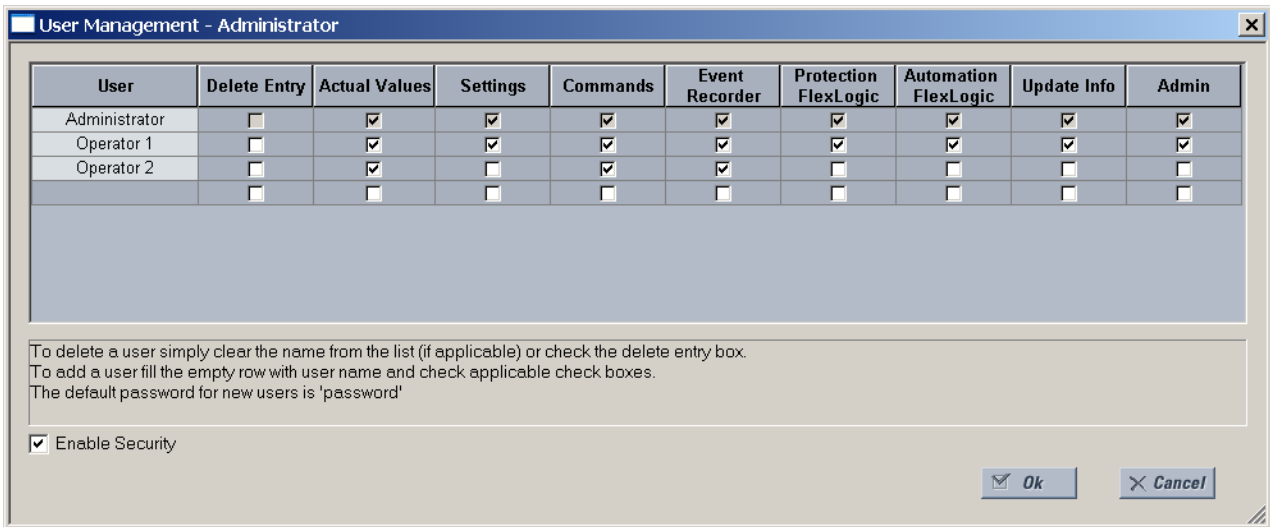
Modify user privileges

The following pre-requisites are required to modify user privileges in the EnerVista security management system:

- The user modifying the privileges must have administrator rights
- The EnerVista security management system must be enabled (the **Enable Security** check box enabled)

To modify user privileges:

1. Select the **Security > User Management** menu from the top menu to open the user management window.



2. Locate the username in the **User** field.
3. Modify the user access rights by enabling or disabling one or more of the check boxes.

Table 44: Access rights summary

Field	Description
Delete Entry	Deletes the user account when exiting the user management window
Actual Values	Allows the user to read actual values
Settings	Allows the user to read setting values
Commands	Allows the user to execute commands
Event Recorder	Allows the user to use the digital fault recorder
Protection FlexLogic	Allows the user to read protection FlexLogic values
Automation Logic	Allows the user to read automation logic values
Update Info	Allows the user to write to any function to which they have read privileges. When any of the Settings , Event Recorder , Protection FlexLogic , and Automation Logic check boxes are enabled by themselves, the user is granted read access. When any of them are enabled in conjunction with the Update Info box, they are granted read and write access. The user is not granted write access to functions that are not enabled, even if the Update Info field is enabled.
Admin	When this check box is enabled, the user becomes an EnerVista UR ^{PLUS} Setup administrator and has all administrative rights. Exercise caution when granting administrator rights.

4. Click **OK** to save the changes.

D90^{Plus} Line Distance Protection System

Chapter 14: Testing

This section outlines the D90^{Plus} testing features.

Test mode

The D90^{Plus} provides test settings to verify functionality using simulated conditions for contact inputs and outputs. To initiate test mode, the **Test Mode Function** setting must be “Enabled” and the operand assigned to the **Test Mode Initiate** setting must be set to logic 1.

Specifically, test mode is initiated as follows:

- To initiate test mode through the D90^{Plus} settings, set the **Test Mode Initiate** to “ON,” then start test mode by “Enabling” the **Test Mode Function** setting.
- To initiate test mode through a user-programmable condition, such as FlexLogic operand, set the **Test Mode Function** setting to “Enabled” and the **Test Mode Initiate** to the desired operand. The test mode starts when the selected operand assumes a logic 1 state.

When in test mode, the D90^{Plus} remains fully operational, allowing for various testing procedures. The only difference between normal operation and test mode is the behavior of the input and output contacts. The former can be forced to report as open or closed or remain fully operational; the latter can be forced to open, close, freeze, or remain fully operational. The response of the digital input and output contacts to the test mode is programmed individually for each input and output using the force contact inputs and force contact outputs test functions described in the following sections.

Force contact inputs

The force contact inputs feature provides a method to perform checks on the function of all contact inputs. Once enabled, the D90^{Plus} is placed into test mode, allowing this feature to override the normal function of contact inputs. All contact input operations return to normal when all settings for this feature are disabled.

Select the **Settings > Testing > Force Contact Inputs** menu to open the force contact inputs configuration window.

Figure 544: Force contact inputs configuration settings

SETTING	PARAMETER
Test Mode Function	Enabled
Test Mode Initiate	ON
BKR1 52a (G9)	Closed
BKR2 52a (G10)	Normal
Cont Ip 3 (G11)	Normal
Cont Ip 4 (G12)	Normal
Cont Ip 5 (K5)	Normal
Cont Ip 6 (K6)	Normal
Cont Ip 7 (K7)	Normal
Cont Ip 8 (K8)	Normal
DSC1 89a (K9)	Normal
DSC2 89a (K10)	Normal
Cont Ip 11 (K11)	Normal
Cont Ip 12 (K12)	Normal

Distance 1 Settings: Testing

The following settings are available.

Test Mode Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the test mode functionality for contact inputs.

Test Mode Initiate

Range: any FlexLogic operand

Default: ON

The test mode initiates when the operand assigned to this setting is logic 1.

Cont Ip 1, Cont Ip 2, ..., Cont Ip 12

Range: Normal, Open, Closed

Default: Normal

These settings allow the D90^{PLUS} contact inputs to respond to the test mode in the following ways:

- If set to “Normal,” the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. Select this value if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.
- If set to “Open,” the input is forced to report as opened (logic 0) for the entire duration of the test mode regardless of the voltage across the input terminals
- If set to “Closed,” the input is forced to report as closed (logic 1) for the entire duration of the test mode regardless of the voltage across the input terminals

These setting names reflect the programmed contact input names.

Force contact outputs

The force contact output feature allows relay contact outputs to be pre-programmed to respond to the test mode. These settings are applied two ways. First, external circuits can be tested by energizing or de-energizing contacts. Second, by controlling the output contact state, relay logic can be tested and undesirable effects on external circuits avoided.

Select the **Settings > Testing > Force Contact Outputs** menu to open the force contact outputs configuration window.

Figure 545: Force contact outputs configuration settings

SETTING	PARAMETER
Test Mode Function	Enabled
Test Mode Initiate	ON
BKR1 TR COIL (G1)	Normal
BKR1 CL COIL (G2)	Normal
BKR2 TR COIL (G3)	Normal
BKR2 CL COIL (G4)	Normal
DSC1 TR COIL (G5)	Normal
DSC1 CL COIL (G6)	Normal
DSC2 TR COIL (G7)	Normal
DSC2 CL COIL (G8)	Normal
Cont Op 9 (K1)	Normal
Cont Op 10 (K2)	Normal
Cont Op 11 (K3)	Normal
Cont Op 12 (K4)	Normal

The following settings are available.

Test Mode Function

Range: Enabled, Disabled

Default: Disabled

This setting enables and disables the test mode functionality for contact outputs.

Test Mode Initiate

Range: any FlexLogic operand

Default: ON

The test mode initiates when the operand assigned to this setting is logic 1.

Cont Op 1, Cont Op 2, ..., Cont Op 12

Range: Normal, Energized, De-energized, Freeze

Default: Normal

These settings allow the D90^{Plus} contact outputs to respond to the test mode in the following ways:

- If set to "Normal," the contact output remains fully operational. It operates when its control operand is logic 1 and resets when its control operand is logic 0.
- If set to "Energized," the output closes and remains closed for the entire duration of the test mode, regardless of the status of the operand configured to control the output contact
- If set to "De-energized," the output opens and remain open for the entire duration of the test mode regardless of the status of the operand configured to control the output contact
- If set to "Freeze," the output retains its position from before entering the test mode, regardless of the status of the operand configured to control the output contact

These setting names reflect the programmed contact output names.

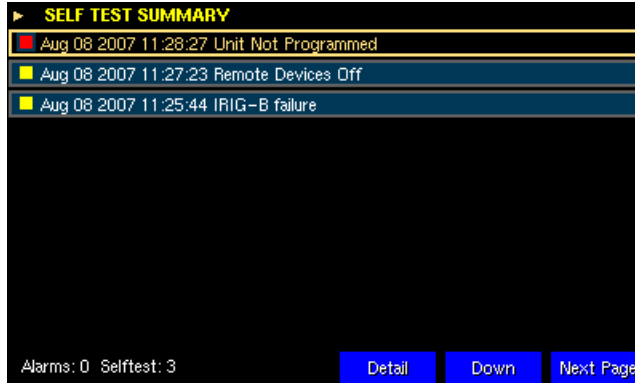
Self-tests

The D90^{Plus} performs a number of self-test checks to ensure device integrity. When a self-test error occurs, an item displays in the self-test summary on the annunciator. All errors record an event in the event recorder.

Self-test error messages

The self-test error messages display on the annunciator panel. Error messages are accessible from the self-test tab. The self-test tab illuminates when there are errors to report.

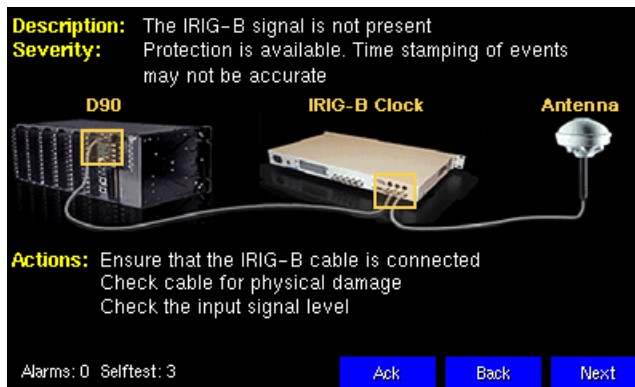
Figure 546: Typical self-test error page



There are three soft-keys associated with the self-test summary page.

- The **Next Page** soft-key cycles through the pages of alarms and to the error messages page. If there are more errors present than can be displayed, scroll bars appear to notify the user to scroll beyond the screen to view more error messages.
- The **Down** soft-key allows the user to cycle through the self-test error messages from top to bottom. A white frame borders the selected self-test error message.
- The **Detail** soft-key displays additional details of the selected error message. A definition of problem, a graphical indication, and some possible solutions display. The following figure shows details about the IRIG-B FAILURE self-test error message.

Figure 547: IRIG-B failure message details



Self-test errors are classed as minor errors and major errors.

The major self-test error messages are indicated in red on the annunciator display and are described as follows.

AC SLOT F FIRMWARE MISMATCH

AC SLOT J FIRMWARE MISMATCH

Description: There a firmware mismatch between the AC card in the indicated slot and the CPU.

Severity: Protection is not available, and relay is not operational.

If either message appears, contact GE Grid Solutions.

AC SLOT F NOT CALIBRATED**AC SLOT J NOT CALIBRATED**

Description: The AC module in the indicated slot is not properly calibrated.

Severity: Device is temporarily out-of-service.

If either message appears, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

AC SLOT F TROUBLE**AC SLOT J TROUBLE**

Description: The AC module in the indicated slot is not operational.

Severity: Device is temporarily out-of-service.

If either message appears, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

AUTOMATION LOGIC ERROR

Description: There is an error within an automation logic equation.

Severity: Protection is not available, and relay is not operational.

If this message appears, modify the automation logic to make it valid and reload.

CPU CARD TROUBLE

Description: The CPU module in the indicated slot is not operational.

Severity: Device is temporarily out-of-service

If this message appears, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

EXTERNAL IO 1 COMMUNICATIONS FAILURE**EXTERNAL IO 2 COMMUNICATIONS FAILURE**

Description: A communications error has been encountered on the external input/output device.

Severity: Protection is not available.

If this message appears, check all external input/output modules against the order code. Ensure that they are connected properly, then recycle power.

EXTERNAL IO 1 EQUIPMENT MISMATCH**EXTERNAL IO 2 EQUIPMENT MISMATCH**

Description: The configuration of external input/output equipment does not match the order code stored in the CPU.

Severity: Protection is not available.

If this message appears, check all external input/output modules against the order code. Ensure that they are connected properly, then recycle power.

EQUIPMENT MISMATCH

Description: The configuration of modules does not match the order code stored in the CPU.

Severity: Protection is not available.

If this message appears, check all modules against the order code. Ensure that they are inserted properly, then recycle power.

IO SLOT E FIRMWARE MISMATCH**IO SLOT F FIRMWARE MISMATCH****IO SLOT G FIRMWARE MISMATCH****IO SLOT H FIRMWARE MISMATCH****IO SLOT J FIRMWARE MISMATCH****IO SLOT K FIRMWARE MISMATCH**

Description: There a firmware mismatch between the input/output card in the indicated slot and the CPU.

Severity: Protection is not available, and relay is not operational.

If any of these messages appear, contact GE Grid Solutions.

IO SLOT E NOT CALIBRATED
IO SLOT F NOT CALIBRATED
IO SLOT G NOT CALIBRATED
IO SLOT H NOT CALIBRATED
IO SLOT J NOT CALIBRATED
IO SLOT K NOT CALIBRATED

Description: The input/output module in the indicated slot is not properly calibrated.

Severity: Device is temporarily out-of-service.

If any of these messages appear, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

IO SLOT E TROUBLE
IO SLOT F TROUBLE
IO SLOT G TROUBLE
IO SLOT H TROUBLE
IO SLOT J TROUBLE
IO SLOT K TROUBLE

Description: An input/output module in the indicated slot is not operational.

Severity: Device is temporarily out-of-service.

If any of these messages appear, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

PROTECTION LOGIC ERROR

Description: There is an error within a protection FlexLogic equation.

Severity: Protection is not available, and relay is not operational.

If this message appears, modify the protection FlexLogic to make it valid and reload.

SETTINGS FILE ERROR

Description: The device contains invalid setting values.

Severity: Protection is not available.

If this message appears after an order code update or firmware upgrade, clear the message and load settings into the D90^{PLUS}. In all other cases, contact GE Grid Solutions.

SLOT B FIRMWARE MISMATCH

SLOT C FIRMWARE MISMATCH

Description: There a firmware mismatch between the card in the indicated slot and the CPU.

Severity: Protection is not available, and relay is not operational.

If either message appears, contact GE Grid Solutions.

SLOT B TROUBLE

SLOT C TROUBLE

Description: The module in the indicated slot is not operational.

Severity: Device is temporarily out-of-service.

If either message appears, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

SYSTEM EXCEPTION

Description: An internal error has occurred.

Severity: Device is temporarily out-of-service

If this message appears, reset the alarm. If the alarm recurs, contact GE Grid Solutions.

UNIT NOT PROGRAMMED

Description: The unit is configured as not programmed.

Severity: Protection is not available

If this message appears, confirm that the unit has the proper settings. Change the Relay Settings value to "Programmed" in the **Settings > Protection > Power System > Installation** menu.

The minor self-test error messages are indicated in yellow on the annunciator display and are described as follows.

AC SLOT F HIGH TEMP**AC SLOT J HIGH TEMP**

Description: The ambient temperature is outside the specifications for the AC card in the indicated slot.

Severity: Relay remains operational.

If this message appears, ensure proper ventilation.

CH 1 DIRECT DEVICE OFF**CH 2 DIRECT DEVICE OFF**

Description: A direct device is specified in the configuration but is not connected to the network. This self-test should occur within 2 seconds of disconnecting the device.

Severity: Protection is available. Direct input/output messaging with the offline device is not available.

If this message appears, check that all devices that are connected to the direct input/output network are properly configured. Check the direct input/output wiring.

CH 1 DIRECT RING BREAK**CH 2 DIRECT RING BREAK**

Description: The direct input/output settings are configured for a ring, but the connection is not in a ring. This self-test is asserted approximately 2 seconds after a disconnection occurs in a ring configuration.

Severity: Protection and direct input/output messaging is available. However, there is no redundant path available.

If this message appears, check the direct input/output configuration and wiring.

COMMUNICATION CARD TROUBLE

Description: An error has been encountered on the communications module.

Severity: Protection is available.

If this message appears, update the order code to clear the self-test error.

COMM HIGH TRAFFIC

Description: The D90^{PLUS} is actively limiting IP bandwidth usage.

Severity: Protection is available.

This message indicates that the D90^{PLUS} is actively limiting bandwidth usage in one or more Ethernet ports through the network filtering settings.

DELAYED AUTOMATION EXECUTION

Description: Execution of the automation logic is longer than specified.

Severity: Protection is available. Automation logic may not produce expected results.

If this message appears, review the automation logic to confirm correct programming. Move less critical tasks to an automation block with a slower scan.

FILE SYSTEM TROUBLE

Description: System files are missing on the flash disk during the boot process or files are deleted or modified after the system was booted.

Severity: Protection is available.

If this message appears, repeat the firmware upgrade process.

FRONT PANEL MISMATCH

Description: The order code does not match the front panel type.

Severity: Protection is available.

If this message appears, update the order code to clear the self-test error.

FRONT PANEL TROUBLE

Description: An error has been encountered on the front panel.

Severity: Protection is available.

If this message appears, update the order code to clear the self-test error.

HIGH TEMPERATURE

Description: The ambient temperature is outside the specifications.

Severity: Relay remains operational.

If this message appears, ensure proper ventilation.

IR CH 1 FAIL**IR CH 2 FAIL**

Description: These self-tests are caused by any one of the following: low Rx power (fiber option only), loss of signal alarm for fiber and G.703 options or RS422 clock problem (no clock or incorrect clock), yellow bit alarm (C37.94 option only), optical transceiver SPI interface failure (fiber option only), or Tx Fault (transmitter failure, monitored by the transceiver).

Severity: Protection is available. Timestamping of events can be inaccurate.

If either message appears, check the inter-relay communications wiring. If the failure persists, contact GE Grid Solutions.

IRIG-B FAILURE

Description: The IRIG-B input signal is not present.

Severity: Protection is available. Timestamping of events may not be accurate.

If this message appears, ensure that the IRIG-B receiver is operational and properly configured. Ensure that the IRIG-B cable is connected. Check cable integrity (that is, look for physical damage or perform a continuity test). Check the input signal level.

NON-VOLATILE DATA LOST

Description: Non-volatile data was lost.

Severity: Protection is available; however, some data loss may be encountered.

If this message appears, check all logs for lost or corrupt data. This includes the event recorder, transient recorder, fault reports, disturbance recorder, data logger, and phasor measurement unit recorder.

OVERFLOW RESULT

Description: An overflow error has occurred during automation logic execution.

Severity: Automation logic execution is not suspended, and protection is still available.

Automation logic implements saturated arithmetic operations. An operation resulted in a saturated result while running automation logic. Execution continues with the saturated result. Analyze and correct the automation logic equations.

POWER SUPPLY TROUBLE

Description: The power supply module has a problem.

Severity: Protection is available; however, power supply failure can occur. The 48 volt supply can also be impacted.

If this message appears, check that the voltage at the power supply input is within limits. If acceptable, check that the 48 volt supply is healthy. If not acceptable, contact GE Grid Solutions.

REMOTE DEVICES OFF

Description: A remote device is specified in the configuration for GOOSE messaging but is not connected to the network.

Severity: Protection is available. GOOSE messaging with the offline device is not available.

If this message appears, check that all devices that are specified for GOOSE messaging are connected to the network, are functioning properly, and are configured correctly.

SNTP ERROR FAILURE

Description: The SNTP server is not responding.

Severity: Protection is available. Timestamping of events can be inaccurate.

If this message appears, check that the SNTP server is operational and configured correctly. Check for Ethernet LAN problems.

UNDEFINED RESULT

Description: An error has occurred during automation logic execution.

Severity: Automation logic execution is not suspended, and protection is still available.

Analyze and correct the automation logic equations.

Self-test logic operands

The following self-test logic operands are available for the D90^{Plus}. They are listed alphabetically by operand syntax.

Self-test error logic operands

AC SLOT F HIGH TEMP.....	Asserted when the AC SLOT F HIGH TEMP self-test error message is issued.
AC SLOT F TROUBLE.....	Asserted when the AC SLOT F TROUBLE self-test error message is issued.
AC SLOT J FMW MSMTCH.....	Asserted when the AC SLOT J FIRMWARE MISMATCH self-test error message is issued.
AC SLOT J HIGH TEMP.....	Asserted when the AC SLOT J HIGH TEMP self-test error message is issued.
AC SLOT J NOT CAL.....	Asserted when the AC SLOT J NOT CALIBRATED self-test error message is issued.
AC SLOT J TROUBLE.....	Asserted when the AC SLOT J TROUBLE self-test error message is issued.
ANY MAJOR ERROR.....	Asserted when any major self-test error message is issued.
ANY MINOR ERROR.....	Asserted when any minor self-test error message is issued.
AUTOMATION LOGIC ERR.....	Asserted when the AUTOMATION LOGIC ERROR self-test error message is issued.
CH1 DIR IO RING BRK.....	Asserted when the CH1 DIRECT IO RING BREAK self-test error message is issued.
CH2 DIR IO RING BRK.....	Asserted when the CH2 DIRECT IO RING BREAK self-test error message is issued.
CPU CARD TROUBLE.....	Asserted when the CPU CARD TROUBLE self-test error message is issued.
DELAYED AUTOMATION.....	Asserted when the DELAYED AUTOMATION self-test error message is issued.
EQUIPMENT MISMATCH.....	Asserted when the EQUIPMENT MISMATCH self-test error message is issued.
FILE SYSTEM TROUBLE.....	Asserted when the FILE SYSTEM TROUBLE self-test error message is issued.
FRONT PANEL MISMATCH.....	Asserted when the FRONT PANEL MISMATCH self-test error message is issued.
HIGH TEMPERATURE.....	Asserted when the HIGH TEMPERATURE self-test error message is issued.
IO SLOT E FMW MSMTCH.....	Asserted when the IO SLOT E FIRMWARE MISMATCH self-test error message is issued.
IO SLOT E NOT CAL.....	Asserted when the IO SLOT E NOT CALIBRATED self-test error message is issued.

IO SLOT E TROUBLE.....	Asserted when the IO SLOT E TROUBLE self-test error message is issued.
IO SLOT F FMW MSMTCH.....	Asserted when the IO SLOT F FIRMWARE MISMATCH self-test error message is issued.
IO SLOT F NOT CAL	Asserted when the IO SLOT F NOT CALIBRATED self-test error message is issued.
IO SLOT F TROUBLE.....	Asserted when the IO SLOT F TROUBLE self-test error message is issued.
IO SLOT G FMW MSMTCH.....	Asserted when the IO SLOT G FIRMWARE MISMATCH self-test error message is issued.
IO SLOT G NOT CAL	Asserted when the IO SLOT G NOT CALIBRATED self-test error message is issued.
IO SLOT G TROUBLE.....	Asserted when the IO SLOT G TROUBLE self-test error message is issued.
IO SLOT H FMW MSMTCH.....	Asserted when the IO SLOT H FIRMWARE MISMATCH self-test error message is issued.
IO SLOT H NOT CAL	Asserted when the IO SLOT H NOT CALIBRATED self-test error message is issued.
IO SLOT H TROUBLE.....	Asserted when the IO SLOT H TROUBLE self-test error message is issued.
IO SLOT K FMW MSMTCH	Asserted when the IO SLOT K FIRMWARE MISMATCH self-test error message is issued.
IO SLOT K NOT CAL.....	Asserted when the IO SLOT K NOT CALIBRATED self-test error message is issued.
IO SLOT K TROUBLE.....	Asserted when the IO SLOT K TROUBLE self-test error message is issued.
OVERFLOW RESULT	Asserted when the OVERFLOW RESULT self-test error message is issued.
PROTECTION LOGIC ERR.....	Asserted when the PROTECTION LOGIC ERROR self-test error message is issued.
REMOTE DEVICES OFF.....	Asserted when the REMOTE DEVICES OFF self-test error message is issued.
SETTINGS ERR.....	Asserted when the SETTINGS ERROR self-test error message is issued.
SLOT B TROUBLE	Asserted when the SLOT B TROUBLE self-test error message is issued.

D90^{Plus} Line Distance Protection System

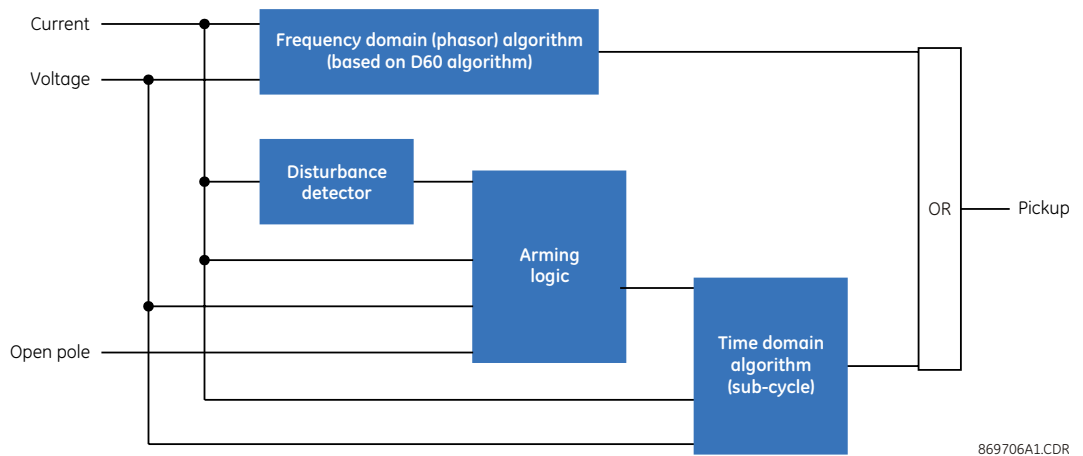
Chapter 15: Theory of operation

This chapter outlines advanced information on operation.

Distance elements

The distance element is composed of two separate algorithms. The first is a conventional frequency domain (phasor) algorithm based on the UR-series D60 implementation. The second is a time domain algorithm that achieves sub-cycle operating times. The two algorithms run in parallel and each can independently issue a trip command.

Figure 548: D90^{Plus} distance algorithm



Distance element arming logic

The distance element arming logic grants permission to the time domain algorithm only if *all* of the following conditions are met for five cycles prior to a disturbance:

- Zero-sequence current is less than 0.2 pu
- Negative-sequence current is less than 0.2 pu
- Zero-sequence voltage is less than 0.2 pu
- Negative-sequence voltage is less than 0.2 pu

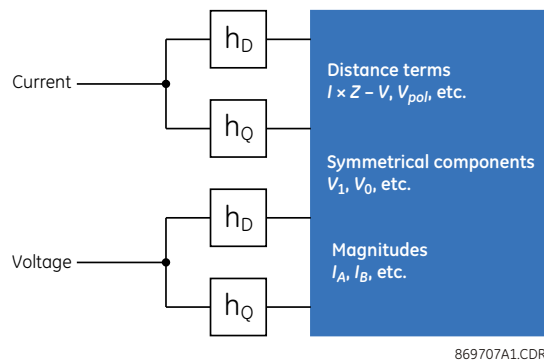
- Positive-sequence voltage is between 0.8 and 1.2 pu
- Source frequency differs from tracking frequency by less than 0.5 Hz
- Source frequency differs from nominal frequency by less than 5.5 Hz
- No open pole condition exists

If these conditions are not met, then the time-domain algorithm is not armed and the D90^{PLUS} trips from the frequency domain algorithm if required. If the conditions are met, then the arming logic opens a two-cycle window that begins when the disturbance is detected. During this two-cycle period, the time domain algorithm operates if required. After this window expires, the time domain algorithm cannot be re-armed for another five cycles.

Distance element time domain algorithm

The time domain algorithm uses virtually the same comparators to shape the impedance zones. Short-window orthogonal filters (h_D and h_Q) are used to calculate direct and quadrature axis quantities for voltage and current in the time domain. These signals then are used to calculate symmetrical components, fast magnitudes (for example, current supervision), symmetrical components, and operating and polarizing quantities for comparators. A particular operating characteristic (mho, quadrilateral, and so on) is composed of several two-input comparators. The time domain and frequency domain algorithms each utilize the same number of comparators and the same input signals as described in the [Distance element characteristic summary](#) on page 634. The only difference between the two algorithms is in the formation of the input signals and the comparators themselves.

Figure 549: Time domain algorithm



869707A1.CDR

Distance element frequency domain algorithm

The D90^{PLUS} samples AC input signals at 128 samples per power system cycle. A fast and accurate frequency tracking mechanism ensures accurate filtering and phasor estimation during off-nominal frequency conditions.

The frequency domain phasor estimation process for both currents and voltages is based on the commonly used Fourier algorithm. Due to the different nature of signal distortions in the current and voltage signals, digital pre-filtering algorithms have been designed and optimized separately for the current and voltage channels.

The current signals are pre-filtered using an improved digital MIMIC filter. The filter removes effectively the DC components, guaranteeing transient overshoot below 2% regardless of the initial magnitude and time constant of the components. The filter has significantly better frequency response for higher frequencies as compared to a classical MIMIC filter. This is possible without introducing any significant phase delay thanks to the high sampling rate used by the D90^{PLUS}.

The voltage signals are pre-filtered using a special digital filter designed to cope with CVT transients. This patented filter combines filtering and memory actions enabling the relay to cope with CVT noise under high source impedance ratios (SIRs). The filter controls underestimation of the fault voltage magnitude to less than 1% of the nominal and prevents certain phase angle anomalies that can be encountered under heavy CVT noise and high SIRs.

The frequency domain algorithm uses phase angle comparators to shape the operating characteristics as described in [Distance characteristics](#) on page 630. The voltage and current phasors are estimated using optimized techniques as explained in the following section.

Distance supervision

The phase and ground distance elements use memory voltage for polarization. Additional supervising functions—different for ground and phase distance zones—complement a classical mho characteristic to enhance directional integrity and reach accuracy.

- To avoid overreaching during resistive faults under heavy pre-fault load conditions, the ground distance elements utilize a load-adaptive (zero-sequence polarized) reactance characteristic to supervise the base mho characteristic
- Both negative and zero-sequence currents are compared with the memory voltage to enhance directional integrity of the ground distance elements
- It is well-known that ground distance elements—as per the principle of distance relaying—can have limited accuracy during double-line-to-ground faults. To prevent maloperation in such cases, the ground elements are blocked by an extra *fault-type comparator* that utilizes the phase angle between the negative-sequence and zero-sequence currents.
- The phase distance elements use reactance and memory polarized directional characteristics to supervise the mho characteristic
- Both ground and phase distance elements have the current supervision functions built-in

The quadrilateral distance characteristic uses the reactance, directional, and current supervising functions described above. Adjustable right and left blinders to both resistive and angular positions complete the characteristic.

Additional information regarding the distance characteristics is found in [Distance characteristics](#) on page 630. An example of analysis of the steady-state operation of the distance elements is found in [Distance elements analysis](#) on page 637.

The D90^{PLUS} provides three zones of distance protection. All zones are identical in terms of settings. Ground zones 1 through 3 have an extra zero-sequence directional supervision implemented for their time-delayed operation after the memory expires. Consequently, zone 1 is recommended as an underreaching element, and zones 2 through 3 are recommended as overreaching elements and for time-delayed tripping.

Offset ground directional overcurrent functions are used as an optional supplement of the ground distance protection for pilot-aided schemes. The elements are described in detail in [Ground directional overcurrent theory](#) on page 647.

An adaptive distance reach control is provided to cope with the overreaching and sub-synchronous oscillations when applied to, or in a near vicinity of, series compensated lines. For more, see [Series compensated lines](#) on page 649.

Distance characteristics

The relay shapes its distance characteristics using phase angle comparators and estimated voltage and current phasors. The following distance characteristic definitions pertain to all phase and ground distance functions:

Phase A, B, and C current phasors

$$I_A, I_B, I_C$$

Ground current from a parallel line

$$I_G$$

Phase A to ground, phase B to ground, and phase C to ground voltage phasors

$$V_A, V_B, V_C$$

Positive-sequence phasor of () term derived from the phase quantities

$$()_1$$

Negative-sequence phasor of () term derived from the phase quantities

$$()_2$$

Zero-sequence phasor of () term derived from the phase quantities

$$()_0$$

Memorized value of the () quantity

$$()_M$$

Reach impedance

$$Z = \text{Reach} \angle \text{RCA}$$

Reverse reach impedance for non-directional applications

$$Z_{REV} = \text{Reverse Reach} \angle \text{Reverse Reach RCA} + 180^\circ$$

Directional characteristic impedance

$$Z_D = 1 \angle \text{Directional RCA}$$

Right blinder characteristic impedance

$$Z_R = \text{Right Blinder} \times \sin(\text{Right Blinder RCA}) \times 1 \angle (\text{Right Blinder RCA} - 90^\circ)$$

Left blinder characteristic impedance

$$Z_L = \text{Left Blinder} \times \sin(\text{Left Blinder RCA}) \times 1 \angle (\text{Left Blinder RCA} + 90^\circ)$$

Zero-sequence compensating factor

$$K_0 = (Z_0/Z_1 \text{ Magnitude} \angle Z_0/Z_1 \text{ Angle}) - 1$$

Mutual zero-sequence compensating factor

$$K_{0M} = \frac{1}{3} \times Z_{0M}/Z_1 \text{ Magnitude} \angle Z_{0M}/Z_1 \text{ Angle}$$

Non-homogeneity angle setting

$$\Theta = \text{Non-Homogeneous Angle}$$

Directional mho characteristic

The dynamic 100% memory polarized mho characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

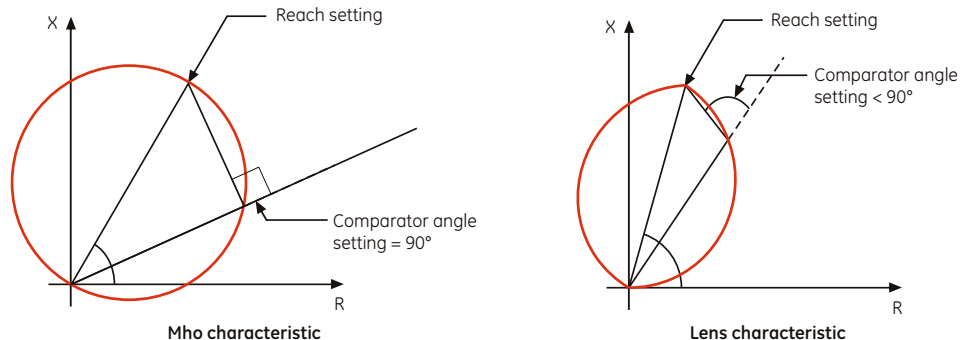
Table 45: Directional mho characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z - (V_A - V_B)$	$(V_A - V_B)_1M$
BC phase element	$(I_B - I_C) \times Z - (V_B - V_C)$	$(V_B - V_C)_1M$
CA phase element	$(I_C - I_A) \times Z - (V_C - V_A)$	$(V_C - V_A)_1M$

Element	Value 1	Value 2
A ground element	$I_A \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A$	V_{A_1M}
B ground element	$I_B \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_B$	V_{B_1M}
C ground element	$I_C \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_C$	V_{C_1M}

The limit angle of the comparator is adjustable. This allows the user to shape the characteristic as a mho or a lens as shown in the following figure. The memory-polarized mho characteristic has excellent built-in directional integrity. See the Memory Polarization section later for details.

Figure 550: Mho and lens characteristics



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Non-directional mho characteristic

The non-directional mho characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-1: Non-directional mho characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z - (V_A - V_B)$	$(V_A - V_B) - (I_A - I_B) \times Z_{REV}$
BC phase element	$(I_B - I_C) \times Z - (V_B - V_C)$	$(V_B - V_C) - (I_B - I_C) \times Z_{REV}$
CA phase element	$(I_C - I_A) \times Z - (V_C - V_A)$	$(V_C - V_A) - (I_C - I_A) \times Z_{REV}$
A ground element	$I_A \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A$	$V_A - (I_A \times Z_{REV} + I_{L0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV})$
B ground element	$I_B \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_B$	$V_B - (I_B \times Z_{REV} + I_{L0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV})$
C ground element	$I_C \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_C$	$V_C - (I_C \times Z_{REV} + I_{L0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV})$

Mho reactance characteristic for directional applications

The mho reactance characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-2: Mho reactance characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z - (V_A - V_B)$	$(I_A - I_B) \times Z$
BC phase element	$(I_B - I_C) \times Z - (V_B - V_C)$	$(I_B - I_C) \times Z$
CA phase element	$(I_C - I_A) \times Z - (V_C - V_A)$	$(I_C - I_A) \times Z$
A ground element	$I_A \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A$	$(I_{L0}) \times Z$
B ground element	$I_B \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_B$	$(I_{L0}) \times Z$
C ground element	$I_C \times Z + I_{L0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_C$	$(I_{L0}) \times Z$

If the mho characteristic is selected, the limit angle of the comparator is adjustable concurrently with the limit angle of the mho characteristic, resulting in a tent shape complementing the lens characteristic being effectively applied.

Quadrilateral reactance characteristic for directional applications

The quadrilateral reactance characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-3: Quadrilateral reactance characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z - (V_A - V_B)$	$(I_A - I_B) \times Z$
BC phase element	$(I_B - I_C) \times Z - (V_B - V_C)$	$(I_B - I_C) \times Z$
CA phase element	$(I_C - I_A) \times Z - (V_C - V_A)$	$(I_C - I_A) \times Z$
A ground element	$I_A \times Z + I_{0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A$	$(j \times I_{0} \text{ or } j \times I_{2A}) \times e^{j\theta}$
B ground element	$I_B \times Z + I_{0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_B$	$(j \times I_{0} \text{ or } j \times I_{2B}) \times e^{j\theta}$
C ground element	$I_C \times Z + I_{0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_C$	$(j \times I_{0} \text{ or } j \times I_{2C}) \times e^{j\theta}$

The ground elements are polarized from either zero-sequence or negative-sequence current as per the programmed settings to maximize performance in non-homogeneous systems. The polarizing current is shifted additionally by the user-programmable non-homogeneity correction angle.

Reverse quadrilateral reactance characteristic for non-directional applications

The reverse quadrilateral reactance characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-4: Reverse quadrilateral reactance characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z_{REV} - (V_A - V_B)$	$(I_A - I_B) \times Z_{REV}$
BC phase element	$(I_B - I_C) \times Z_{REV} - (V_B - V_C)$	$(I_B - I_C) \times Z_{REV}$
CA phase element	$(I_C - I_A) \times Z_{REV} - (V_C - V_A)$	$(I_C - I_A) \times Z_{REV}$
A ground element	$I_A \times Z_{REV} + I_{0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV} - V_A$	$(j \times I_{0} \text{ or } j \times I_{2A}) \times e^{j(180^\circ + \theta)}$
B ground element	$I_B \times Z_{REV} + I_{0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV} - V_B$	$(j \times I_{0} \text{ or } j \times I_{2B}) \times e^{j(180^\circ + \theta)}$
C ground element	$I_C \times Z_{REV} + I_{0} \times K_0 \times Z_{REV} + I_G \times K_{0M} \times Z_{REV} - V_C$	$(j \times I_{0} \text{ or } j \times I_{2C}) \times e^{j(180^\circ + \theta)}$

The ground elements are polarized from either zero-sequence or negative-sequence current as per the programmed settings to maximize performance in non-homogeneous systems. The polarizing current is shifted additionally by the user-programmable non-homogeneity correction angle.

Directional characteristic

The directional characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-5: Directional characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z_D$	$(V_A - V_B)_{1M}$
BC phase element	$(I_B - I_C) \times Z_D$	$(V_B - V_C)_{1M}$
CA phase element	$(I_C - I_A) \times Z_D$	$(V_C - V_A)_{1M}$

Element	Value 1	Value 2
A ground element	$I_{L0} \times Z_D$	V_{A_1M}
	$I_{A_2} \times Z_D$	V_{A_1M}
B ground element	$I_{L0} \times Z_D$	V_{B_1M}
	$I_{B_2} \times Z_D$	V_{B_1M}
C ground element	$I_{L0} \times Z_D$	V_{C_1M}
	$I_{C_2} \times Z_D$	V_{C_1M}

The characteristic and limit angles of the directional comparator are adjusted independently from the mho and reactance comparators. The directional characteristic improves the directional integrity of the distance functions.

Right and left blinder characteristics

The right blinder characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-6: Right blinder characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z_R - (V_A - V_B)$	$(I_A - I_B) \times Z_R$
BC phase element	$(I_B - I_C) \times Z_R - (V_B - V_C)$	$(I_B - I_C) \times Z_R$
CA phase element	$(I_C - I_A) \times Z_R - (V_C - V_A)$	$(I_C - I_A) \times Z_R$
A ground element	$I_A \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R - V_A$	$I_A \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R$
B ground element	$I_B \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R - V_B$	$I_B \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R$
C ground element	$I_C \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R - V_C$	$I_C \times Z_R + I_{L0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R$

Similarly, the left right blinder characteristic is achieved by checking the angle between the two values for the various phase and ground distance elements shown in the table.

Table 15-7: Left blinder characteristic angle calculation parameters

Element	Value 1	Value 2
AB phase element	$(I_A - I_B) \times Z_L - (V_A - V_B)$	$(I_A - I_B) \times Z_L$
BC phase element	$(I_B - I_C) \times Z_L - (V_B - V_C)$	$(I_B - I_C) \times Z_L$
CA phase element	$(I_C - I_A) \times Z_L - (V_C - V_A)$	$(I_C - I_A) \times Z_L$
A ground element	$I_A \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L - V_A$	$I_A \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L$
B ground element	$I_B \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L - V_B$	$I_B \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L$
C ground element	$I_C \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L - V_C$	$I_C \times Z_L + I_{L0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L$

The blinders apply to the quadrilateral characteristic only.

Fault type characteristic

The fault type characteristic is achieved by checking the angle between the two values for the elements shown in the table. This characteristic applies to ground distance elements only.

Table 15-8: Fault type characteristic angle calculation parameters

Element	Value 1	Value 2
A ground element	I_{L0}	I_{A_2}
B ground element	I_{L0}	I_{B_2}
C ground element	I_{L0}	I_{C_2}

The limit angle of the comparator is not adjustable and equals 50°. The fault type characteristic is intended to block ground distance elements during double-line-to-ground faults.

Zero-sequence directional characteristic

The extra zero-sequence characteristic is achieved by checking the angle between the two values for the elements shown in the table. This characteristic applies to ground distance zones 2 and 3 only.

Table 15-9: Zero-sequence directional characteristic angle calculation parameters

Element	Value 1	Value 2
A ground element	$I_0 \times Z_D$	$-V_0$
B ground element	$I_0 \times Z_D$	$-V_0$
C ground element	$I_0 \times Z_D$	$-V_0$

The limit angle of the comparator is not adjustable and equals 90°. The zero-sequence directional characteristic improves directional integrity for time-delayed operations after the memory expires.

Overcurrent supervision

The overcurrent supervision function responds to the following currents.

Table 15-10: Overcurrent supervision parameters

Element	Current
AB phase element	$(I_A - I_B) / \sqrt{3}$
BC phase element	$(I_B - I_C) / \sqrt{3}$
CA phase element	$(I_C - I_A) / \sqrt{3}$
A, B, and C ground elements	$3 \times I_0$

Distance element characteristic summary

The following tables summarize the characteristics of the distance elements.

Table 15-11: Directional mho phase distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Variable mho	$I \times Z - V$	V_{1M}	Comparator limit
Reactance	$I \times Z - V$	$I \times Z$	Comparator limit
Directional	$I \times Z_D$	V_{1M}	Directional comparator limit

Table 15-12: Directional mho ground distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Variable mho	$I \times Z - V$	V_{1M}	Comparator limit
Reactance	$I \times Z - V$	$I \times Z$	Comparator limit
Directional	$I_0 \times Z_D$	V_{1M}	Directional comparator limit
	$I_2 \times Z_D$	V_{1M}	Directional comparator limit (removed when $3I_0 >$ overcurrent supervision and $I_2 <$ cutoff)
Fault type	I_0	I_2	50° (removed during open pole conditions or when $3I_0 >$ overcurrent supervision and $I_2 <$ cutoff)

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Zero-sequence	$I_0 \times Z_D$	$-V_0$	90° (zones 2 and 3 only; removed during open pole conditions)

Table 15-13: Directional quadrilateral phase distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Reactance	$I \times Z - V$	$I \times Z$	Comparator limit
Directional	$I \times Z_D$	V_{1M}	Directional comparator limit
Right blinder	$I \times Z_R - V$	$I \times Z_R$	90°
Left blinder	$I \times Z_L - V$	$I \times Z_L$	90°

Table 15-14: Directional quadrilateral ground distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Reactance	$I \times Z - V$	$j \times I_{L0} \times e^{j\theta}$ or $j \times I_{L2} \times e^{j\theta}$	Comparator limit
Directional	$I_0 \times Z_D$	V_{1M}	Directional comparator limit
	$I_2 \times Z_D$	V_{1M}	Directional comparator limit (removed when $3I_0 > \text{overcurrent supervision}$ and $I_2 < \text{cutoff}$)
Right blinder	$I \times Z_R - V$	$I \times Z_R$	90°
Left blinder	$I \times Z_L - V$	$I \times Z_L$	90°
Fault type	I_0	I_2	50° (removed during open pole conditions or when $3I_0 > \text{overcurrent supervision}$ and $I_2 < \text{cutoff}$)
Zero-sequence	$I_0 \times Z_D$	$-V_0$	90° (zones 2 and 3 only; removed during open pole conditions)

Table 15-15: Non-directional mho phase distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Offset mho	$I \times Z - V$	$I \times Z_{REV} - V$	Comparator limit

Table 15-16: Non-directional mho ground distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Offset mho	$I \times Z - V$	$I \times Z_{REV} - V$	Comparator limit
Fault type	I_0	I_2	50° (removed during open pole conditions or when $3I_0 > \text{overcurrent supervision}$ and $I_2 < \text{cutoff}$)

Table 15-17: Non-directional quadrilateral phase distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Forward reactance	$I \times Z - V$	$I \times Z$	Comparator limit
Reverse reactance	$I \times Z_{REV} - V$	$I \times Z_{REV}$	Comparator limit
Right blinder	$I \times Z_R - V$	$I \times Z_R$	90°
Left blinder	$I \times Z_L - V$	$I \times Z_L$	90°

Table 15-18: Non-directional quadrilateral ground distance functions

Characteristic	Comparator inputs		Limit angle
	Input 1	Input 2	
Forward reactance	$I \times Z - V$	$j \times I_{L0} \times e^{j\theta}$ or $j \times I_{L2} \times e^{j\theta}$	Comparator limit
Reverse reactance	$I_{L0} \times Z_D$	$-j \times I_{L0} \times e^{j\theta}$ or $-j \times I_{L2} \times e^{j\theta}$	Comparator limit
Right blinder	$I \times Z_R - V$	$I \times Z_R$	90°
Left blinder	$I \times Z_L - V$	$I \times Z_L$	90°
Fault type	I_{L0}	I_{L2}	50° (removed during open pole conditions or when $3I_{L0} >$ overcurrent supervision and $I_{L2} <$ cutoff)

Memory polarization

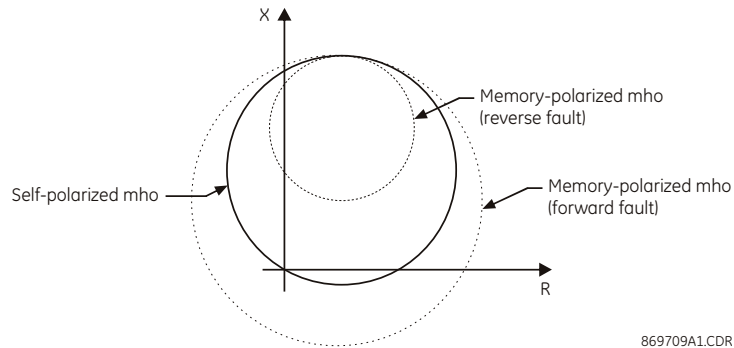
All distance functions use memory polarization. The positive-sequence voltage, either memorized or actual, is used as a polarizing signal. The memory is established when the positive-sequence voltage remains above 80% of its nominal value for five power system cycles. The memory voltage is a two-cycle old voltage.

Once established, the memory is applied for the user-specified time interval. The memory timer is started when the voltage drops below 80% of nominal or when the user-programmable condition is asserted to force memory polarization. After the memory expires, the D90^{PLUS} checks the magnitude of the actual positive-sequence voltage. If it is greater than 10% of nominal, the actual voltage is used; if it is less than 10% of nominal, the memory voltage continues to be used.

A provision is added to force self-polarization from any user-programmable condition.

The memory-polarized mho has an extra directional integrity built-in as illustrated in the following figure. The self-polarized mho characteristic is shifted in the reverse direction for a forward fault by an amount proportional to the source impedance, and in the forward direction for a reverse fault.

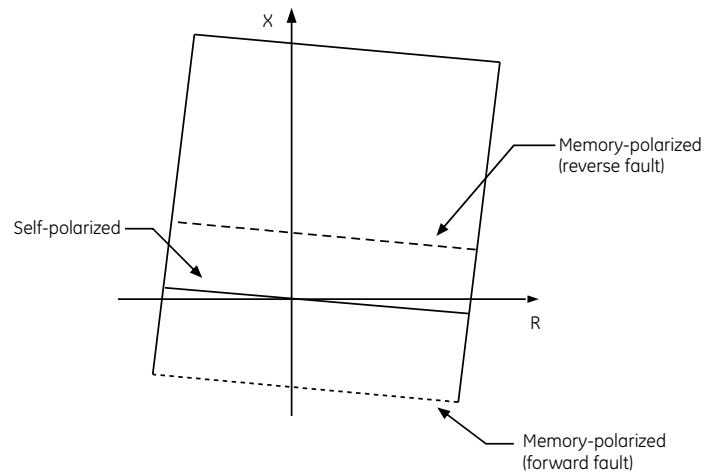
Figure 551: Dynamic shift of the memory-polarized mho characteristic



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The same desirable effect of memory polarization applies to the directional comparator of the quadrilateral characteristic.

Figure 552: Dynamic shift of the memory-polarized quadrilateral characteristic



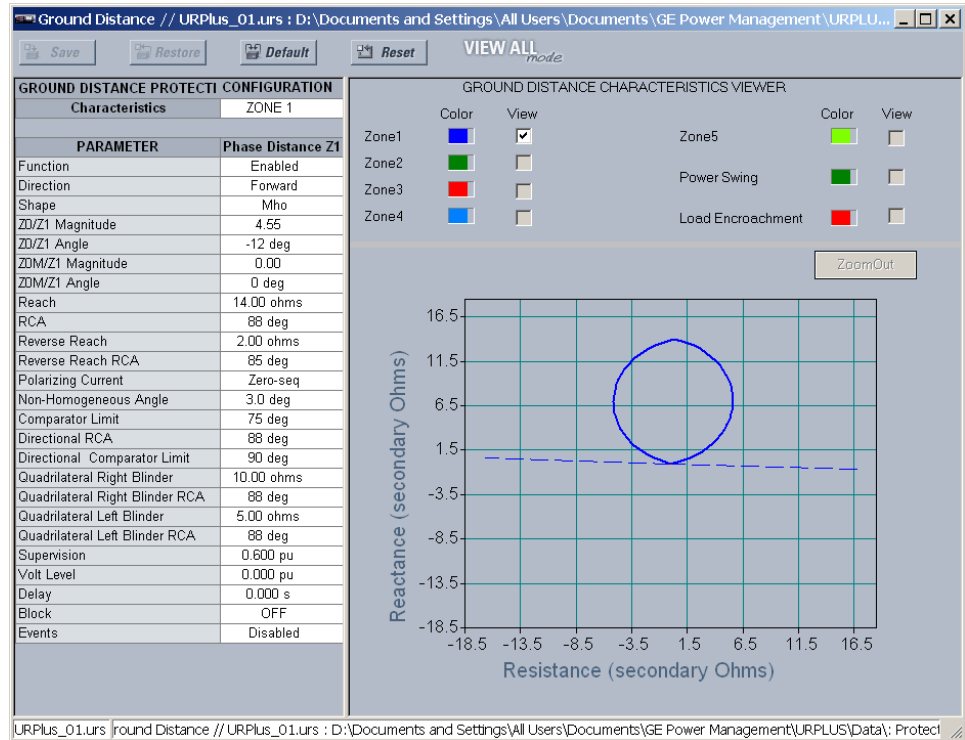
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Mutual zero-sequence compensation can raise concerns regarding directional integrity on reverse faults in the situation when the relay gets *overcompensated*. This problem does not affect the D90^{PLUS} because its ground distance elements use zero-sequence and negative-sequence currents in extra directional comparators. Both the currents are from the protected line and are not affected by any compensation as the latter applies only to the reach defining comparators: the mho, reactance, and blinder characteristics.

Distance elements analysis

This subsection shows how to analyze the operation of the distance elements in steady states using the results of short circuit studies. All quantities are secondary ohms, volts, and amperes. Ground phase A and phase AB distance elements are analyzed. Assume the following settings have been entered in the **Settings > Protection > Elements > Group 1 > Ground Distance** menu.

Figure 553: Typical ground distance settings window



Assume the following signals are injected into the D90^{Plus}:

$$\begin{aligned}
 V_A &= 64.71 \text{ V } \angle 0.0^\circ \text{ (pre-fault)} & I_A &= 4.47 \text{ A } \angle -107.8^\circ \\
 V_A &= 25.43 \text{ V } \angle -19.9^\circ & I_B &= 2.92 \text{ A } \angle 68.9^\circ \\
 V_B &= 80.22 \text{ V } \angle -133.5^\circ & I_C &= 2.93 \text{ A } \angle -51.1^\circ \\
 V_C &= 77.33 \text{ V } \angle 135.7^\circ
 \end{aligned}
 \tag{Eq. 69}$$

Based on these signals and the programmed settings, the D90^{Plus} calculates the following values:

$$\begin{aligned}
 K_{0_1} &= 3.58 \angle -15.2^\circ & Z_D &= 1 \Omega \angle 88^\circ \\
 K_{0M} &= 0 & Z_R &= 9.99 \Omega \angle 2^\circ \\
 Z &= 14.00 \Omega \angle 88^\circ & Z_L &= 4.99 \Omega \angle 178^\circ
 \end{aligned}
 \tag{Eq. 70}$$

From the assumed steady-state injection, the D90^{Plus} also calculates the following:

$$\begin{aligned}
 V_{A_1} &= 58.3 \text{ V } \angle -2.1^\circ & -V_0 &= 29.18 \text{ V } \angle -8.4^\circ \\
 V_{A_1M} &= 64.71 \text{ V } \angle 0^\circ & (V_A - V_B)_{_1} &= 93.35 \text{ V } \angle -32.0^\circ \\
 I_{_0} &= 1.37 \text{ A } \angle -68.2^\circ & (V_A - V_B)_{_1M} &= 112.08 \text{ V } \angle -30.0^\circ \\
 I_{A_2} &= 1.37 \text{ A } \angle -68.1^\circ & I_A - I_B &= 7.39 \text{ A } \angle -109.1^\circ
 \end{aligned}
 \tag{Eq. 71}$$

The following sub-sections describe the operation of each of the distance characteristics with respect to these values.

Mho phase A to ground element analysis, before memory expires

Before the memory expires, the following values are calculated for the mho phase A to ground distance element:

$$I_A \times Z + I_0 \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A = 103.33 \text{ V } \angle -3.9^\circ$$

$$V_{A_1M} = 64.71 \text{ V } \angle 0.0^\circ$$

$$I_{A_2} \times Z_D = 1.37 \text{ V } \angle 19.8^\circ$$

$$I_0 \times Z = 19.11 \text{ V } \angle 19.8^\circ$$

$$I_0 \times Z_D = 1.37 \text{ V } \angle 19.8^\circ$$

Eq. 72

The ground distance element checks for the following conditions for overcurrent supervision and the difference angles.

Table 16: Mho phase A to ground element conditions

Parameter	Condition
Overcurrent supervision	$3 \times I_0 > \text{Supervision}$
Mho difference angle	$ \angle(I_A \times Z + I_0 \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A) - \angle(V_{A_1M}) < \text{Comparator Limit}$
Reactance difference angle	$ \angle(I_A \times Z + I_0 \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A) - \angle(I_0 \times Z) < \text{Comparator Limit}$
Zero-sequence directional difference angle	$ \angle(I_0 \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Negative-sequence directional difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Fault type comparator difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(I_0 \times Z_D) < 50^\circ$

The results are shown in the following table.

Table 17: Mho phase A to ground element analysis

Parameter	Calculation	Requirement	Condition met
Overcurrent supervision	$3 \times 1.377 \text{ A} = 4.09 \text{ A}$	$> 3 \text{ A}$	Yes
Mho difference angle	$ -3.9^\circ - 0^\circ = 3.9^\circ$	$< 75^\circ$	Yes
Reactance difference angle	$ -3.9^\circ - 19.8^\circ = 23.7^\circ$	$< 75^\circ$	Yes
Zero-sequence directional difference angle	$ 19.8^\circ - 0.0^\circ = 19.8^\circ$	$< 75^\circ$	Yes
Negative-sequence directional difference angle	$ 19.8^\circ - 0.0^\circ = 19.8^\circ$	$< 75^\circ$	Yes
Fault type comparator difference angle	$ 19.8^\circ - 19.8^\circ = 0.0^\circ$	$< 50^\circ$	Yes

All the comparators and the overcurrent supervision are satisfied.

Mho phase A to ground element analysis, after memory expires

After memory expires, the D90^{PLUS} checks the actual positive sequence voltage and compares it to 10% of the nominal voltage.

$$V_{A_1} = 53.38 \text{ V} > 0.1 \times 69.28 \text{ V}$$

Eq. 73

When memory expires, the D90^{Plus} uses the actual voltage for polarization. The following values are calculated for the mho phase A to ground distance element:

$$\begin{aligned}
 I_A \times Z + I_0 \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A &= 103.33 \text{ V } \angle -3.9^\circ \\
 V_{A_1} &= 58.83 \text{ V } \angle -2.1^\circ \\
 I_{A_2} \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z &= 19.11 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ
 \end{aligned}
 \tag{Eq. 74}$$

The ground distance element checks for the following conditions for overcurrent supervision and the difference angles.

Table 18: Mho phase A to ground element conditions

Parameter	Condition
Overcurrent supervision	$3 \times I_0 > \text{Supervision}$
Mho difference angle	$ \angle(I_A \times Z + I_0 \times K_0 \times Z_R + I_G \times K_{0M} \times Z - V_A) - \angle(V_{A_1M}) < \text{Comparator Limit}$
Reactance difference angle	$ \angle(I_A \times Z + I_0 \times K_0 \times Z_R + I_G \times K_{0M} \times Z - V_A) - \angle(I_0 \times Z) < \text{Comparator Limit}$
Zero-sequence directional difference angle	$ \angle(I_0 \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Negative-sequence directional difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Fault type comparator difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(I_0 \times Z_D) < 50^\circ$

The results are shown in the following table.

Table 19: Mho phase A to ground element analysis

Parameter	Calculation	Requirement	Condition met
Overcurrent supervision	$3 \times 13.7 \text{ A} = 4.09 \text{ A}$	$> 3 \text{ A}$	Yes
Mho difference angle	$ -3.9^\circ - (-2.1^\circ) = 1.8^\circ$	$< 75^\circ$	Yes
Reactance difference angle	$ -3.9^\circ - 19.8^\circ = 23.7^\circ$	$< 75^\circ$	Yes
Zero-sequence directional difference angle	$ 19.8^\circ - (-2.1^\circ) = 21.9^\circ$	$< 75^\circ$	Yes
Negative-sequence directional difference angle	$ 19.8^\circ - (-2.1^\circ) = 21.9^\circ$	$< 75^\circ$	Yes
Fault type comparator difference angle	$ 19.8^\circ - 19.8^\circ = 0.0^\circ$	$< 50^\circ$	Yes

All the comparators and the overcurrent supervision are satisfied. The zone 1 mho phase A ground distance element operates for this fault.

The zero-sequence directional difference angle for zones 2 through 4 (phase A) is $|19.8^\circ - 8.4^\circ| = 11.4^\circ < 90^\circ$. Therefore, the phase A ground distance elements pick up, time out, and operate.

Mho phase AB element analysis

The following values are calculated for the mho phase AB distance element:

$$\begin{aligned}
 (I_A \times I_B) \times Z - (V_A - V_B) &= 88.65 \text{ V } \angle -78.7^\circ \\
 (V_A - V_B)_{1M} &= 112.08 \text{ V } \angle 30.0^\circ \\
 (I_A - I_B) \times Z &= 103.50 \text{ V } \angle -21.2^\circ \\
 (I_A - I_B) \times Z_D &= 7.39 \text{ V } \angle -21.2^\circ
 \end{aligned}
 \tag{Eq. 75}$$

The phase distance element checks for the following conditions for overcurrent supervision and the difference angles.

Table 20: Mho phase AB element conditions

Parameter	Condition
Overcurrent supervision	$ I_A - I_B / \sqrt{3} > \text{Supervision}$
Mho difference angle	$ \angle((I_A - I_B) \times Z - (V_A - V_B)) - \angle((V_A - V_B)_{1M}) < \text{Comparator Limit}$
Reactance difference angle	$ \angle((I_A - I_B) \times Z - (V_A - V_B)) - \angle((I_A - I_B) \times Z) < \text{Comparator Limit}$
Directional difference angle	$ \angle((I_A - I_B) \times Z) - \angle((V_A - V_B)_{1M}) < \text{Directional Comparator Limit}$

The results are shown in the following table.

Table 21: Mho phase AB element analysis

Parameter	Calculation	Requirement	Condition met
Overcurrent supervision	$ (7.39 \text{ A}) / \sqrt{3} = 4.27 \text{ A}$	$> 3 \text{ A}$	Yes
Mho difference angle	$ -78.7^\circ - 30.0^\circ = 108.7^\circ$	$< 75^\circ$	No
Reactance difference angle	$ -78.7^\circ - (-21.2^\circ) = 57.5^\circ$	$< 75^\circ$	Yes
Directional difference angle	$ -21.2^\circ - 30.0^\circ = 51.2^\circ$	$< 75^\circ$	Yes

The mho difference angle comparator is not satisfied. Therefore, the mho phase AB element does not operate for this fault.

Quadrilateral phase A to ground element analysis, before memory expires

Before the memory expires, the following values are calculated for the quadrilateral phase A to ground distance element:

$$I_A \times Z + I_{0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A = 103.33 \text{ V} \angle -3.9^\circ$$

$$V_{A_1M} = 64.71 \text{ V} \angle 0.0^\circ$$

$$j \times I_{0} \times e^{j3} = 1.37 \text{ A} \angle 24.8^\circ$$

$$I_{A_2} \times Z_D = 1.37 \text{ V} \angle 19.8^\circ$$

$$I_{0} \times Z = 19.11 \text{ V} \angle 19.8^\circ$$

$$I_{0} \times Z_D = 1.37 \text{ V} \angle 19.8^\circ$$

$$I_A \times Z_R + I_{0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R - V_A = 87.6 \text{ V} \angle -109.2^\circ$$

$$I_A \times Z_R + I_{0} \times K_0 \times Z_R = 91.5 \text{ V} \angle -93.0^\circ$$

$$I_A \times Z_L + I_{0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L - V_A = 57.0 \text{ V} \angle 108.7^\circ$$

$$I_A \times Z_L + I_{0} \times K_0 \times Z_L = 45.8 \text{ V} \angle 82.9^\circ$$

Eq. 76

The ground distance element checks for the following conditions for overcurrent supervision and the difference angles.

Table 22: Quadrilateral phase A to ground element conditions

Parameter	Condition
Overcurrent supervision	$3 \times I_{0} > \text{Supervision}$
Reactance difference angle	$ \angle(I_A \times Z + I_{0} \times K_0 \times Z + I_G \times K_{0M} \times Z - V_A) - \angle(j \times I_{0} \times e^{j3}) < \text{Comparator Limit}$
Zero-sequence directional difference angle	$ \angle(I_{0} \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Negative-sequence directional difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(V_{A_1M}) < \text{Directional Comparator Limit}$
Right blinder difference angle	$ \angle(I_A \times Z_R + I_{0} \times K_0 \times Z_R + I_G \times K_{0M} \times Z_R - V_A) - \angle(I_A \times Z_R + I_{0} \times K_0 \times Z_R) < 90^\circ$
Left blinder difference angle	$ \angle(I_A \times Z_L + I_{0} \times K_0 \times Z_L + I_G \times K_{0M} \times Z_L - V_A) - \angle(I_A \times Z_L + I_{0} \times K_0 \times Z_L) < 90^\circ$
Fault type comparator difference angle	$ \angle(I_{A_2} \times Z_D) - \angle(I_{0} \times Z_D) < 50^\circ$

The results are shown in the following table.

Table 23: Quadrilateral phase A to ground element analysis

Parameter	Calculation	Requirement	Condition met
Overcurrent supervision	$3 \times 1.37 \text{ A} = 4.09 \text{ A}$	$> 3 \text{ A}$	Yes
Reactance difference angle	$ -3.9^\circ - 24.8^\circ = 28.7^\circ$	$< 75^\circ$	Yes
Zero-sequence directional difference angle	$ 19.8^\circ - 0.0^\circ = 19.8^\circ$	$< 75^\circ$	Yes
Negative-sequence directional difference angle	$ 19.8^\circ - 0.0^\circ = 19.8^\circ$	$< 75^\circ$	Yes
Right blinder difference angle	$ -93.0^\circ - (-109.2^\circ) = 16.2^\circ$	$< 90^\circ$	Yes
Left blinder difference angle	$ 82.9^\circ - 108.7^\circ = 25.8^\circ$	$< 90^\circ$	Yes
Fault type comparator difference angle	$ 19.8^\circ - 19.8^\circ = 0.0^\circ$	$< 50^\circ$	Yes

All the comparators and the overcurrent supervision are satisfied. The quadrilateral phase A ground element operates for this fault.

Other phase and ground distance elements

Repeating the analysis in the preceding sections for each phase and ground distance element, it follows that only the ground element in phase A operates for this fault.

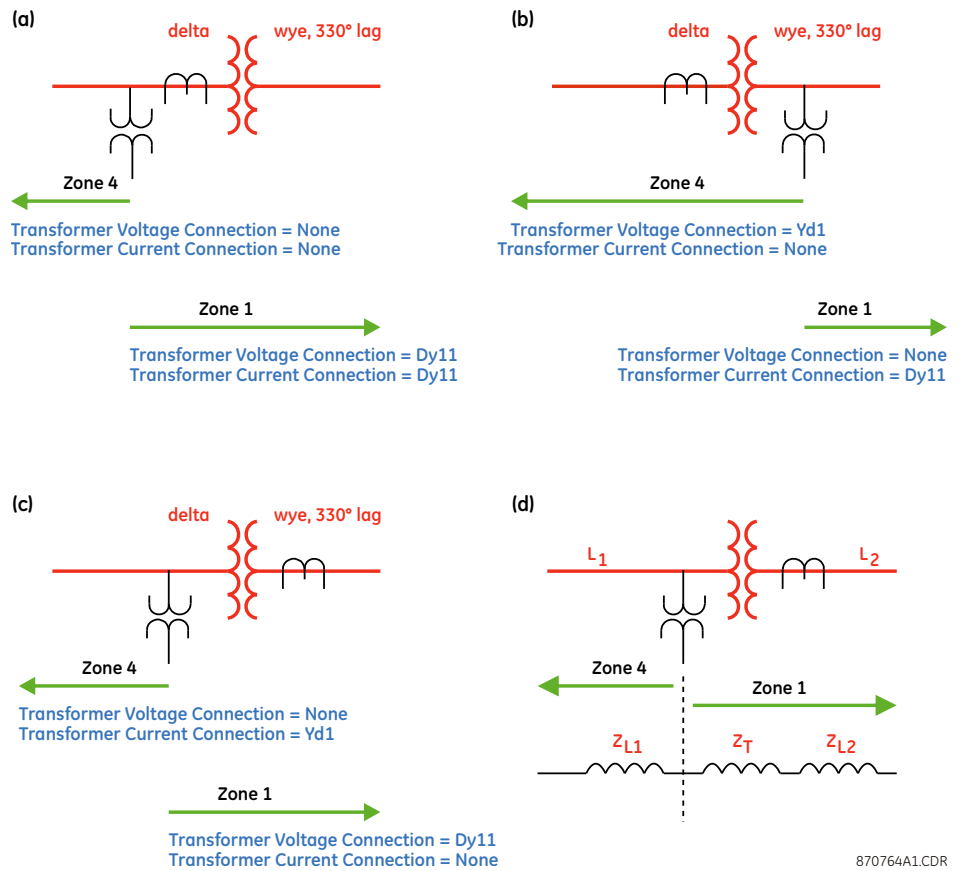
Phase distance applied to power transformers

As a wye-delta transformer introduces discontinuity for the zero-sequence circuit, the ground distance protection cannot be applied, except special circumstances, to respond to faults behind the transformer.

The phase distance elements, however, can be developed so that both accurate reach and correct fault phase identification are retained for faults behind the power transformer as seen from the relaying point. Without appropriate compensation, the $D90^{PLUS}$ reach depends on a type of fault, creating considerable difficulties in applying protection.

The $D90^{PLUS}$ provides for any location of the VTs and CTs with respect to the involved power transformer and the direction of any given zone. In the following equations, the VT and CT locations are referenced as *None* if the transformer is not present between the CT/VT and the intended reach point. Otherwise, the location is to be selected as a type of a transformer as seen from the VT/CT position towards the intended reach point. The figure explains the adopted rules.

Figure 554: Applications of the phase distance transformer settings



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In the following tables, the suffix “_21P” indicates current or voltage inputs to the phase distance (ANSI 21P) element.

Table 24: Phase distance input signals for delta-wye transformers

Transformer connection	Loop	Current transformation	Voltage transformation
None	AB	$I_{AB_21P} = I_A - I_B$	$V_{AB_21P} = V_{AB}$
	BC	$I_{BC_21P} = I_B - I_C$	$V_{BC_21P} = V_{BC}$
	CA	$I_{CA_21P} = I_C - I_A$	$V_{CA_21P} = V_{CA}$
Dy1	AB	$I_{A_21P} = \sqrt{3} I_A$	$V_{AB_21P} = \frac{1}{\sqrt{3}} (V_{AB} - V_{CA})$
	BC	$I_{B_21P} = \sqrt{3} I_B$	$V_{BC_21P} = \frac{1}{\sqrt{3}} (V_{BC} - V_{AB})$
	CA	$I_{C_21P} = \sqrt{3} I_C$	$V_{CA_21P} = \frac{1}{\sqrt{3}} (V_{CA} - V_{BC})$
Dy3	AB	$I_{AB_21P} = -\sqrt{3} I_C$	$V_{AB_21P} = \frac{1}{\sqrt{3}} (V_{BC} - V_{CA})$
	BC	$I_{BC_21P} = -\sqrt{3} I_A$	$V_{BC_21P} = \frac{1}{\sqrt{3}} (V_{CA} - V_{AB})$
	CA	$I_{CA_21P} = -\sqrt{3} I_B$	$V_{CA_21P} = \frac{1}{\sqrt{3}} (V_{AB} - V_{BC})$

Transformer connection	Loop	Current transformation	Voltage transformation
Dy5	AB	$I_{AB_21P} = -\sqrt{3}I_B$	$V_{AB_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{AB})$
	BC	$I_{BC_21P} = -\sqrt{3}I_C$	$V_{BC_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{BC})$
	CA	$I_{CA_21P} = -\sqrt{3}I_A$	$V_{CA_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{CA})$
Dy7	AB	$I_{AB_21P} = -\sqrt{3}I_A$	$V_{AB_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{AB})$
	BC	$I_{BC_21P} = -\sqrt{3}I_B$	$V_{BC_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{BC})$
	CA	$I_{CA_21P} = -\sqrt{3}I_C$	$V_{CA_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{CA})$
Dy9	AB	$I_{AB_21P} = -\sqrt{3}I_C$	$V_{AB_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{BC})$
	BC	$I_{BC_21P} = -\sqrt{3}I_A$	$V_{BC_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{CA})$
	CA	$I_{CA_21P} = -\sqrt{3}I_B$	$V_{CA_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{AB})$
Dy11	AB	$I_{AB_21P} = -\sqrt{3}I_B$	$V_{AB_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{BC})$
	BC	$I_{BC_21P} = -\sqrt{3}I_C$	$V_{BC_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{CA})$
	CA	$I_{CA_21P} = -\sqrt{3}I_A$	$V_{CA_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{AB})$

Table 25: Phase distance input signals for wye-delta transformers

Transformer connection	Loop	Current transformation	Voltage transformation
Yd1	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$	$V_{AB_21P} = \sqrt{3}V_A$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$	$V_{BC_21P} = \sqrt{3}V_B$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$	$V_{CA_21P} = \sqrt{3}V_C$
Yd3	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$	$V_{AB_21P} = -\sqrt{3}V_C$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$	$V_{BC_21P} = -\sqrt{3}V_A$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$	$V_{CA_21P} = -\sqrt{3}V_B$

Transformer connection	Loop	Current transformation	Voltage transformation
Yd5	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$	$V_{AB_21P} = \sqrt{3}V_B$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$	$V_{BC_21P} = \sqrt{3}V_C$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$	$V_{CA_21P} = \sqrt{3}V_A$
Yd7	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$	$V_{AB_21P} = -\sqrt{3}V_A$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$	$V_{BC_21P} = -\sqrt{3}V_B$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$	$V_{CA_21P} = -\sqrt{3}V_C$
Yd9	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$	$V_{AB_21P} = \sqrt{3}V_C$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$	$V_{BC_21P} = \sqrt{3}V_A$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$	$V_{CA_21P} = \sqrt{3}V_B$
Yd11	AB	$I_{AB_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$	$V_{AB_21P} = -\sqrt{3}V_B$
	BC	$I_{BC_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$	$V_{BC_21P} = -\sqrt{3}V_C$
	CA	$I_{CA_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$	$V_{CA_21P} = -\sqrt{3}V_A$

Equations from the *current transformation* and *voltage transformation* columns are used to derive inputs to the three (AB, BC, and CA) phase distance elements. For example, if the CTs are located at the delta side of the delta-wye 11 (Dy11) transformer, and a given zone is set to look through the transformer into the system connected to the wye winding, the CT location setting for that zone is to be set to "Dy11" and the relay uses $-\sqrt{3}I_B$ instead of a traditional $I_A - I_B$ for the AB phase distance element.

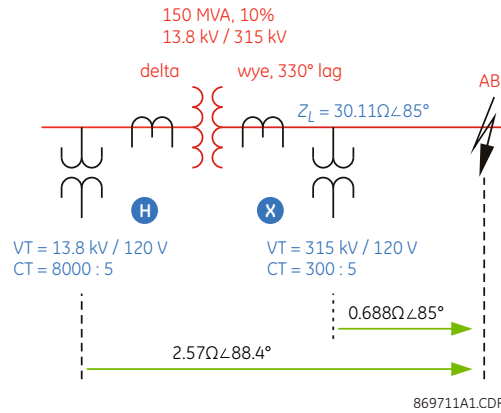
The current supervision pickup setting applies to the currents specified in the *current transformation* columns.

A distance zone originates at the location of the VTs (regardless of the location of the CTs).

Example of system with power transformers

Consider the system shown. To respond to the indicated fault, a distance relay is applied at the relay point X.

Figure 555: Example system configuration



The D90^{Plus} input signals at point X are shown in the following table.

Table 26: Input signals at point X for example system with power transformers

Input	Primary	Secondary
V_A	100.4 kV $\angle -7.32^\circ$	38.25 V $\angle -7.32^\circ$
V_B	97.23 kV $\angle -53.4^\circ$	37.04 V $\angle -53.4^\circ$
V_C	181.8 kV $\angle -150.0^\circ$	69.26 V $\angle -150.0^\circ$
I_A	1.288 kA $\angle -27.6^\circ$	21.47 A $\angle -27.6^\circ$
I_B	1.288 kA $\angle 152.4^\circ$	21.47 A $\angle 152.4^\circ$
I_C	0	0

If installed at location X, the D90^{Plus} uses the following input signals for its phase AB distance element.

$$V = V_{AB} = 77.402 \text{ kV } \angle 57.5^\circ \text{ primary or } 29.49 \text{ V } \angle 57.5^\circ \text{ secondary.}$$

$$I = I_A - I_B = 2.576 \text{ kA } \angle -27.6^\circ \text{ primary or } 42.93 \text{ A } \angle -27.6^\circ \text{ secondary.}$$

And consequently, the D90^{Plus} sees the following apparent impedance:

$$Z_{APP} = V / I = 30.05 \text{ } \Omega \angle 85^\circ \text{ primary or } 0.687 \text{ } \Omega \angle 85^\circ \text{ secondary}$$

If applied at location H, the D90^{Plus} input signals are shown in the following table.

Table 27: Input signals at point H for example system with power transformers

Input	Primary	Secondary
V_A	7.854 kV $\angle -5.59^\circ$	69.95 V $\angle -5.59^\circ$
V_B	6.269 kV $\angle -120.1^\circ$	54.52 V $\angle -120.1^\circ$
V_C	7.751 kV $\angle 125.5^\circ$	65.84 V $\angle 125.5^\circ$
I_A	16.976 kA $\angle -27.6^\circ$	10.61 A $\angle -27.6^\circ$
I_B	33.952 kA $\angle 152.4^\circ$	21.11 A $\angle 152.4^\circ$
I_C	16.976 kA $\angle -27.6^\circ$	10.61 A $\angle -27.6^\circ$

The following settings are applied in the D90^{Plus}:

Transformer Voltage Connection: "Dy11"

Transformer Current Connection: "Dy11"

Consequently, the following signals are applied to the phase AB distance element:

$$V = \frac{1}{\sqrt{3}} V_{AB} - V_{BC}$$

$$= 10.681 \text{ kV } \angle 27.6^\circ \text{ primary or } 94.45 \text{ V } \angle 59.9^\circ \text{ secondary} \quad \text{Eq. 77}$$

$$I = -\sqrt{3} I_B$$

$$= 58.860 \text{ kA } \angle -27.6^\circ \text{ primary or } 36.75 \text{ A } \angle -27.6^\circ \text{ secondary} \quad \text{Eq. 78}$$

This results in the following apparent impedance:

$$Z_{APP} = \frac{V}{I} = \frac{94.45 \text{ kV } \angle 59.9^\circ}{36.75 \text{ kA } \angle -27.6^\circ} = 2.570 \Omega \angle 87.5^\circ \text{ secondary} \quad \text{Eq. 79}$$

The apparent impedance calculated in the equation is a correct measure of the distance from the VT location to the fault. For relay location *H*, this certainly includes the positive-sequence impedance of the transformer.

$$Z_T \text{ (at 13.8 kV)} = \frac{10}{100} \times \frac{(13.8 \text{ kV})^2}{150 \text{ MVA}} = 0.127 \Omega \angle 90^\circ$$

$$Z_L \text{ (at 13.8 kV)} = 30.11 \Omega \angle 85^\circ \times \left(\frac{13.8 \text{ kV}}{315 \text{ kV}} \right)^2 = 0.05779 \Omega \angle 85^\circ \quad \text{Eq. 80}$$

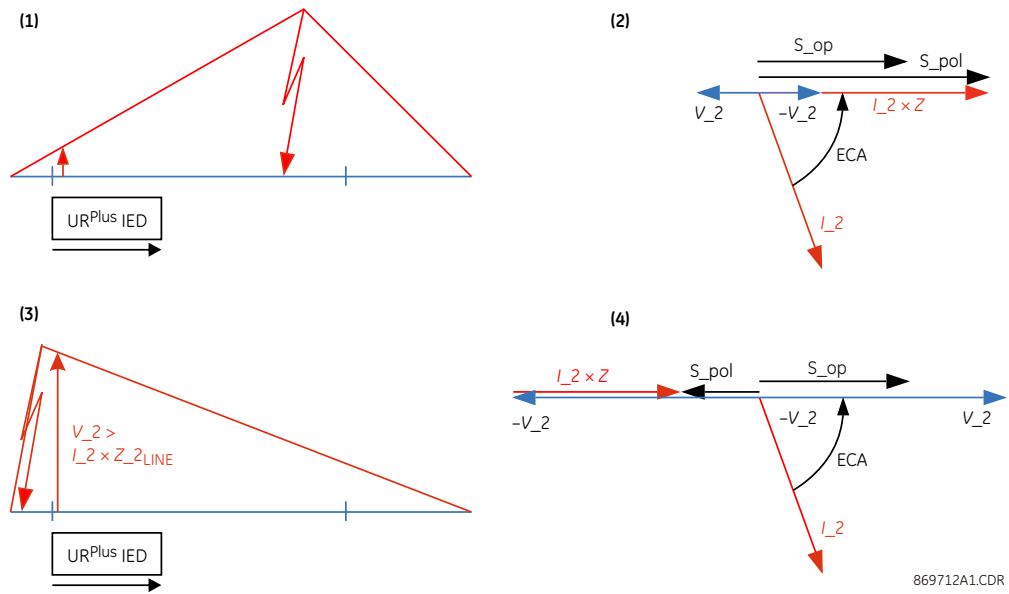
Therefore, $0.127 \Omega \angle 90^\circ + 0.05779 \Omega \angle 85^\circ = 0.1847 \Omega \angle 88.4^\circ$ on the primary side or $2.569 \Omega \angle 88.4^\circ$ on the secondary side.

This example illustrates how the $D90^{PLUS}$ maintains correct reach for fault behind power transformers. When installed at location *X*, set the $D90^{PLUS}$ reach to $0.687 \Omega \angle 85^\circ$ secondary to cover the fault shown in the figure. When installed at location *H*, set the $D90^{PLUS}$ reach to $2.569 \Omega \angle 88.4^\circ$ to ensure exactly the same coverage.

Ground directional overcurrent theory

Consider the negative-sequence directional overcurrent element. As illustrated here, the negative-sequence voltage can be low during internal fault conditions.

Figure 556: Offset impedance augmentation



To ensure operation of the element under such circumstances, the angle comparator uses a polarizing voltage augmented by the negative-sequence current as shown in the following equations.

For the forward-looking element:

$$\begin{aligned} S_{pol} &= -V_2 + I_2 \times Z_{offset} \times 1 \angle ECA \\ S_{op} &= I_2 \times 1 \angle ECA \end{aligned} \quad \text{Eq. 81}$$

For the reverse-looking element:

$$\begin{aligned} S_{pol} &= -V_2 + I_2 \times Z_{offset} \times 1 \angle ECA \\ S_{op} &= -I_2 \times 1 \angle ECA \end{aligned} \quad \text{Eq. 82}$$

In these equations, ECA represents the forward element characteristic angle (maximum torque angle) and Z_{offset} represents the offset impedance. The effect of the augmentation for forward and reverse fault is shown in the preceding figure. As long as the offset impedance is less than or equal to the negative-sequence line impedance, the element ensures correct and fast fault direction identification for both forward and reverse faults. The same principle applies to the neutral directional overcurrent element.

Ground directional overcurrent example

Consider a D90^{Plus} with the following input signals:

$$\begin{aligned} V_A &= 64.71 \text{ V} \angle 0.0^\circ \text{ (pre-fault)} & I_A &= 4.47 \text{ A} \angle -107.8^\circ \\ V_A &= 25.43 \text{ V} \angle -19.9^\circ & I_B &= 2.92 \text{ A} \angle 68.9^\circ \\ V_B &= 80.22 \text{ V} \angle -133.5^\circ & I_C &= 2.93 \text{ A} \angle -51.1^\circ \\ V_C &= 77.33 \text{ V} \angle 135.7^\circ \end{aligned} \quad \text{Eq. 83}$$

Assume an offset impedance of 4 Ω , an ECA angle of 88°, and a limit angle of 90°. The D90^{Plus} calculates the following negative-sequence quantities:

$$\begin{aligned} V_2 &= 6.39 \text{ V} \angle -159.6^\circ \\ I_2 &= 1.37 \text{ A} \angle -68.1^\circ \\ I_1 &= 2.94 \text{ A} \angle -144.2^\circ \end{aligned}$$

The following signals for the directional unit of the negative-sequence directional overcurrent element also are calculated. For the forward element, we have

$$\begin{aligned} S_{pol} &= 11.8 \text{ V} \angle 20.2^\circ \\ S_{op} &= 1.37 \text{ V} \angle 20.2^\circ \end{aligned}$$

For the reverse element, we have

$$\begin{aligned} S_{pol} &= 11.87 \text{ V} \angle 20.2^\circ \\ S_{op} &= 1.37 \text{ V} \angle -160.0^\circ \end{aligned}$$

After comparing the angles, a solid forward indication is given.

Assume further a pickup setting of 0.25 A for both forward and reverse directions, and the negative-sequence mode set for the overcurrent unit of the element. The relay calculates the operating signal using the positive-sequence restraint as follows:

$$I_{op} = \frac{|I_2| - |I_1|}{8} = 1.003 \text{ A} \quad \text{Eq. 84}$$

The operating signal is greater than the pickup setting of 0.25 A. Therefore, the overcurrent unit picks up and the element operates in the forward direction.

Series compensated lines

Faults on or in close vicinity to series compensated lines can create problems for distance protection.

Voltage or current inversion can lead to false direction discrimination by directional elements. This can potentially include both a failure to operate on a forward in-zone fault as well as misoperation on a reverse fault. Both distance and overcurrent directional elements can be affected.

Series-capacitors and their overvoltage protection equipment (air gaps and/or metal-oxide varistors) have a steady-state overreaching effect on the apparent impedance seen by the relay—a forward fault can appear much closer to the relay as compared with the actual fault location. The apparent impedance can be shifted towards the relay by as much as the total reactance of the series capacitors placed between the potential source of the relay and the fault point. This extreme steady-state overreach happens during low-current faults when the air-gaps do not flashover or the MOVs do not conduct any significant current.

In addition to this steady-state overreach effect, sub-synchronous oscillations in both currents and voltages can cause significant transient overreach.

Memory polarized directional comparators

Distance protection elements of the D90^{PLUS} deal with the problem of voltage inversion by using 100% memory polarized directional comparators. As the memory duration is set longer than the slowest fault clearing time for reverse faults, it is guaranteed that the distance element does not pick-up on reverse faults if the voltage inversion happens.

At the same time, it is guaranteed that the distance element picks up for all forward faults regardless of any voltage inversion as long as the memory voltage is used. Before the memory expires, the relay responds to any fault on the protected line. Stepped distance backup zones operate after the memory voltage expires. But the backup protection responds to distant faults that do not cause any inversion of the positive-sequence voltage. As a result, the time-delayed stepped-distance zones are guaranteed to operate.

Distance protection elements of the D90^{PLUS} deal with the problem of current inversion by using a multi-input comparator approach. If the current inversion happens, then the distance elements are secure on reverse faults because multiple conditions involving fault-loop, negative-sequence, and zero-sequence currents and the memory voltage are checked prior to declaring a forward fault.

On close-in forward faults beyond the series capacitors as seen from the relaying point, the current inversion phenomenon can take place for a short period of time. The condition cannot sustain for a long time as very high fault currents occur, causing large voltage drops across the series capacitors and prompting the overvoltage protection of the capacitors to operate quickly. This effectively removes the series compensation and eliminates the current inversion. However, when the currents used by distance comparator (fault-loop current for ground and phase distance protection, and the negative-sequence and zero-sequence currents for ground elements) stay shifted by more than 90° from their natural fault position determined by the user as the element characteristic angle, the distance elements can fail to pick-up on such a forward fault for the brief period of current inversion. This is an inherent attribute of the 100% memory polarized mho element, and not a weakness particular to the D90^{PLUS}.

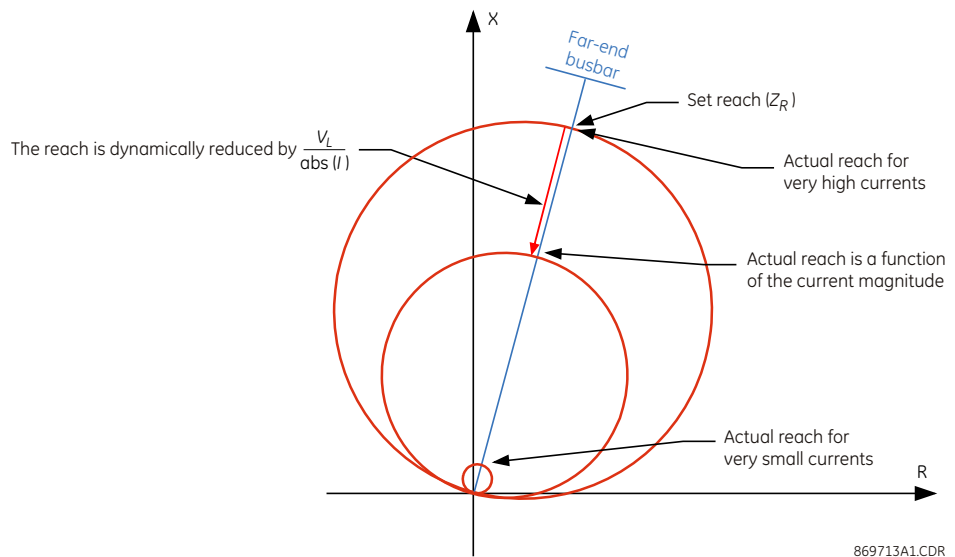
Therefore, for dependability, it is recommended to use high-set phase overcurrent protection for direct tripping on close-in faults potentially causing current inversion, and overreaching ground fault directional overcurrent functions (such as negative-sequence, ground or neutral) for communication-aided schemes.

Dynamic reach control

The problem of steady-state overreaching due to the negative reactance of the series capacitors can be addressed in the D90^{PLUS} in a traditional way by shortening the reach of an underreaching distance element to the net inductive reactance of the line between the potential source and the far end busbars. This generic approach has two major drawbacks. First, it leaves a large portion of the line uncovered by the directly tripping distance protection. Second, it does not solve the transient overreaching problem caused by sub-synchronous oscillations.

Therefore, the D90^{PLUS} offers a unique option for dynamic reach control that is effectively based on the magnitude of the current flowing through the series capacitor banks. The underreaching distance functions can be set as for a plain uncompensated line; that is, using the impedance of the line alone, and the relay controls an effective reach accordingly using the current magnitude, as illustrated.

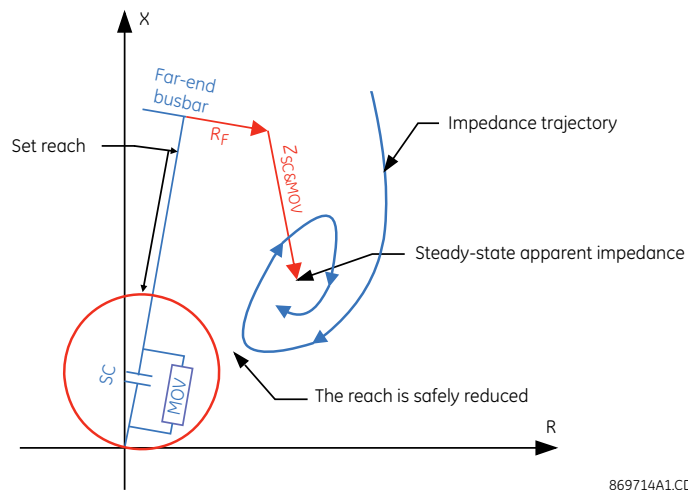
Figure 557: Dynamic reach control



The reach is reduced sufficiently to cope with both steady-state and transient overreach phenomena. For large degrees of compensation and small-current faults, the transient overreach can be as high as 100%. This means that fast distance protection is not achievable. The D90^{PLUS} adaptive mechanism guarantees security on external faults. Overreaching ground fault directional overcurrent functions (such as negative-sequence, ground or neutral) are to be used for dependability.

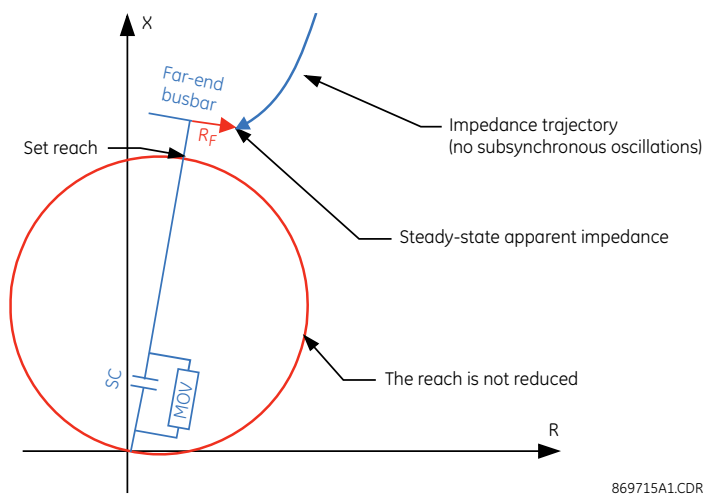
The following figure shows the effect of adaptive reach control for low-current external fault. The reach is reduced sufficiently to cope with both transient and steady-state overreach.

Figure 558: Dynamic reach, low-current external fault



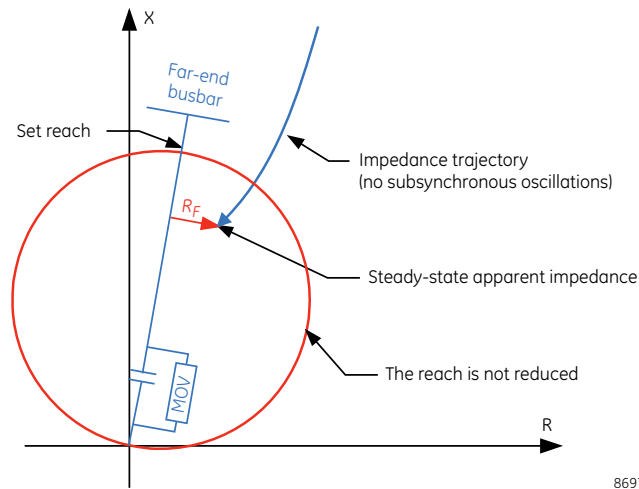
The following figure shows a high-current external fault. The air gaps or MOVs conduct the majority of the fault current and neither steady-state nor transient overreach takes place. The relay does not reduce its reach because it is not necessary.

Figure 559: Dynamic reach, high-current external fault



The following figure shows a high-current internal fault. Because of the large current, the reach is not reduced and the element responds to the internal fault. A traditional approach leaves this fault out of the relay reach.

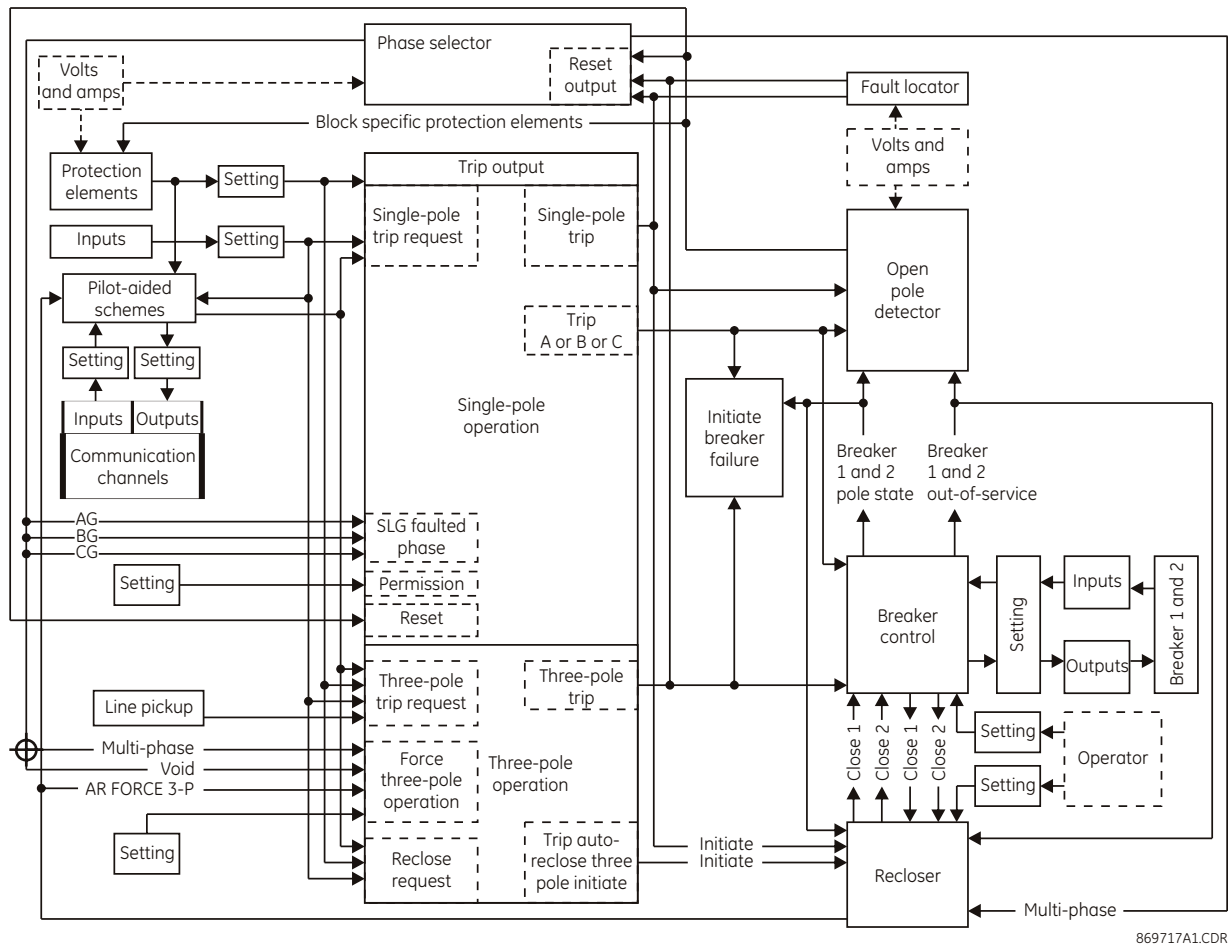
Figure 560: Dynamic reach, high-current internal fault



Single-pole tripping

Single-pole operations make use of many D90^{PLUS} features. At a minimum, the trip output, recloser, breaker control, open pole detector, and phase selector must be fully programmed and in-service, and either protection elements or digital inputs representing fault detection must be available for successful operation. When single pole trip-and-reclose is required, overall control within the relay is performed by the trip output element. This element includes interfaces with pilot-aided schemes, the line pickup, breaker control, and breaker failure elements. Single-pole operations are based on use of the phase selector to identify the type of the fault, to eliminate incorrect fault identification that can be made by distance elements in some circumstances and to provide trip initiation from elements that are not capable of any fault type identification, such as high-set negative-sequence directional overcurrent element. The scheme also is designed to make use of the advantages provided by communications channels with multiple-bit capacities for fault identification.

Figure 561: Single pole operation



The trip output element receives requests for single-pole and three-pole trips and three-pole reclose initiation. It then processes these requests to generate outputs that are used to perform the following functions:

- Determine whether a single- or three-pole operation is to be performed
- Initiate tripping of breaker poles A, B, and C, either individually or as a group
- Initiate breaker failure protection for phases A, B, and C, either individually or as a group
- Notify the open pole detector when a single-pole operation is imminent
- Initiate either single-pole or three-pole reclosing
- Notify the phase selector when a trip operation is imminent

When notified that a single-pole operation has been initiated, the open pole detector performs the following functions:

- Initiates blocking of protection elements that potentially can misoperate when a breaker pole is open
- Instructs the phase selector to de-assert all outputs, as an open pole invalidates calculations

Single-pole operation on a line in a single breaker arrangement is described. The line is protected by a D90^{PLUS} using the line pickup and zone 1 phase and ground distance zone 2 phase and ground distance elements, as well as negative-sequence directional overcurrent elements. Zone 1 is configured to issue a single-pole trip when appropriate:

Trip 1-Pole Input 1: "GND DIST Z1 OP"

Trip 1-Pole Input 2: "PHS DIST Z1 OP"

By default the POTT scheme issues a single-pole trip. It is assumed that when tripping three poles both the zone 1 and the POTT initiate three-pole reclosing. This is achieved by making the following settings:

Trip Reclose Input 1: "POTT TRIP 3P"

Trip Reclose Input 2: "GND DIST Z1 OP"

Trip Reclose Input 3: "PHS DIST Z1 OP"

It is assumed for this discussion that the relay features that are shown on single-pole operation diagram have all been programmed for the application and are in-service. The description begins with line breakers open at both the local and remote ends, and the operation of the scheme is described in chronological order.

Since the line is de-energized, the line pickup element is armed. The recloser presently is enabled. An operator requests that breaker control close the breaker, and it operates output relays to close breaker poles A, B, and C. This operator manual close request is also forwarded from breaker control to recloser, which becomes disabled, de-asserting its enabled output. This output is transferred to trip output, where it converts any input request for a single-pole operation into a three-pole operation. At the recloser, the **Block Time Upon Manual Close** timer is started.

The breaker closes and status monitoring contacts on the breaker poles change state. The new breaker pole states are reported to breaker control, which in turn transfers these states to the recloser, trip output, breaker failure, and open pole detector. Because a fault is not detected, the **Block Time Upon Manual Close** timer times out and the recloser is enabled. This asserts the "Enabled" output, informing the trip output element that single-pole trip operations are permitted. When normal voltage appears on the line, the line pickup element is disarmed. As the local line breaker has not tripped, the operator closes the breaker at the remote end of the line, placing the line in-service.

Several scenarios are considered in the following sections.

SLG fault scenario for single-pole tripping

An AG fault occurs close to the considered relay. Immediately after the fault, the disturbance detector (ANSI 50DD) picks-up and activates the phase selector. The phase selector recognizes an AG fault by asserting its **PHASE SELECT AG** operand. Ground distance zone 1 (AG element) responds to the fault. As the fault is close to the relay, phase distance zone 1 (AB, CA elements) can respond to this fault as well. In any case, a single-pole operation is requested by zone 1 via the **GND DIST Z1 OP** or **PHS DIST Z1 OP** operands.

At this moment the request to trip is placed for the trip output. As the fault is recognized as an AG fault, the **TRIP PHASE A** operand is asserted by the trip output. This signal is passed to the breaker control scheme and results in tripping pole A of the breaker.

Simultaneously with the **TRIP PHASE A** operand, the **TRIP 1-POLE** operand is asserted. This operand activates the open pole detector. The latter detector responds to the **TRIP PHASE A** signal by declaring phase A open by asserting the **OPEN POLE OP ?A** operand (even before it is actually opened). The **TRIP PHASE A** signal resets only after the breaker actually operates as indicated by its auxiliary contact. At this moment, the open pole detector responds to the breaker position and continues to indicate phase A opened. This indication results in establishing blocking signals for distance elements (the **OPEN POLE BLK AB** and **OPEN POLE BLK CA** operands are asserted). If neutral and negative-sequence overcurrent elements are mapped into the trip output to trigger single-pole tripping, they must be blocked with the **OPEN POLE BLK N** operand, specifically provided for this purpose. The **OPEN POLE BLK N** operand must be assigned through the block setting of the overcurrent element. The two latter operands block phase distance AB and CA elements, respectively (all zones); the **OPEN POLE ?A OP** operand blocks the ground distance AG elements (all zones). As a result, the

zone 1 operate and zone 2 pickup operands that were picked up reset immediately. The BG, CG, and BC distance elements remain operational guarding the line against evolving faults.

As zone 2 or negative-sequence directional elements pick up due to the fault, the permission to trip is keyed to the remote end. Assume here that a single-bit channel is used. If so, no extra information is sent to the remote end, just permission to trip sent over the TX1 operand. Upon receiving permission to trip over RX1, the POTT scheme decides to trip. The scheme checks the phase selector for phase type identification and issues a trip for phase A by asserting the **POTT TRIP A** operand. This operand is passed to the trip output and results in exactly same action as described above for zone 1.

Depending on response times, the actual trip is initiated either by zone 1 or by the POTT scheme. At the moment the **TRIP 1-POLE** operand is asserted, the phase selector resets and no other trip action can take place. After the trip command is issued, all the picked up elements are forced to reset by the open pole detector.

The **TRIP 1-POLE** operand initiates automatically a single-pole autoreclose. The autoreclose is started and asserts the **AR RIP** operand. This operand keeps blocking the phase selector so that it does not respond to any subsequent events. At the same time, the operand removes zero-sequence directional supervision from ground distance zones 2 and 3 so that they can respond to a single-line-to-ground fault during open pole conditions.

The **AR FORCE 3-P TRIP** operand is asserted 1.25 cycles following autoreclose initiation. This operand acts as an enabler for any existing trip request. In this case, none of the protection elements is picked up at this time, therefore no more trips are initiated.

When the recloser dead time interval is complete, it signals the breaker control element to close the breaker. The breaker control element operates output relays to close the breaker.

When pole A of the breaker closes, this new status is reported to the breaker control element, which transfers this data to the breaker failure, autorecloser, open pole detector, and trip output elements. The response at breaker failure depends on the programming of that element. The response at the autorecloser is not relevant to this discussion. At the open pole detector, the blocking signals to protection elements are de-asserted.

If the fault was transient, the reset time then expires at the autorecloser and the **AR FORCE 3-P TRIP** and **AR RIP** outputs are de-asserted, returning all features to the state described at the beginning of this section.

If the fault was permanent, appropriate protection elements detect it and place a trip request for the trip output element. As the **AR FORCE 3-P TRIP** is still asserted, the request is executed as a three-pole trip.

The response of the system from this point is as described earlier for the second trip, except that the autorecloser goes to lockout upon the next initiation (depending on the number of shots programmed).

SLG fault evolving into an LLG fault scenario for single-pole tripping

When an AG fault occurs, the events unfold initially as in the previous example. If the fault evolves quickly, the phase selector changes its initial assessment from AG to ABG fault and when the trip request is placed either by the zone 1 or the POTT scheme, a three-pole trip is initiated. If this is the case, the **TRIP PHASE A**, **TRIP PHASE B**, and **TRIP PHASE C** operands are asserted. The command is passed to the breaker control element and results in a three-pole trip. At the same time, the recloser is initiated as per settings of the trip output. As the **TRIP 3-POLE** operand is asserted (not the **TRIP 1-POLE** operand), the open pole is not activated. Because the **AR RIP** in progress is asserted, the phase selector is blocked as well.

If the fault evolves slowly, the sequence is different—the relay trips phase A as in the previous example. The phase selector resets, the open pole detector is activated and forces the zone 1 and zone 2 AG, AB, CA and negative-sequence overcurrent elements to

reset. If the zone 1 BG element picks up, or the zone 2 BG element picks up resulting in operation of the POTT scheme, no trip command is issued until the **AR FORCE 3-P TRIP** is asserted. This happens 1.25 cycles after the first trip. If at this time or any time later a request for trip is placed (due to an evolving fault), a three-pole trip is initiated. The **TRIP 1-POLE** operand is de-asserted by the **TRIP 3-POLE** operand, resetting the open pole detector. Shortly all three-poles are opened.

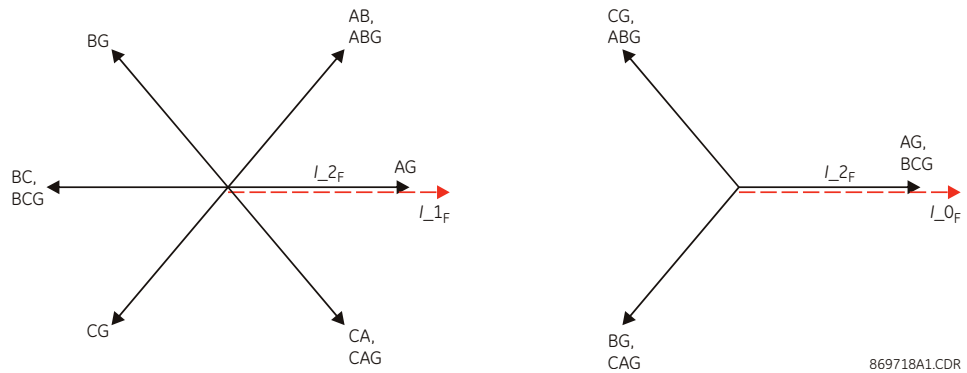
When the dead time expires, the recloser signals the breaker control to close the breaker. At this time, all the protection elements are operational, as the open pole detector is not blocking any elements. If the line-side VTs are used, the line pickup element is armed as well. If there is a fault on the line, these elements pick up the fault and issue the next request for trip. This request results in three-pole trip as the **AR FORCE 3-P TRIP** is still asserted.

The response of the system from this point is as described above for the second trip, except that the recloser goes to lockout upon the next initiation (depending on the number of shots programmed).

Phase selection

The D90^{Plus} uses phase relations between current symmetrical components for phase selection. First, the algorithm validates if there is enough zero-sequence current, positive-sequence current, and negative-sequence current for reliable analysis. The comparison is adaptive; that is, the magnitudes of the three symmetrical components used mutually as restraints confirm if a given component is large enough to be used for phase selection. Once the current magnitudes are validated, the algorithm analyzes phase relations between the negative-sequence and positive-sequence currents and negative-sequence and zero-sequence currents (when applicable), as illustrated.

Figure 562: Phase selection principle (ABC phase rotation)



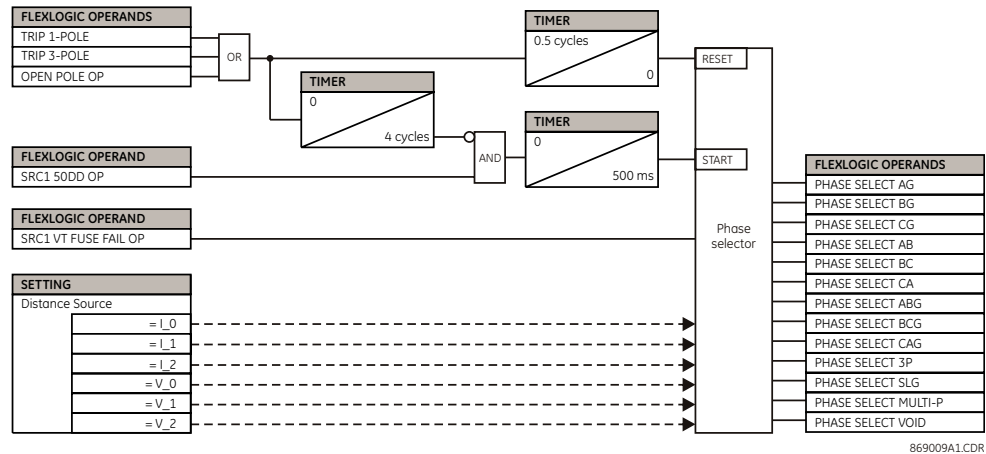
Due to dual comparisons, the algorithm is very secure. For increased accuracy and to facilitate operation in weak systems, the pre-fault components are removed from the analyzed currents. The algorithm is very fast and ensures proper phase selection before any of the correctly set protection elements operate.

Under unusual circumstances, such as weak-infeed conditions with the zero-sequence current dominating during any ground fault, or during cross-country faults, the current-based phase selector does not always recognize any of the known fault pattern. If this is the case, voltages are used for phase selection. The voltage algorithm is the same as the current-based algorithm; for example, phase angles between the zero-sequence, negative-sequence, and positive-sequence voltages are used. The pre-fault values are subtracted prior to any calculations.

The pre-fault quantities are captured and the calculations start when the disturbance detector (ANSI 50DD) operates.

When the trip command is issued by the trip output logic (TRIP 1-POLE or TRIP 3-POLE operands asserted) and during open pole conditions (OPEN POLE OP operand asserted), the phase selector resets all of its output operands and ignores any subsequent operations of the disturbance detector.

Figure 563: Phase selector logic



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Communications channels for pilot-aided schemes

In the D90^{Plus}, pilot-aided schemes transmit a code representing the type of fault determined by the local phase selector according to the scheme logic. At a receiving terminal, the local and remote data are combined to determine the action to be performed. Schemes can be used with channels that can carry one, two, or four bits. Using a one-bit channel, the schemes at all terminals of the line use their local phase selectors to identify the fault type and initiate appropriate tripping actions. In single-pole operation applications however, a three-pole trip can be performed in the event of an in-line single-phase fault co-incident with a fault on a different phase (cross-country fault) that is within the reach of the local phase selector, which is considerably longer than the line. This possibility can be reduced by using a two-bit channel, and eliminated by using a four-bit channel.

Using two-bit channels, the relays can share limited information about their local phase selection, improving considerably the accuracy of single-pole tripping on cross-country faults. Two-bit channels however can only provide four different messages, one of which must be *no fault has been detected*. With only three messages available, it is not possible to transmit sufficient information to eliminate the use of local phase selector data, so a three-pole operation can occur in a cross-country fault condition. Using four-bit channels, the relays share enough information about fault types seen from all the line terminals that local fault selector data can be rejected. In addition, in multiple bit systems the relays do not respond to non-valid bit combinations, making the protection system more immune to communication problems than in a single-bit system.

Each scheme within the relay has a setting that specifies the number of bits available on the associated communications channel. This setting defines the input operands (defined by RX1, RX2, RX3, and RX4 settings for each scheme) and output operands (defined by TX1, TX2, TX3, and TX4 settings for communications and trip A, trip B, trip C, and trip 3P settings for actions, for each scheme) used by the scheme, the data codes used to convey fault data between terminals, and the method of combining information from the local and remote terminals to produce an output.

Single-bit channels

Single-bit communication channels for pilot-aided schemes use the RX1 and TX1 operands for each scheme. The tables show how fault data is coded.

Table 28: Permissive scheme transmit codes for single-bit channels

Phase selector determination of fault type	Bit pattern
	TX1
AG, BG, CG, ABG, BCG, CAG, AB, BC, CA, and 3P	1
Unrecognized or AR FORCE 3P TRIP	1
None of the above	0

Table 29: Blocking scheme transmit codes for single-bit channels

Phase selector determination of fault type	Bit pattern
	TX1
AG, BG, CG, ABG, BCG, CAG, AB, BC, CA, and 3P	0
Unrecognized or AR FORCE 3P TRIP	0
None of the above	1

Table 30: Unblocking scheme transmit codes for single-bit channels

Phase selector determination of fault type	Bit pattern
	TX1
AG, BG, CG, ABG, BCG, CAG, AB, BC, CA, and 3P	1
Unrecognized or AR FORCE 3P TRIP	1
None of the above	0

Table 31: Permissive scheme trip table for single-bit channels

Remote data		Local data	
Bit pattern	Remote determination of fault type	Local determination of fault type	Trip output
RX1			
1	Any	AG fault	TRIP PHASE A
1	Any	BG fault	TRIP PHASE B
1	Any	CG fault	TRIP PHASE C
1	Any	ABG, BCG, CAG, AB, BC, CA, or 3P fault, or unrecognized	TRIP 3-POLE

Table 32: Blocking scheme trip table for single-bit channels

Remote data		Local data	
Bit pattern	Remote determination of fault type	Local determination of fault type	Trip output
RX1			
0	Any	AG fault	TRIP PHASE A
0	Any	BG fault	TRIP PHASE B
0	Any	CG fault	TRIP PHASE C
0	Any	ABG, BCG, CAG, AB, BC, CA, or 3P fault, or unrecognized	TRIP 3-POLE

Table 33: Unblocking scheme trip table for single-bit channels

Remote data		Remote determination of fault type	Local data	
Bit pattern			Local determination of fault type	Trip output
RX1	LOG1			
0 or 1	1	Any	AG fault	DCUB TRIP A
0 or 1	1	Any	BG fault	DCUB TRIP B
0 or 1	1	Any	CG fault	DCUB TRIP C
0 or 1	1	Any	ABG, BCG, CAG, AB, BC, CA, or 3P fault, or unrecognized	DCUB TRIP 3P

The scheme initiates a three-phase trip if the phase selector fails to recognize the fault type or after the **AR FORCE 3P TRIP** operand is asserted.

Two-bit channels

Two-bit communication channels for pilot-aided schemes use the RX1, RX2, TX1, and TX2 operands for each scheme. The tables show how the fault data is coded.

Table 34: Permissive scheme transmit codes for two-bit channels

Phase selector determination of fault type	Bit pattern	
	TX1	TX2
AG, BC, or BCG	1	0
BG, CA, or CAG	0	1
CG, AB, ABG, 3P, or unrecognized	1	1

Table 35: Blocking scheme transmit codes for two-bit channels

Phase selector determination of fault type	Bit pattern		Operands asserted	
	TX1	TX2	TX1 STOP	TX2 STOP
AG, BC, or BCG	0	1	1	0
BG, CA, or CAG	1	0	0	1
CG, AB, ABG, 3P, or unrecognized	0	0	1	1

Table 36: Unblocking scheme transmit codes for two-bit channels

Phase selector determination of fault type	Bit pattern	
	TX1	TX2
AG, BC, or BCG	1	0
BG, CA, or CAG	0	1
CG, AB, ABG, 3P, or unrecognized	1	1

Table 37: Permissive scheme trip table for two-bit channels

Remote data		Remote determination of fault type	Local data	
Bit pattern			Local determination of fault type	Trip output
RX1	RX2			
1	0	AG, BC, or BCG	AG, AB, ABG, CA, CAG, or 3P	TRIP PHASE A
0	1	BG, CA, or CAG	AG	TRIP PHASE A
1	1	CG, AB, ABG, 3P, or unrecognized	AG	TRIP PHASE A
0	1	BG, CA, or CAG	BG, AB, ABG, BC, BCG, or 3P	TRIP PHASE B
1	1	CG, AB, ABG, 3P, or unrecognized	BG	TRIP PHASE B

Remote data		Remote determination of fault type	Local data	
Bit pattern			Local determination of fault type	Trip output
RX1	RX2			
1	0	AG, BC, or BCG	BG	TRIP PHASE B
1	1	CG, AB, ABG, 3P, or unrecognized	CG, BC, BCG, CA, or CAG	TRIP PHASE C
1	0	AG, BC, or BCG	CG	TRIP PHASE C
0	1	BG, CA, or CAG	CG	TRIP PHASE C
1	1	CG, AB, ABG, 3P, or unrecognized	AB, ABG, 3P, or unrecognized	TRIP 3-POLE
1	0	AG, BC, or BCG	BC, BCG, or unrecognized	TRIP 3-POLE
0	1	BG, CA, or CAG	CA, CAG, or unrecognized	TRIP 3-POLE

Table 38: Blocking scheme trip table for two-bit channels

Remote data		Remote determination of fault type	Local data	
Bit pattern			Local determination of fault type	Trip output
RX1	RX2			
0	1	AG, BC, or BCG	AG, AB, ABG, CA, CAG, or 3P	DIR BLOCK TRIP A
1	0	BG, CA, or CAG	AG	DIR BLOCK TRIP A
0	0	CG, AB, ABG, 3P, or unrecognized	AG	DIR BLOCK TRIP A
1	0	BG, CA, or CAG	BG, AB, ABG, BC, BCG, or 3P	DIR BLOCK TRIP B
0	0	CG, AB, ABG, 3P, or unrecognized	BG	DIR BLOCK TRIP B
0	1	AG, BC, or BCG	BG	DIR BLOCK TRIP B
0	0	CG, AB, ABG, 3P, or unrecognized	CG, BC, BCG, CA, or CAG	DIR BLOCK TRIP C
0	1	AG, BC, or BCG	CG	DIR BLOCK TRIP C
1	0	BG, CA, or CAG	CG	DIR BLOCK TRIP C
0	0	CG, AB, ABG, 3P, or unrecognized	AB, ABG, 3P, or unrecognized	DIR BLOCK TRIP 3P
0	1	AG, BC, or BCG	BC, BCG, or unrecognized	DIR BLOCK TRIP 3P
1	0	BG, CA, or CAG	CA, CAG, or unrecognized	DIR BLOCK TRIP 3P

Table 39: Unblocking scheme trip table for two-bit channels

Remote data				Remote determination of fault type	Local data	
Bit pattern					Local determination of fault type	Trip output
RX 1	LO G1	RX 2	LO G2			
1	1	0	0	AG, BC, BCG	AG, AB, ABG CA, CAG, 3P	DCUB TRIP A
0	1	0	0	AG, BC, BCG	AG, AB, ABG CA, CAG, 3P	DCUB TRIP A
0	0	1	1	BG, CA, CAG	AG	DCUB TRIP A
0	0	0	1	BG, CA, CAG	AG	DCUB TRIP A
1	1	1	1	CG, AB, ABG, 3P, unrecognized	AG	DCUB TRIP A
0	1	1	1	CG, AB, ABG, 3P, unrecognized	AG	DCUB TRIP A
1	1	0	1	CG, AB, ABG, 3P, unrecognized	AG	DCUB TRIP A
0	1	0	1	CG, AB, ABG, 3P, unrecognized	AG	DCUB TRIP A

Remote data				Local data		
Bit pattern				Remote determination of fault type	Local determination of fault type	Trip output
RX 1	LO G1	RX 2	LO G2			
0	0	1	1	BG, CA, CAG	BG, AB, ABG BC, BCG, 3P	DCUB TRIP B
0	0	0	1	BG, CA, CAG	BG, AB, ABG BC, BCG, 3P	DCUB TRIP B
1	1	1	1	CG, AB, ABG, 3P, unrecognized	BG	DCUB TRIP B
0	1	1	1	CG, AB, ABG, 3P, unrecognized	BG	DCUB TRIP B
1	1	0	1	CG, AB, ABG, 3P, unrecognized	BG	DCUB TRIP B
0	1	0	1	CG, AB, ABG, 3P, unrecognized	BG	DCUB TRIP B
1	1	0	0	AG, BC, BCG	BG	DCUB TRIP B
0	1	0	0	AG, BC, BCG	BG	DCUB TRIP B
1	1	0	0	AG, BC, BCG	CG	DCUB TRIP C
0	1	0	0	AG, BC, BCG	CG	DCUB TRIP C
0	0	1	1	BG, CA, CAG	CG	DCUB TRIP C
0	0	0	1	BG, CA, CAG	CG	DCUB TRIP C
1	1	1	1	CG, AB, ABG, 3P, unrecognized	CG, BC, BCG, CA, CAG	DCUB TRIP C
0	1	1	1	CG, AB, ABG, 3P, unrecognized	CG, BC, BCG, CA, CAG	DCUB TRIP C
1	1	0	1	CG, AB, ABG, 3P, unrecognized	CG, BC, BCG, CA, CAG	DCUB TRIP C
0	1	0	1	CG, AB, ABG, 3P, unrecognized	CG, BC, BCG, CA, CAG	DCUB TRIP C
1	1	0	0	AG, BC, BCG	BC, BCG, unrecognized	DCUB TRIP 3P
0	1	0	0	AG, BC, BCG	BC, BCG, unrecognized	DCUB TRIP 3P
0	0	1	1	BG, CA, CAG	CA, CAG, unrecognized	DCUB TRIP 3P
0	0	0	1	BG, CA, CAG	CA, CAG, unrecognized	DCUB TRIP 3P
1	1	1	1	CG, AB, ABG, 3P, unrecognized	AB, ABG, 3P, unrecognized	DCUB TRIP 3P
0	1	1	1	CG, AB, ABG, 3P, unrecognized	AB, ABG, 3P, unrecognized	DCUB TRIP 3P
1	1	0	1	CG, AB, ABG, 3P, unrecognized	AB, ABG, 3P, unrecognized	DCUB TRIP 3P
0	1	0	1	CG, AB, ABG, 3P, unrecognized	AB, ABG, 3P, unrecognized	DCUB TRIP 3P

Four-bit channels

Four-bit communication channels for pilot-aided schemes use the RX1, RX2, RX3, RX4, TX1, TX2, TX3, and TX4 operands for each scheme. The tables show how fault data is coded.

Table 40: Permissive scheme transmit codes for four-bit channels

Phase selector determination of fault type	Bit pattern			
	TX1	TX2	TX3	TX4
AG	1	0	0	0
BG	0	1	0	0
CG	0	0	1	0
AB, ABG, BC, BCG, CA, CAG, 3P, or unrecognized	0	0	0	1

Table 41: Blocking scheme transmit codes for four-bit channels

Phase selector determination of fault type	Bit pattern				Operands asserted			
	TX1	TX2	TX3	TX4	TX1 STOP	TX2 STOP	TX3 STOP	TX4 STOP
AG	0	1	1	1	1	0	0	0
BG	1	0	1	1	0	1	0	0
CG	1	1	0	1	0	0	1	0
AB, ABG, BC, BCG, CA, CAG, 3P, or unrecognized	1	1	1	0	0	0	0	1

Table 42: Unblocking scheme transmit codes for four-bit channels

Phase selector determination of fault type	Bit pattern			
	TX1	TX2	TX3	TX4
AG	1	0	0	0
BG	0	1	0	0
CG	0	0	1	0
AB, ABG, BC, BCG, CA, CAG, 3P, or unrecognized	0	0	0	1

The generated action output is indicated in the following tables.

Table 43: Permissive scheme trip table for four-bit channels

Remote data					Local data	
Bit pattern				Remote determination of fault type	Local determination of fault type	Trip output
RX1	RX2	RX3	RX4			
0	0	0	1	MULTI-P	AG	TRIP PHASE A
0	1	0	0	BG	AG	TRIP PHASE A
0	0	1	0	CG	AG	TRIP PHASE A
1	0	0	0	AG	AG, AB, ABG, CA, CAG, 3P, Unrecognized	TRIP PHASE A
0	1	0	0	BG	BG, AB, ABG, BC, BCG, 3P, Unrecognized	TRIP PHASE B
1	0	0	0	AG	BG	TRIP PHASE B
0	0	1	0	CG	BG	TRIP PHASE B
0	0	0	1	MULTI-P	BG	TRIP PHASE B
0	0	1	0	CG	CG, BC, BCG, CA, CAG, 3P, Unrecognized	TRIP PHASE C
1	0	0	0	AG	CG	TRIP PHASE C
0	1	0	0	BG	CG	TRIP PHASE C
0	0	0	1	MULTI-P	CG	TRIP PHASE C
1	0	0	0	AG	BC, BCG	TRIP 3-POLE
0	1	0	0	BG	CA, CAG	TRIP 3-POLE
0	0	1	0	CG	AB, ABG	TRIP 3-POLE
0	0	0	1	MULTI-P	Unrecognized	TRIP 3-POLE

Table 44: Blocking scheme trip table for four-bit channels

Remote data				Local data		
Bit pattern				Remote determination of fault type	Local determination of fault type	Trip output
RX1	RX2	RX3	RX4			
0	0	0	0	Any while the INIT signal was not established	---	Trip as for single-bit channel
1	1	1	0	MULTI-P	AG	DIR BLOCK TRIP A
1	0	1	1	BG	AG	DIR BLOCK TRIP A
1	1	0	1	CG	AG	DIR BLOCK TRIP A
0	1	1	1	AG	AG, AB, ABG, CA, CAG, 3P, Unrecognized	DIR BLOCK TRIP A
1	0	1	1	BG	BG, AB, ABG, BC, BCG, 3P, Unrecognized	DIR BLOCK TRIP B
0	1	1	1	AG	BG	DIR BLOCK TRIP B
1	1	0	1	CG	BG	DIR BLOCK TRIP B
1	1	1	0	MULTI-P	BG	DIR BLOCK TRIP B
1	1	0	1	CG	CG, BC, BCG, CA, CAG, 3P, Unrecognized	DIR BLOCK TRIP C
0	1	1	1	AG	CG	DIR BLOCK TRIP C
1	0	1	1	BG	CG	DIR BLOCK TRIP C
1	1	1	0	MULTI-P	CG	DIR BLOCK TRIP C
0	1	1	1	AG	BC, BCG	DIR BLOCK TRIP 3P
1	0	1	1	BG	CA, CAG	DIR BLOCK TRIP 3P
1	1	0	1	CG	AB, ABG	DIR BLOCK TRIP 3P
1	1	1	0	MULTI-P	Unrecognized	DIR BLOCK TRIP 3P

Table 45: Unblocking scheme trip table for four-bit channels

Remote data								Local data		
Bit pattern								Remote determination of fault type	Local determination of fault type	Trip output
RX 1	LO G1	RX 2	LO G2	RX 3	LO G3	RX 4	LO G4			
0	0	0	0	0	0	1	1	MULTI-P	AG	DCUB TRIP A
0	0	0	0	0	0	0	1	MULTI-P	AG	DCUB TRIP A
0	0	1	1	0	0	0	0	BG	AG	DCUB TRIP A
0	0	0	1	0	0	0	0	BG	AG	DCUB TRIP A
0	0	0	0	1	1	0	0	CG	AG	DCUB TRIP A
0	0	0	0	0	1	0	0	CG	AG	DCUB TRIP A
1	1	0	0	0	0	0	0	AG	AG, AB, ABG, CA, CAG, 3P, unrecognized	DCUB TRIP A
0	1	0	0	0	0	0	0	AG	AG, AB, ABG, CA, CAG, 3P, unrecognized	DCUB TRIP A
0	0	1	1	0	0	0	0	BG	AG, AB, ABG, CA, CAG, 3P, unrecognized	DCUB TRIP B

Remote data								Local data		
Bit pattern								Remote determination of fault type	Local determination of fault type	Trip output
RX 1	LO G1	RX 2	LO G2	RX 3	LO G3	RX 4	LO G4			
0	0	0	1	0	0	0	0	BG	AG, AB, ABG, CA, CAG, 3P, unrecognized	DCUB TRIP B
1	1	0	0	0	0	0	0	AG	BG	DCUB TRIP B
0	1	0	0	0	0	0	0	AG	BG	DCUB TRIP B
0	0	0	0	1	1	0	0	CG	BG	DCUB TRIP B
0	0	0	0	0	1	0	0	CG	BG	DCUB TRIP B
0	0	0	0	0	0	1	1	MULTI-P	BG	DCUB TRIP B
0	0	0	0	0	0	0	1	MULTI-P	BG	DCUB TRIP B
0	0	0	0	1	1	0	0	CG	CG, BC, BCG, CA, CAG, 3P, unrecognized	DCUB TRIP C
0	0	0	0	0	1	0	0	CG	CG, BC, BCG, CA, CAG, 3P, unrecognized	DCUB TRIP C
1	1	0	0	0	0	0	0	AG	CG	DCUB TRIP C
0	1	0	0	0	0	0	0	AG	CG	DCUB TRIP C
0	0	1	1	0	0	0	0	BG	CG	DCUB TRIP C
0	0	0	1	0	0	0	0	BG	CG	DCUB TRIP C
0	0	0	0	0	0	1	1	MULTI-P	CG	DCUB TRIP C
0	0	0	0	0	0	0	1	MULTI-P	CG	DCUB TRIP C
1	1	0	0	0	0	0	0	AG	BC, BCG	DCUB TRIP 3P
0	1	0	0	0	0	0	0	AG	BC, BCG	DCUB TRIP 3P
0	0	1	1	0	0	0	0	BG	CA, CAG	DCUB TRIP 3P
0	0	0	1	0	0	0	0	BG	CA, CAG	DCUB TRIP 3P
0	0	0	0	1	1	0	0	CG	AB, ABG	DCUB TRIP 3P
0	0	0	0	0	1	0	0	CG	AB, ABG	DCUB TRIP 3P
0	0	0	0	0	0	1	1	MULTI-P	3P or unrecognized	DCUB TRIP 3P
0	0	0	0	0	0	0	1	MULTI-P	3P or unrecognized	DCUB TRIP 3P

Permissive echo signaling

The echo feature can reduce the response time of an over-reaching scheme when a terminal is disconnected from the line. In this condition, a zone 2 element at the terminal that remains in-service can detect a fault, but cannot trip, as a permissive signal is not received from the remote terminal. This feature is provided in the permissive over-reaching transfer trip and hybrid permissive over-reaching transfer trip schemes.

When used with the permissive overreaching transfer trip (POTT) scheme, this feature echoes a reliable received permissive signal back to the originating terminal when a line-end open condition is identified by the line pickup logic. The permissive echo is programmed as a one-shot logic. The echo is sent only once and then the echo logic locks out for a user-specified period. The duration of the echo pulse does not depend on the duration or shape of the received RX signals but is user-programmable. The echo is sent back only if none of the overreaching protection elements operates.

When used with the hybrid permissive overreaching transfer trip (hybrid POTT) scheme, this feature echoes a reliable received permissive signal back to the originating terminal if the line-end open condition is recognized by the line pickup scheme and the fault is not identified as a reverse fault by the zone 4 or the ground directional overcurrent function (if

used). The permissive echo is programmed as a one-shot logic. The echo is sent only once and then the echo logic locks out for a user-specified period. The duration of the echo pulse does not depend on the duration or shape of the received RX signal but is programmable with the **Echo Duration** setting. The echo is sent back only if none of the overreaching protection elements operates.

In single-pole tripping, single-bit channel applications the signal received on bit 1 (RX1) is echoed back on bit 1 (TX1). In two-bit and four-bit applications, the following echo tables apply for operands and transit codes.

Table 46: Echo table for two-bit channels

Local determination of fault type	Echoed bits	
	TX1	TX2
AG	1	0
BG	0	1
CG	1	1
AB, ABG, BC, BCG, CA, CAG, 3P, or unrecognized	sent back as received	

Table 47: Echo table for four-bit channels

Local determination of fault type	Echoed bits			
	TX1	TX2	TX3	TX4
AG	1	0	0	0
BG	0	1	0	0
CG	0	0	1	0
AB, ABG, BC, BCG, CA, CAG, 3P, or unrecognized	sent back as received			



For the directional comparison unblocking scheme, the echo is performed in the same manner as the hybrid POTT echo, but by additionally applying the following logic for both the Rx (received) and LOG (loss-of-guard) for each channel: $ECHO = LOG \text{ AND } Rx$.

Pilot scheme and phase selector coordination

The pilot schemes use the phase selector for local fault type identification. The latter can fail to respond to certain fault scenarios. Examples include simultaneous forward and reverse fault, simultaneous SLG and LL fault involving different phases (for example, AG and BC) or two simultaneous faults in the same direction but at very different locations. The phase selector is optimized to indicate correctly the forward fault or to assert the VOID flag. For example, a combination of AG and BC is not a valid fault type. Rather, it is two different, simultaneous faults and as such cannot be described by any single fault pattern. Therefore, the phase selector asserts the VOID flag.

The VOID phase selection combined with a local trip request (such as high-set directional overcurrent) results in three-pole trip as per the trip output logic.

The pilot schemes, however, try to recover additional information from the distance elements. Each scheme uses a forward-looking (either underreaching or overreaching) distance zone. A given pilot scheme analyzes this zone for fault type identification if the phase selector asserts its VOID flag. The DUTT scheme uses zone 1, while all other schemes use zone 2. The schemes analyze all six fault loops of the zone to determine the fault type.

For example, simultaneous forward AG and reverse BG faults can result in the VOID indication. The POTT scheme analyzes the zone 2 response. As only the AG element is picked up, the local phase selection is determined as AG. This is a correct indication.

Depending on the number of bits used for communications, the accuracy of the overall response is further improved as illustrated in the next section.

This enhanced operation of the pilot-aided schemes is the reason to use a short pilot scheme priority time when setting the trip output logic. The timer forces the scheme to wait for a decision from the pilot scheme for a short period of time before accepting any local trip request. The advantage, however, materializes only if two-bit or four-bit communications channels are used, and is important only on parallel lines or when the application requires maximum accuracy of single-pole tripping. In other cases, it is not recommended to delay the local trip decision.

Cross-country fault example

Assume a single-pole operation application where D90^{PLUS} IEDs are used to protect a two-terminal line (terminals T1 and T2) using phase and ground distance zone 1, 2, and 3 elements in a permissive overreaching transfer trip scheme. The performance of the system with one-bit, two-bit, and four-bit communications channels is outlined for a mid-line phase A-to-ground fault and a coincident phase B-to-ground fault just behind terminal T2. Assume also that the reclosers are enabled and reset.

The following protection elements pick up at terminal T1:

- Ground distance zone 1, 2, and 3 for an AG fault
- Ground distance zone 2 and 3 for a BG fault
- Phase distance zone 2 and 3 for an AB fault

The phase selector determines the fault is type ABG at terminal T1. This response is independent from the distance elements; the phase selector sees two forward faults.

The following protection elements pick up at terminal T2:

- Ground distance zone 1, 2, and 3 for an AG fault

The phase selector determines the fault is type AG at terminal T2. The reverse BG fault is likely to be ignored.

If a one-bit channel is used, terminal T1 trips three poles but terminal T2 trips phase A only (see the table), which is undesirable.

Table 48: Trip table for cross-country fault example, one-bit channel

Terminal	Remote data		Local data		
	Bit pattern		Remote determination of fault type	Local determination of fault type	Trip output
	RX1				
T1	1		Any	MULTI-P (ABG)	TRIP 3-POLE
T2	1		Any	AG	TRIP PHASE A

If a two-bit channel is used, both terminal T1 and T2 trip phase A only (see the following table), which is the required outcome.

Table 49: Trip table for cross-country fault example, two-bit channel

Terminal	Remote data			Local data	
	Bit pattern		Remote determination of fault type	Local determination of fault type	Trip output
	RX1	RX2			
T1	1	0	AG	ABG	TRIP PHASE A
T2	1	1	ABG	AG	TRIP PHASE A

If a four-bit channel is used, both terminal T1 and T2 trip phase A only (see the following table), which is the required outcome.

Table 50: Trip table for cross-country fault example, four-bit channel

Terminal	Remote data				Local data		
	Bit pattern				Remote determination of fault type	Local determination of fault type	Trip output
	RX1	RX2	RX3	RX4			
T1	0	0	0	1	AG	ABG	TRIP PHASE A
T2	1	0	0	0	ABG	AG	TRIP PHASE A

D90^{Plus} Line Distance Protection System

Chapter 16: Maintenance

This section outlines maintenance, repair, storage, and disposal of the hardware and software.

General maintenance

The unit requires minimal maintenance. As a microprocessor-based relay, its characteristics do not change over time.

Back up and restore settings

This section describes how to backup settings to a file and how to use that file to restore the settings to the original unit or to a replacement unit.

Back up settings

The following file types can be saved:

- URS — D90^{Plus} settings file

D90^{Plus} device settings can be saved in a backup URS file using the EnerVista UR^{Plus} Setup software. The URS file is the standard UR^{Plus}-series settings file.

The options that display in the EnerVista software when right-clicking depend on device options.

To save a settings file in the URS format in EnerVista Online Window:

1. In EnerVista, connect to the device in the Online Window area.
2. Right-click the device name in the Online Window area and select **Read Device Settings**. A window opens.
3. Select or enter a file name and location, and click the **Receive** button. A .urs file is created in the Offline Window area.

To save a settings file in the URS format in EnerVista Offline Window:

1. In EnerVista, right-click in the Offline Window area and select **New Settings File**. A window opens.
2. Change the file name at the end of the **Path** field, keeping the .urs extension.
3. From the **Associate File with Device** drop-down list, select the D90^{Plus} device. Other fields complete automatically. Otherwise, when you do not select a device from the drop-down list, all fields need to be completed manually and only devices that match the entered order code and version display in the list.
4. The **Serial # Lock** field is the serial number of the intended device. It ensures that the settings file is sent only to the specific relay that matches the serial number.
5. Click the **OK** button to create the .urs file in the Offline Window area.

Restore settings

D90^{Plus} device settings can be restored to the values they were at when a URS backup file was created using the EnerVista UR^{Plus} Setup software. Note that TFTP cannot be used here, as TFTP "put" mode is disabled for security reasons.

To restore completely, a few settings need to be entered manually using EnerVista UR^{Plus} Setup software. If the restore operation is to be via Ethernet, first the D90^{Plus} device must have its IP address settings entered under **Settings > Communications > Network > Ethernet**.

When importing a file, it cannot have a blank numeric value. All numeric values must be non-blank, otherwise the file is rejected.

To restore settings from a URS file:

1. In EnerVista, connect to the device in the Online Window area.
2. Right-click the .urs file in the Offline Window area and select **Add Existing Settings File** to locate a file, and/or drag-and-drop the file from the Offline Window area to the device in the Online Window area.
3. Manually enter the following settings not transferred to the D90^{Plus} with the setting files.

- Modbus Slave Address
- Modbus TCP Port Number
- Serial Port
- Baud Rate
- Parity
- Minimum Response Time
- Connection
- IP Subnet Mask
- IP Routing

Upgrade software

In general, the latest releases of the EnerVista software can be used with all firmware versions, for example EnerVista software released for D90^{Plus} 1.7 can be used to access multiple D90^{Plus} devices that have version 1.7x and 1.8x firmware installed.

The latest EnerVista software and firmware can be downloaded from

<https://www.gegridsolutions.com/multilin>

After upgrading, check the version number under **Help > About**. If the new version does not display, try uninstalling the software and reinstalling the new versions.

You can also downgrade the software; use the same procedure here.

A message can display in the EnerVista software when accessing a D90^{Plus} device that the "relay has a firmware version that does not match EnerVista UR^{Plus} Setup version for the device." This means that the order codes for the D90^{Plus} device and in the EnerVista software are inconsistent. For example the D90^{Plus} v1.8 device is really a v1.7 device. The device is still functional, but the message displays each time the device is accessed. This can be fixed by making the order codes consistent.

To make the order codes consistent:

1. In EnerVista, click the **Device Setup** button. The window opens.
2. Expand the entry for the D90^{Plus} device.
3. Click the **Read Order Code** button. The order code and version of the device are populated to the software.
4. Click the **OK** button to save the change.

Upgrade firmware

If upgrading both EnerVista software and D90^{Plus} firmware, upgrade the software first.

The firmware of the D90^{Plus} device can be upgraded locally (not remotely) using the EnerVista software. Upgrades are possible for the same release (such as 1.81 to 1.82) and from one firmware version to another (such as 1.7 to 1.8). When upgrading to another firmware version, check the release notes for compatibility. Release notes are located in the Support Documents section of the website,

You can also downgrade firmware; use the same procedure.

To upgrade the firmware:

1. Connect the computer to the device with an Ethernet cable.
2. In EnerVista, back up the device settings by right-clicking the device and selecting **Read Device Settings**. In the window that displays, enter a name for a new settings file and optionally a location for the new file. Click the **Receive** button to start the backup.
3. If an "Incompatible device order codes or versions" message displays, it means that you are trying to overwrite a file for another product. You access the **Convert Settings File** option by right-clicking the file in the Offline Window area at the lower left.
4. In EnerVista, navigate to **Maintenance > Update Firmware**, select the firmware update by locating the locked .zip file, and proceed with the update. When the update is finished, the relay restarts automatically.
5. Restart the EnerVista software, and refresh the order code in EnerVista under the **Device Setup** button.
6. Verify the firmware version while the device is starting up or in EnerVista under **Actual Values > Product Info > Firmware Revisions**.
7. Set the device to "programmed" under **Settings > Protection > Power System > Installation > Relay Settings**. A self-test error displays on the device until this is done.
8. To apply any previously saved settings, right-click the saved settings file in the Offline Window area and select **Write to Device**.



NOTE

Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (that is, default values, minimum/maximum values, data type, and item size) can change slightly from version to version of firmware. The addresses are rearranged

when new features are added or existing features are enhanced or modified. The EEPROM DATA ERROR message displayed after upgrading/downgrading the firmware is a resettable, self-test message intended to inform users that the Modbus addresses have changed with the upgraded firmware. This message does not signal any problems when appearing after firmware upgrades.

Uninstall and clear files and data

The unit can be decommissioned by turning of the power to the unit and disconnecting the wires to it.

Files can be cleared after uninstalling the EnerVista software or the device, for example to comply with data security regulations.

To uninstall the EnerVista software, use the built-in computer function, such as **Control Panel > Programs and Features**.

Repairs

The firmware and software can be upgraded without return of the device to the factory.

For issues not solved by troubleshooting, the process to return the device to the factory for repair is as follows:

- Contact a GE Grid Solutions Technical Support Center.
- Obtain a Return Materials Authorization (RMA) number from the Technical Support Center.
- Verify that the RMA and Commercial Invoice received have the correct information.
- Tightly pack the unit in a box with bubble wrap, foam material, or styrofoam inserts or packaging peanuts to cushion the item(s). You may also use double boxing whereby you place the box in a larger box that contains at least 5 cm of cushioning material.
- Ship the unit by courier or freight forwarder, along with the Commercial Invoice and RMA, to the factory address on the RMA papers.

Customers are responsible for shipping costs to the factory, regardless of whether the unit is under warranty.

- Fax a copy of the shipping information to the GE Grid Solutions service department in Canada at +1 905 927 5098.

Use the detailed return procedure outlined at

https://www.gegridsolutions.com/multilin/support/ret_proc.htm

The current warranty and return information are outlined at

<https://www.gegridsolutions.com/multilin/warranty.htm>

Storage

Store the unit indoors in a cool, dry place. If possible, store in the original packaging. Follow the storage temperature range outlined in the Specifications.

NOTICE

To avoid deterioration of electrolytic capacitors, power up units that are stored in a de-energized state once per year, for one hour continuously.

Disposal

There are no special requirements for disposal of the unit at the end its service life. To prevent non-intended use of the unit, remove interior modules, dismantle the unit, and recycle the metal when possible.

D90^{Plus} Line Distance Protection System

Chapter 17: Appendix

This section provides the warranty and revision history.

Warranty

For products shipped as of 1 October 2013, GE Grid Solutions warrants most of its GE manufactured products for 10 years. For warranty details including any limitations and disclaimers, see the GE Grid Solutions Terms and Conditions at <http://gegridsolutions.com/multilin/warranty.htm>

For products shipped before 1 October 2013, the standard 24-month warranty applies.

Revision history

The tables outline the releases and revision history of this document.

Table 51: Revision history (English)

Publication number	Part number	Firmware	Release date	ECO
GEK-113284	1601-9019-A1	1.4x	30 August 2007	---
GEK-113284A	1601-9019-A2	1.4x	7 May 2008	08-0225
GEK-113258	1601-9019-C1	1.6x	28 November 2008	08-0718
GEK-113258B	1601-9019-C2	1.6x	10 August 2012	12-3463
GEK-113240	1601-9019-D1	1.7x	30 January 2010	09-1486
GEK-113240B	1601-9019-D2	1.7x	20 March 2012	12-3213
GEK-113240C	1601-9019-D3	1.7x	10 August 2012	12-3463
GEK-113248	1601-9019-E1	1.8x	September 2010	10-1969
GEK-113248B	1601-9019-E2	1.8x	22 June 2012	12-3393
GEK-113248C	1601-9019-E3	1.8x	10 August 2012	12-3463
GEK-113468	1601-9019-F1	1.9x	30 April 2013	13-0104
GEK-113468B	1601-9019-F2	1.9x	29 July 2014	14-1350
GEK-113468C	1601-9019-F3	1.9x	31 July 2015	14-1352
GEK-113468D	1601-9019-F4	1.9x	31 October 2016	16-2337

Table 52: Major changes for document version F4

Page	Change
---	Minor revision. Updated branding to GE Grid Solutions from GE Digital Energy.
38	Added Noise specification under Environmental Specifications
69	Added sentence to Front Panel section that no settings are entered on the front panel and to use the software instead
309	Updated Figure 261 Directional Comparison Blocking Scheme Logic
497	Added sentence in Battery Monitor section that there is no battery inside the device
668	Added Maintenance chapter

Table 53: Major changes for document version F3

Page	Change
---	Updated design of Instruction Manual and Communications Guide by putting into new template
---	Edited entire documents, minor restructuring to make more consistent with UR manuals
--	Minor revisions to both Instruction Manual and Communications Guide, for example to Trip Output and Breaker Configuration logic diagrams
2-	Added Communications Overview section after Hardware Architecture section, from C90Plus instruction manual
46	Updated Rear Terminal Layout figure to show parts
---	Updated Modbus memory map in Communications Guide

Table 54: Major updates for version F2

Page	Change
--	General editing
56	Updated polarity for A_4 and A_5 in Figure 27 Dry and Wet Contact Input Connections
304	Updated Figure 107 Hybrid POTT Scheme Logic
669	Updated product warranty from 24 months to 10 years

Table 55: Major updates for version F1

Page	Change
--	General editing
--	Added Parallel Redundancy Protocol (PRP), including to the order code table and Communications > Network > Ethernet section
10	Added support for Windows 7 (64-bit), and Server 2008 (64-bit)
406	Deleted Viewpoint Engineer content by deleting Graphical Programming Interface section

D90^{Plus} Line Distance Protection System

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