GE Power Management

D60 Line Distance Relay

UR Series Instruction Manual

D60 Revision: 2.9X

Manual P/N: 1601-0089-**B7** (GEK-106233D)

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837707A7.CDR

D60 LINE DISTANCE RELAY

GE Power Management
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Canada L6E 1B3
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Internet: http://www.GEindustrial.com/pm

Manufactured under an
ISO9000 Registered system.

ADDENDUM

This Addendum contains information that relates to the D60 relay, version 2.9X. This addendum lists a number of information items that appear in the instruction manual 1601-0089-B7 (GEK-106233D) but are not included in the current D60 operations.

The following functions/items are not yet available with the current version of the D60 relay:

- Signal Sources SRC 3 to SRC 6

STUB BUS:

The final Stub Bus protection is not implemented for this release. This feature can be implemented using a Phase IOC function and the auxiliary contact from the line disconnect, incorporated into a simple FlexLogic™ equation.

NOTE:

- The UCA2 specifications are not yet finalized. There will be changes to the object models described in Appendix C: UCA/MMS.

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A. FLEXANALOG

B. MODBUS® RTU PROTOCOL

C. UCA/MMS

Please read this chapter to help guide you through the initial setup of your new relay.

1.1.1 CAUTIONS AND WARNINGS

WARNING CAUTION

Before attempting to install or use the relay, it is imperative that all WARNINGS and CAUTIONS in this manual are reviewed to help prevent personal injury, equipment damage, and/or downtime.

1.1.2 INSPECTION CHECKLIST

- Open the relay packaging and inspect the unit for physical damage.
- Check that the battery tab is intact on the power supply module (for more details, see the section BATTERY TAB in this chapter).
- View the rear name-plate and verify that the correct model has been ordered.

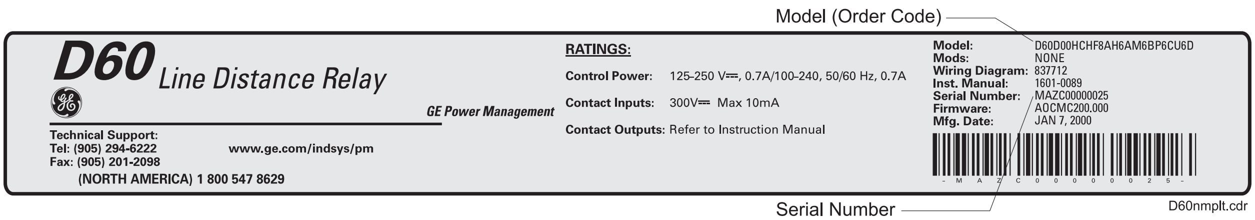


Figure 1–1: REAR NAME-PLATE (EXAMPLE)

- Ensure that the following items are included:
  - Instruction Manual
  - Products CD (includes URPC software and manuals in PDF format)
  - mounting screws
  - registration card (attached as the last page of the manual)
- Fill out the registration form and mail it back to GE Power Management (include the serial number located on the rear nameplate).
- For product information, instruction manual updates, and the latest software updates, please visit the GE Power Management Home Page.

NOTE

If there is any noticeable physical damage, or any of the contents listed are missing, please contact GE Power Management immediately.

GE POWER MANAGEMENT CONTACT INFORMATION AND CALL CENTER FOR PRODUCT SUPPORT:

GE Power Management
215 Anderson Avenue
Markham, Ontario
Canada L6E 1B3

TELEPHONE: (905) 294-6222, 1-800-547-8629 (North America only)
FAX: (905) 201-2098
E-MAIL: info.pm@indsys.ge.com
HOME PAGE: http://www.GEindustrial.com/pm

1.2.1 INTRODUCTION TO THE UR RELAY

Historically, substation protection, control, and metering functions were performed with electromechanical equipment. This first generation of equipment was gradually replaced by analog electronic equipment, most of which emulated the single-function approach of their electromechanical precursors. Both of these technologies required expensive cabling and auxiliary equipment to produce functioning systems.

Recently, digital electronic equipment has begun to provide protection, control, and metering functions. Initially, this equipment was either single function or had very limited multi-function capability, and did not significantly reduce the cabling and auxiliary equipment required. However, recent digital relays have become quite multi-functional, reducing cabling and auxiliaries significantly. These devices also transfer data to central control facilities and Human Machine Interfaces using electronic communications. The functions performed by these products have become so broad that many users now prefer the term IED (Intelligent Electronic Device).

It is obvious to station designers that the amount of cabling and auxiliary equipment installed in stations can be even further reduced, to 20% to 70% of the levels common in 1990, to achieve large cost reductions. This requires placing even more functions within the IEDs.

Users of power equipment are also interested in reducing cost by improving power quality and personnel productivity, and as always, in increasing system reliability and efficiency. These objectives are realized through software which is used to perform functions at both the station and supervisory levels. The use of these systems is growing rapidly.

High speed communications are required to meet the data transfer rates required by modern automatic control and monitoring systems. In the near future, very high speed communications will be required to perform protection signaling with a performance target response time for a command signal between two IEDs, from transmission to reception, of less than 5 milliseconds. This has been established by the Electric Power Research Institute, a collective body of many American and Canadian power utilities, in their Utilities Communications Architecture 2 (MMS/UCA2) project. In late 1998, some European utilities began to show an interest in this ongoing initiative.

IEDs with the capabilities outlined above will also provide significantly more power system data than is presently available, enhance operations and maintenance, and permit the use of adaptive system configuration for protection and control systems. This new generation of equipment must also be easily incorporated into automation systems, at both the station and enterprise levels. The GE Power Management Universal Relay (UR) has been developed to meet these goals.

1.2.2 UR HARDWARE ARCHITECTURE

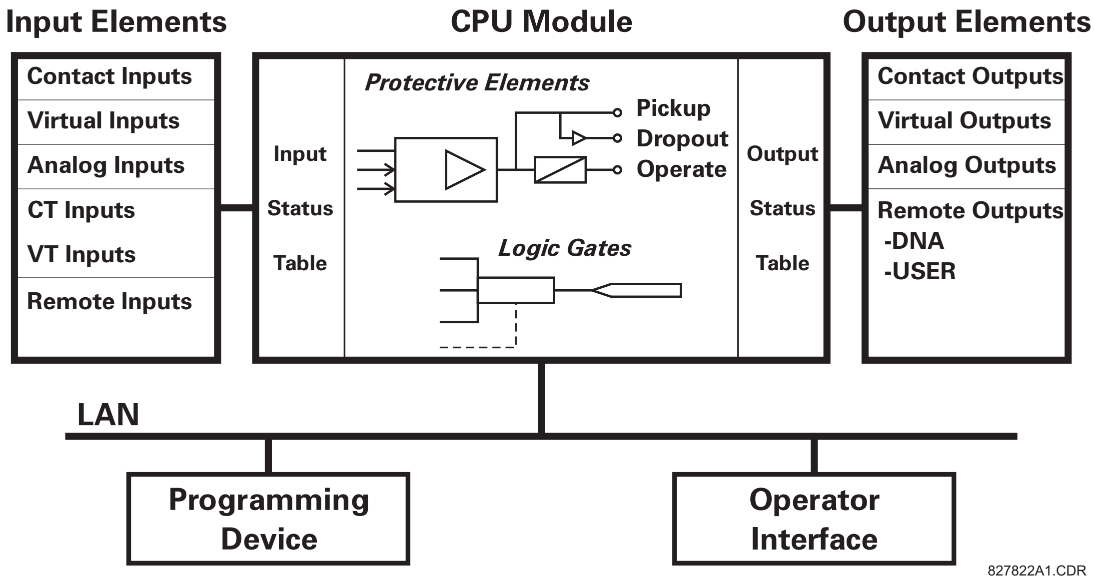


Figure 1–2: UR CONCEPT BLOCK DIAGRAM

a) UR BASIC DESIGN

The UR is a digital-based device containing a central processing unit (CPU) that handles multiple types of input and output signals. The UR can communicate over a local area network (LAN) with an operator interface, a programming device, or another UR device.

The **CPU module** contains firmware that provides protection elements in the form of logic algorithms, as well as programmable logic gates, timers, and latches for control features.

Input elements accept a variety of analog or digital signals from the field. The UR isolates and converts these signals into logic signals used by the relay.

Output elements convert and isolate the logic signals generated by the relay into digital or analog signals that can be used to control field devices.

b) UR SIGNAL TYPES

The **contact inputs and outputs** are digital signals associated with connections to hard-wired contacts. Both ‘wet’ and ‘dry’ contacts are supported.

The **virtual inputs and outputs** are digital signals associated with UR internal logic signals. Virtual inputs include signals generated by the local user interface. The virtual outputs are outputs of FlexLogic™ equations used to customize the UR device. Virtual outputs can also serve as virtual inputs to FlexLogic™ equations.

The **analog inputs and outputs** are signals that are associated with transducers, such as Resistance Temperature Detectors (RTDs).

The **CT and VT inputs** refer to analog current transformer and voltage transformer signals used to monitor AC power lines. The UR supports 1 A and 5 A CTs.

The **remote inputs and outputs** provide a means of sharing digital point state information between remote UR devices. The remote outputs interface to the remote inputs of other UR devices. Remote outputs are FlexLogic™ operands inserted into UCA2 GOOSE messages and are of two assignment types: DNA standard functions and USER defined functions.

c) UR SCAN OPERATION

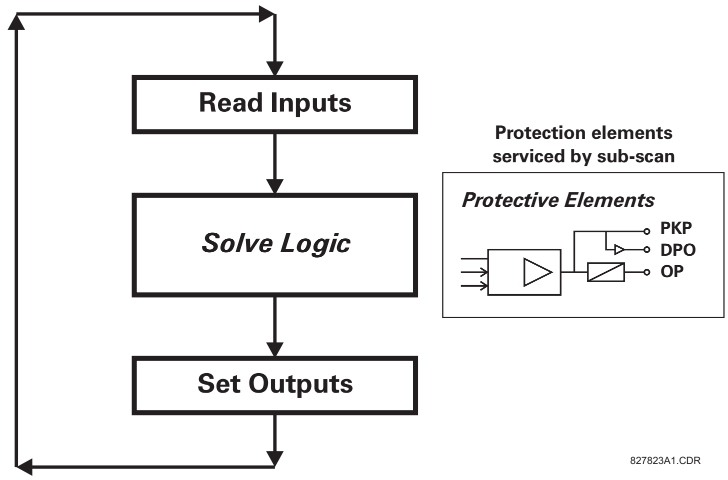


Figure 1–3: UR SCAN OPERATION

The UR device operates in a cyclic scan fashion. The UR reads the inputs into an input status table, solves the logic program (FlexLogic™ equation), and then sets each output to the appropriate state in an output status table. Any resulting task execution is priority interrupt-driven.

1.2.3 UR SOFTWARE ARCHITECTURE

The firmware (software embedded in the relay) is designed in functional modules which can be installed in any relay as required. This is achieved with Object-Oriented Design and Programming (OOD/OOP) techniques.

Object-Oriented techniques involve the use of ‘objects’ and ‘classes’. An ‘object’ is defined as “a logical entity that contains both data and code that manipulates that data”. A ‘class’ is the generalized form of similar objects. By using this concept, one can create a Protection Class with the Protection Elements as objects of the class such as Time Overcurrent, Instantaneous Overcurrent, Current Differential, Undervoltage, Overvoltage, Underfrequency, and Distance. These objects represent completely self-contained software modules. The same object-class concept can be used for Metering, I/O Control, HMI, Communications, or any functional entity in the system.

Employing OOD/OOP in the software architecture of the Universal Relay achieves the same features as the hardware architecture: modularity, scalability, and flexibility. The application software for any Universal Relay (e.g. Feeder Protection, Transformer Protection, Distance Protection) is constructed by combining objects from the various functionality classes. This results in a ’common look and feel’ across the entire family of UR platform-based applications.

1.2.4 IMPORTANT UR CONCEPTS

As described above, the architecture of the UR relay is different from previous devices. In order to achieve a general understanding of this device, some sections of Chapter 5 are quite helpful. The most important functions of the relay are contained in "Elements". A description of UR elements can be found in the INTRODUCTION TO ELEMENTS section. An example of a simple element, and some of the organization of this manual, can be found in the DIGITAL ELEMENTS MENU section. An explanation of the use of inputs from CTs and VTs is in the INTRODUCTION TO AC SOURCES section. A description of how digital signals are used and routed within the relay is contained in the INTRODUCTION TO FLEXLOGIC™ section.

1.3.1 PC REQUIREMENTS

The Faceplate keypad and display or the URPC software interface can be used to communicate with the relay.

The URPC software interface is the preferred method to edit settings and view actual values because the PC monitor can display more information in a simple comprehensible format.

The following minimum requirements must be met for the URPC software to properly operate on a PC.

Processor:	Intel® Pentium 300 or higher
RAM Memory:	64 MB minimum (128 MB recommended)
Hard Disk:	50 MB free space required before installation of URPC software
O/S:	Windows® NT 4.x or Windows® 9x/2000
Device:	CD-ROM drive
Port:	COM1(2) / Ethernet

1.3.2 SOFTWARE INSTALLATION

Refer to the following procedure to install the URPC software:

1. **Start** the Windows® operating system.
2. **Insert** the URPC software CD into the CD-ROM drive.
3. If the installation program does not start automatically, choose **Run** from the Windows® **Start** menu and type D:\SETUP.EXE. Press Enter to start the installation.
4. Follow the on-screen instructions to install the URPC software. When the **Welcome** window appears, click on **Next** to continue with the installation procedure.
5. When the **Choose Destination Location** window appears and if the software is not to be located in the default directory, click **Browse** and type in the complete path name including the new directory name.
6. Click **Next** to continue with the installation procedure.
7. The default program group where the application will be added to is shown in the **Select Program Folder** window. If it is desired that the application be added to an already existing program group, choose the group name from the list shown.
8. Click **Next** to begin the installation process.
9. To launch the URPC application, click Finish in the Setup Complete window.
10. Subsequently, double click on the URPC software icon to activate the application.

NOTE

Refer to the HUMAN INTERFACES chapter in this manual and the URPC Software Help program for more information about the URPC software interface.

1.3.3 CONNECTING URPC® WITH THE D60

This section is intended as a quick start guide to using the URPC software. Please refer to the URPC Help File and the HUMAN INTERFACES chapter for more information.

a) CONFIGURING AN ETHERNET CONNECTION

Before starting, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay.

1. Start the URPC software. Enter the password "URPC" at the login password box.
2. Select the **Help > Connection Wizard** menu item to open the Connection Wizard. Click "Next" to continue.
3. Click the "New Interface" button to open the Edit New Interface window.
   - Enter the desired interface name in the **Enter Interface Name** field.
   - Select the "Ethernet" interface from the drop down list and press "Next" to continue.
4. Click the "New Device" button to open the Edit New Device Window.
   - Enter the desired name in the **Enter Interface Name** field.
   - Enter the Modbus address of the relay (from SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ MODBUS PROTOCOL ⇨ MODBUS SLAVE ADDRESS) in the **Enter Modbus Address** field.
   - Enter the IP address (from SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK ⇨ IP ADDRESS) in the **Enter TCPIP Address** field.
5. Click the "4.1 Read Device Information" button then "OK" when the relay information has been received. Click "Next" to continue.
6. Click the "New Site" button to open the Edit Site Name window.
   - Enter the desired site name in the **Enter Site Name** field.
7. Click the "OK" button then click "Finish". The new Site List tree will be added to the Site List window (or Online window) located in the top left corner of the main URPC window.

The Site Device has now been configured for Ethernet communications. Proceed to Section c) CONNECTING TO THE RELAY below to begin communications.

b) CONFIGURING AN RS232 CONNECTION

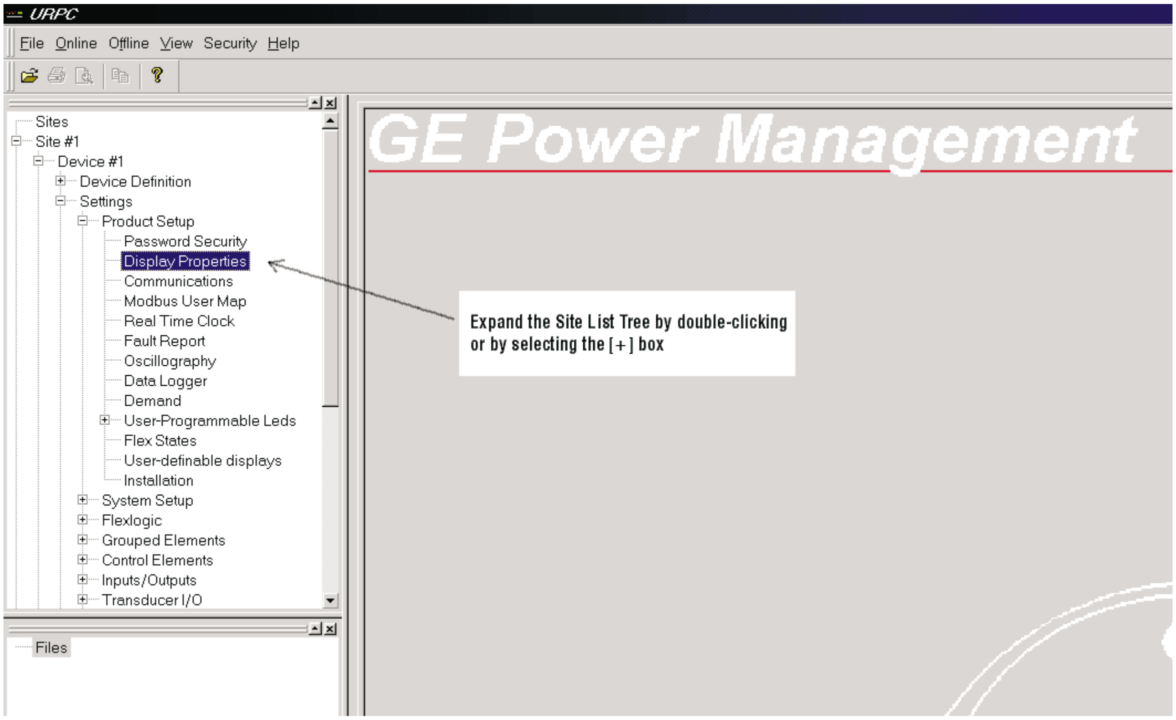
Before starting, verify that the RS232 serial cable is properly connected to the RS232 port on the front panel of the relay.

1. Start the URPC software. Enter the password "URPC" at the login password box.
2. Select the **Help > Connection Wizard** menu item to open the Connection Wizard. Click "Next" to continue.
3. Click the "New Interface" button to open the Edit New Interface window.
   - Enter the desired interface name in the **Enter Interface Name** field.
   - Select the "RS232" interface from the drop down list and press "Next" to continue.
4. Click the "New Device" button to open the Edit New Device Window.
   - Enter the desired name in the **Enter Interface Name** field.
   - Enter the PC COM port number in the **COM Port** field.
5. Click "OK" then click "Next" to continue.
6. Click the "New Site" button to open the Edit Site Name window.
   - Enter the desired site name in the **Enter Site Name** field.
7. Click the "OK" button then click "Finish". The new Site List tree will be added to the Site List window (or Online window) located in the top left corner of the main URPC window.

The Site Device has now been configured for RS232 communications. Proceed to Section c) CONNECTING TO THE RELAY below to begin communications.

c) CONNECTING TO THE RELAY

1. Select the Display Properties window through the Site List tree as shown below:



2. The Display Properties window will open with a flashing status indicator.
   - If the indicator is red, click the Connect button (lightning bolt) in the menu bar of the Displayed Properties window.
3. In a few moments, the flashing light should turn green, indicating that URPC is communicating with the relay.

NOTE

Refer to the HUMAN INTERFACES chapter in this manual and the URPC Software Help program for more information about the URPC software interface.

1.4.1 MOUNTING AND WIRING

Please refer to the HARDWARE chapter for detailed relay mounting and wiring instructions. Review all **WARNINGS and CAUTIONS**.

1.4.2 COMMUNICATIONS

The URPC software communicates to the relay via the faceplate RS232 port or the rear panel RS485 / Ethernet ports. To communicate via the faceplate RS232 port, a standard “straight-through” serial cable is used. The DB-9 male end is connected to the relay and the DB-9 or DB-25 female end is connected to the PC COM1 or COM2 port as described in the HARDWARE chapter.

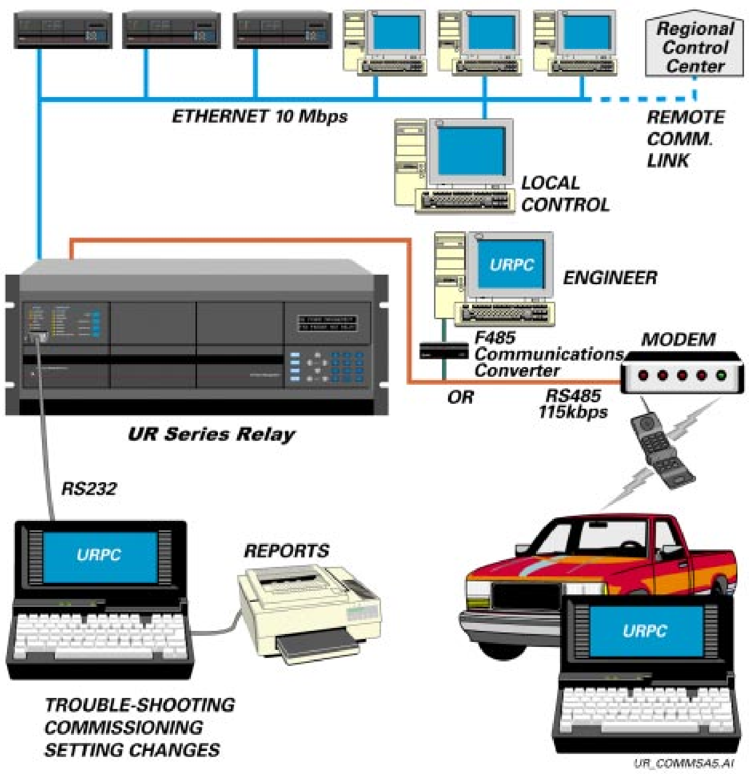


Figure 1–4: RELAY COMMUNICATIONS OPTIONS

To communicate through the D60 rear RS485 port from a PC RS232 port, the GE Power Management 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 D60 rear communications port. The converter terminals (+, –, GND) are connected to the D60 communication module (+, –, COM) terminals. Refer to the CPU COMMUNICATION PORTS section in the HARDWARE chapter for option details. The line should be terminated with an R-C network (i.e. 120 Ω, 1 nF) as described in the HARDWARE chapter.

1.4.3 FACEPLATE DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

1.5.1 FACEPLATE KEYPAD

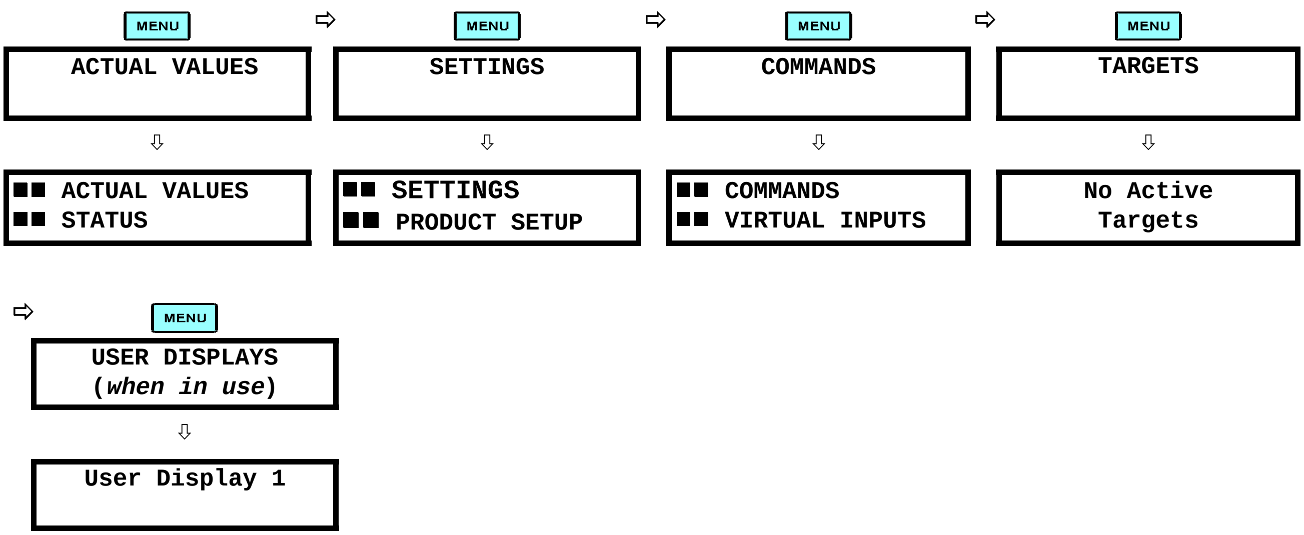
Display messages are organized into ‘pages’ under the following headings: Actual Values, Settings, Commands, and Targets. The MENU key navigates through these pages. Each heading page is broken down further into logical subgroups.

The ▲ ◄ MESSAGE ► ▼ keys navigate through the subgroups. The ▲ VALUE ▼ keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The . key initiates and advance to the next character in text edit mode or enters a decimal point. The HELP key may be pressed at any time for context sensitive help messages. The ENTER key stores altered setting values.

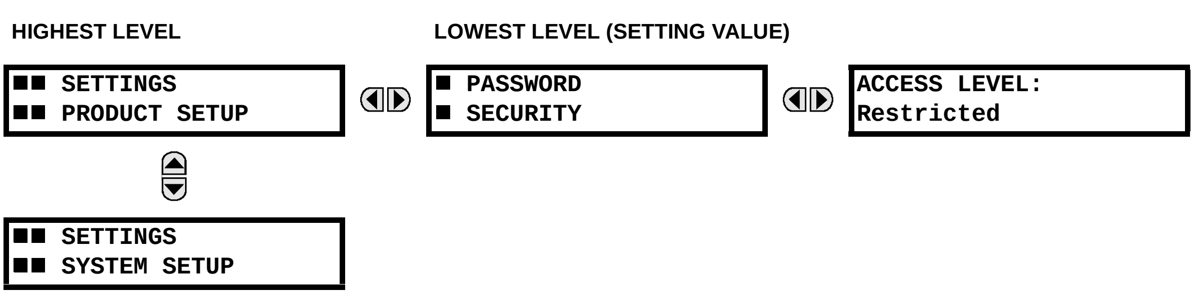
1.5.2 MENU NAVIGATION

Press the MENU key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the main heading pages as illustrated below.



1.5.3 MENU HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE ▲ and ▼ keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE ► key from a header display displays specific information for the header category. Conversely, continually pressing the ◄ MESSAGE key from a setting value or actual value display returns to the header display.



1.5.4 RELAY ACTIVATION

The relay is defaulted to the "Not Programmed" state when it leaves the factory. This safeguards against the installation of a relay whose settings have not been entered. When powered up successfully, the TROUBLE indicator will be on and the IN SERVICE indicator off. The relay in the "Not Programmed" state will block signaling of any output relay. These conditions will remain until the relay is explicitly put in the "Programmed" state.

Select the menu message SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION ⇨ RELAY SETTINGS

```
RELAY SETTINGS:
Not Programmed
```

To put the relay in the "Programmed" state, press either of the ▲ VALUE ▼ keys once and then press ENTER. The faceplate TROUBLE indicator will turn off and the IN SERVICE indicator will turn on. The settings for the relay can be programmed manually (refer to the SETTINGS chapter) via the faceplate keypad or remotely (refer to the URPC Help file) via the URPC software interface.

1.5.5 BATTERY TAB

The battery tab is installed in the power supply module before the D60 shipped from the factory. The battery tab prolongs battery life in the event the relay is powered down for long periods of time before installation. The battery is responsible for backing up event records, oscillography, data logger, and real-time clock information when the relay is powered off. The battery failure self-test error generated by the relay is a minor and should not affect the relay functionality. When the relay is installed and ready for commissioning, the tab should be removed. The battery tab should be re-inserted if the relay is powered off for an extended period of time. If required, contact the factory for a replacement battery or battery tab.

1.5.6 RELAY PASSWORDS

It is recommended that passwords be set up for each security level and assigned to specific personnel. There are two user password SECURITY access levels:

1. COMMAND

The COMMAND access level restricts the user from making any settings changes, but allows the user to perform the following operations:

- operate breakers via faceplate keypad
- change state of virtual inputs
- clear event records
- clear oscillography records

2. SETTING

The SETTING access level allows the user to make any changes to any of the setting values.

NOTE **Refer to the CHANGING SETTINGS section (in the HUMAN INTERFACES chapter) for complete instructions on setting up security level passwords.**

1.5.7 FLEXLOGIC™ CUSTOMIZATION

FlexLogic™ equation editing is required for setting up user-defined logic for customizing the relay operations. See section FLEXLOGIC™ in the SETTINGS chapter.

1.5.8 COMMISSIONING

Templated tables for charting all the required settings before entering them via the keypad are available in the COMMISSIONING chapter.

2.1.1 OVERVIEW

The D60 Line Distance Relay is a microprocessor-based relay 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 primary function of the relay consists of four phase and ground distance zones of protection, either mho or quadrilateral as per user selection, with built-in logic for the five common pilot-aided schemes. The distance elements are optimized to provide good measurement accuracy with a fast operating time, even when used with Capacitive Voltage Transformers, and can be supervised by detection of power swings. The relay also provides directional ground overcurrent elements, which are commonly used as part of an overall line protection system.

A Close-Into-Fault, or Switch-On-To-Fault, function is performed by the Line Pickup element. Out-of-step tripping, three-pole/single-pole dual breaker, autoreclosing, synchrocheck, fault location, and many other functions are also available. In addition, overcurrent and undervoltage protection, fault diagnostics, power metering, and RTU functions are provided. The D60 provides phase, neutral, and ground time overcurrent protection. The time overcurrent functions can be programmed with multiple curve shapes or FlexCurve™ for optimum coordination.

Voltage and current metering is included as a standard feature. Additionally, currents are available as total RMS values. Power, power factor and frequency measurements are also provided.

Diagnostic features include an Event Recorder capable of storing 1024 time-tagged events, Oscillography capable of storing up to 64 records with programmable trigger, content and sampling rate, and Data Logger acquisition of up to 16 channels, with programmable content and sampling rate. The internal clock used for time-tagging can be synchronized with an IRIG-B signal. This precise time stamping allows the sequence of events to be determined throughout the system. Events can also be programmed (via FlexLogic™ equations) to trigger oscillography data capture which may be set to record the measured parameters before and after the event for viewing on a personal computer (PC). These tools significantly reduce troubleshooting time and simplify report generation in the event of a system fault.

A faceplate RS232 port may be used to connect to a PC for the programming of settings and the monitoring of actual values. A variety of communications modules are available. Two rear RS485 ports allow independent access by operating and engineering staff. All serial ports use the Modbus® RTU protocol. The RS485 ports may be connected to system computers with baud rates up to 115.2 kbps. The RS232 port has a fixed baud rate of 19.2 kbps. Optional communications modules include a 10BaseF Ethernet interface which can be used to provide fast, reliable communications in noisy environments. Another option provides two 10BaseF fiber optic ports for redundancy. The Ethernet port supports MMS/UCA2, Modbus®/TCP, and TFTP protocols, and allows access to the relay via any standard web browser (UR web pages). The DNP 3.0 or IEC 60870-5-104 protocol is supported on a user-specified port, including serial and Ethernet ports.

The relay uses flash memory technology which allows field upgrading as new features are added. The following SINGLE LINE DIAGRAM illustrates the relay functionality using ANSI (American National Standards Institute) device numbers.

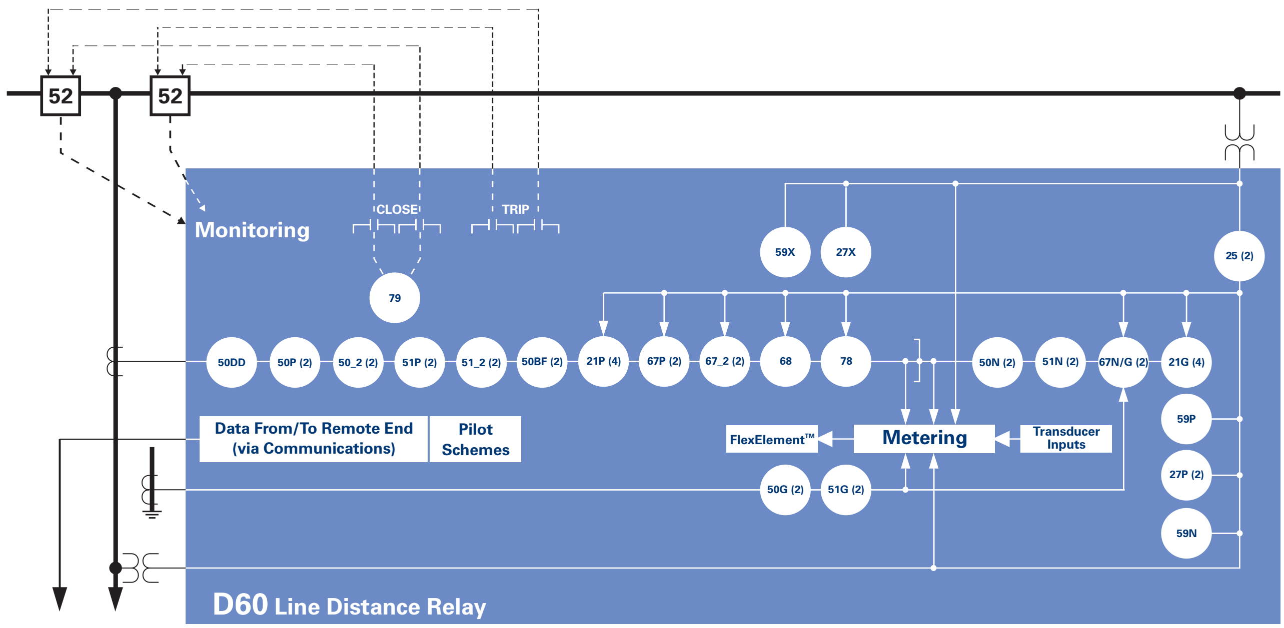


Figure 2–1: SINGLE LINE DIAGRAM

Table 2–1: DEVICE NUMBERS AND FUNCTIONS

DEVICE NUMBER	FUNCTION
21G	Ground Distance
21P	Phase Distance
25	Synchrocheck
27P	Phase Undervoltage
27X	Auxiliary Undervoltage
50BF	Breaker Failure
50DD	Current Disturbance Detector
50G	Ground Instantaneous Overcurrent
50N	Neutral Instantaneous Overcurrent
50P	Phase Instantaneous Overcurrent
50_2	Negative Sequence Instantaneous Overcurrent
51G	Ground Time Overcurrent
51N	Neutral Time Overcurrent

DEVICE NUMBER	FUNCTION
51P	Phase Time Overcurrent
51_2	Negative Sequence Time Overcurrent
52	AC Circuit Breaker
59N	Neutral Overvoltage
59P	Phase Overvoltage
59X	Auxiliary Overvoltage
59_2	Negative Sequence Overvoltage
67N	Neutral Directional Overcurrent
67P	Phase Directional Overcurrent
67_2	Negative Sequence Directional Overcurrent
68	Power Swing Blocking
78	Out-of-Step Tripping
79	Automatic Recloser

Table 2–2: OTHER DEVICE FUNCTIONS

FUNCTION
Breaker Arcing Current (I^2t)
Breaker Control
Contact Inputs (up to 96)
Contact Outputs (up to 64)
Data Logger
Digital Counters (8)
Digital Elements (16)
DNP 3.0 or IEC 60870-5-104
Event Recorder
Fault Locator

FUNCTION
Fault Reporting
FlexElements™
FlexLogic™ Equations
Line Pickup
Metering: Current, Voltage, Power, Power Factor, Frequency
MMS/UCA Communications
MMS/UCA Remote I/O (“GOOSE”)
Modbus Communications
Modbus User Map

FUNCTION
Oscillography
Pilot Schemes
Setting Groups (8)
Transducer I/O
User-Definable Displays
User Programmable LEDs
Virtual Inputs (32)
Virtual Outputs (64)
VT Fuse Failure

2.1.2 ORDERING

The relay is available as a 19-inch rack horizontal mount unit or as a reduced size (¾) vertical mount unit, and consists of the following UR module functions: Power Supply, CPU, CT/VT DSP, Digital Input/Output, and Transducer I/O. Each of these modules can be supplied in a number of configurations which must be specified at the time of ordering. The information required to completely specify the relay is provided in the following table (full details of the modules that are available for the relay are contained in the HARDWARE chapter).

Table 2–3: ORDER CODES

	Base	CPU	Software	Mount	Power	CT/VT						
	D60 -	*	00 -	H C	* -	F ** -	H ** -	M ** -	P ** -	U ** -	W **	For Full Sized Horizontal Mount
	D60 -	*	00 -	V F	* -	F ** -	H ** -	M ** -	P **			For Reduced Size Vertical Mount
BASE UNIT	D60											Base Unit
CPU		A										RS485 + RS485 (ModBus RTU, DNP)
		C										RS485 + 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP)
		D										RS485 + Redundant 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP)
SOFTWARE OPTIONS			00									No Software Options
MOUNT / FACEPLATE				H C								Horizontal (19” rack)
				V F								Vertical (3/4 size)
POWER SUPPLY					H							125 / 250 V AC/DC
					L							24 - 48 V (DC only)
CT/VT DSP						8A						Standard 4CT/4VT
						8B						Sensitive Ground 4CT/4VT
DIGITAL I/O								XX	XX	XX	XX	No module
							6A	6A	6A	6A	6A	2 Form-A (Voltage w/ opt Current) & 2 Form-C Outputs, 8 Digital Inputs
							6B	6B	6B	6B	6B	2 Form-A (Voltage w/ opt Current) & 4 Form-C Outputs, 4 Digital Inputs
							6C	6C	6C	6C	6C	8 Form-C Outputs
							6D	6D	6D	6D	6D	16 Digital Inputs
							6E	6E	6E	6E	6E	4 Form-C Outputs, 8 Digital Inputs
							6F	6F	6F	6F	6F	8 Fast Form-C Outputs
							6G	6G	6G	6G	6G	4 Form-A (Voltage w/ opt Current) Outputs, 8 Digital Inputs
							6H	6H	6H	6H	6H	6 Form-A (Voltage w/ opt Current) Outputs, 4 Digital Inputs
							6K	6K	6K	6K	6K	4 Form-C & 4 Fast Form-C Outputs
							6L	6L	6L	6L	6L	2 Form-A (Current w/ opt Voltage) & 2 Form-C Outputs, 8 Digital Inputs
							6M	6M	6M	6M	6M	2 Form-A (Current w/ opt Voltage) & 4 Form-C Outputs, 4 Digital Inputs
							6N	6N	6N	6N	6N	4 Form-A (Current w/ opt Voltage) Outputs, 8 Digital Inputs
							6P	6P	6P	6P	6P	6 Form-A (Current w/ opt Voltage) Outputs, 4 Digital Inputs
							6R	6R	6R	6R	6R	2 Form-A (No Monitoring) & 2 Form-C Outputs, 8 Digital Inputs
							6S	6S	6S	6S	6S	2 Form-A (No Monitoring) & 4 Form-C Outputs, 4 Digital Inputs
							6T	6T	6T	6T	6T	4 Form-A (No Monitoring) Outputs, 8 Digital Inputs
							6U	6U	6U	6U	6U	6 Form-A (No Monitoring) Outputs, 4 Digital Inputs
TRANSDUCER I/O (MAXIMUM OF 4 PER UNIT)							5C	5C	5C	5C	5C	8 RTD Inputs
							5E	5E	5E	5E	5E	4 dcmA Inputs, 4 RTD Inputs
							5F	5F	5F	5F	5F	8 dcmA Inputs

The order codes for replacement modules to be ordered separately are shown in the following table. **When ordering a replacement CPU module or Faceplate, please provide the serial number of your existing unit.**

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Table 2–4: ORDER CODES FOR REPLACEMENT MODULES

	UR - ** -	
POWER SUPPLY	1H	125 / 250 V AC/DC
	1L	24 - 48 V (DC only)
CPU	9A	RS485 + RS485 (ModBus RTU, DNP 3.0)
	9C	RS485 + 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP 3.0)
	9D	RS485 + Redundant 10BaseF (MMS/UCA2, ModBus TCP/IP, DNP 3.0)
FACEPLATE	3C	Horizontal Faceplate with Display & Keypad
	3F	Vertical Faceplate with Display & Keypad
DIGITAL I/O	6A	2 Form-A (Voltage w/ opt Current) & 2 Form-C Outputs, 8 Digital Inputs
	6B	2 Form-A (Voltage w/ opt Current) & 4 Form-C Outputs, 4 Digital Inputs
	6C	8 Form-C Outputs
	6D	16 Digital Inputs
	6E	4 Form-C Outputs, 8 Digital Inputs
	6F	8 Fast Form-C Outputs
	6G	4 Form-A (Voltage w/ opt Current) Outputs, 8 Digital Inputs
	6H	6 Form-A (Voltage w/ opt Current) Outputs, 4 Digital Inputs
	6K	4 Form-C & 4 Fast Form-C Outputs
	6L	2 Form-A (Current w/ opt Voltage) & 2 Form-C Outputs, 8 Digital Inputs
	6M	2 Form-A (Current w/ opt Voltage) & 4 Form-C Outputs, 4 Digital Inputs
	6N	4 Form-A (Current w/ opt Voltage) Outputs, 8 Digital Inputs
	6P	6 Form-A (Current w/ opt Voltage) Outputs, 4 Digital Inputs
	6R	2 Form-A (No Monitoring) & 2 Form-C Outputs, 8 Digital Inputs
	6S	2 Form-A (No Monitoring) & 4 Form-C Outputs, 4 Digital Inputs
	6T	4 Form-A (No Monitoring) Outputs, 8 Digital Inputs
	6U	6 Form-A (No Monitoring) Outputs, 4 Digital Inputs
CT/VT DSP	8A	Standard 4CT/4VT
	8B	Sensitive Ground 4CT/4VT
	8C	Standard 8CT
	8D	Sensitive Ground 8CT
	8Z	HI-Z 4CT
L60 INTER-RELAY COMMUNICATIONS	7U	110/125 V, 20 mA Input/Output Channel Interface
	7V	48/60 V, 20 mA Input/Output Channel Interface
	7Y	125 V Input, 5V Output, 20 mA Channel Interface
	7Z	5 V Input, 5V Output, 20 mA Channel Interface
L90 INTER-RELAY COMMUNICATIONS	7A	820 nm, multi-mode, LED, 1 Channel
	7B	1300 nm, multi-mode, LED, 1 Channel
	7C	1300 nm, single-mode, ELED, 1 Channel
	7D	1300 nm, single-mode, LASER, 1 Channel
	7E	Channel 1: G.703; Channel 2: 820 nm, multi-mode LED
	7F	Channel 1: G.703; Channel 2: 1300 nm, multi-mode LED
	7G	Channel 1: G.703; Channel 2: 1300 nm, single-mode ELED
	7Q	Channel 1: G.703; Channel 2: 820 nm, single-mode LASER
	7H	820 nm, multi-mode, LED, 2 Channels
	7I	1300 nm, multi-mode, LED, 2 Channels
	7J	1300 nm, single-mode, ELED, 2 Channels
	7K	1300 nm, single-mode, LASER, 2 Channels
	7L	Channel 1 - RS422; Channel 2 - 820 nm, multi-mode, LED
	7M	Channel 1 - RS422; Channel 2 - 1300 nm, multi-mode, LED
	7N	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED
	7P	Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, LASER
	7R	G.703, 1 Channel
	7S	G.703, 2 Channels
	7T	RS422, 1 Channel
	7W	RS422, 2 Channels
	72	1550 nm, single-mode, LASER, 1 Channel
	73	1550 nm, single-mode, LASER, 2 Channel
	74	Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER
	75	Channel 1 - G.703, Channel 2 - 1550 nm, single -mode, LASER
TRANSDUCER I/O	5C	8 RTD Inputs
	5E	4 dcmA Inputs, 4 RTD Inputs
	5F	8 dcmA Inputs

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE

2.2.1 PROTECTION ELEMENTS

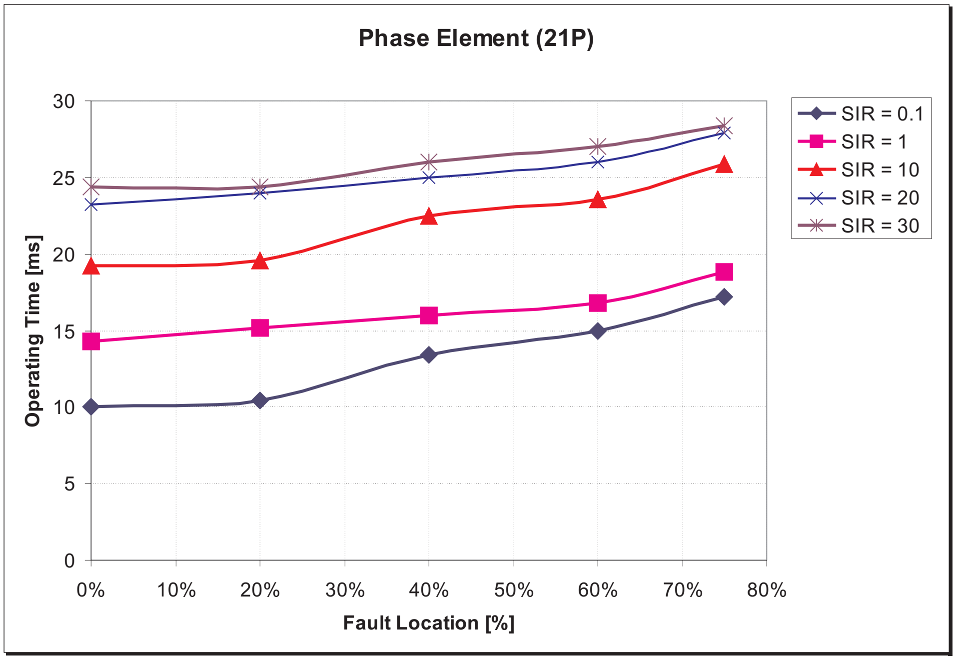
NOTE The operating times below include the activation time of a trip rated Form-A output contact unless otherwise indicated. FlexLogic™ operands of a given element are 4 ms faster. This should be taken into account when using FlexLogic™ to interconnect with other protection or control elements of the relay, building FlexLogic™ equations, or interfacing with other IEDs or power system devices via communications or different output contacts.

PHASE DISTANCE

Characteristic: Dynamic (100% memory-polarized) MHO or QUAD, selectable individually per zone
Number of Zones: 4
Directionality: All zones reversible
Reach (secondary Ω): 0.02 to 250.00 Ω in steps of 0.01
Reach Accuracy: ±5% including the effect of CVT transients up to an SIR of 30
Distance Characteristic Angle: 30 to 90° in steps of 1
Distance Comparator Limit Angle: 30 to 90° in steps of 1
Directional Supervision:
  Characteristic Angle: 30 to 90° in steps of 1
  Limit Angle: 30 to 90° in steps of 1
Right Blinder (QUAD only):
  Reach: 0.02 to 250 Ω in steps of 0.01
  Characteristic Angle: 60 to 90° in steps of 1
Left Blinder (QUAD only):
  Reach: 0.02 to 250 Ω in steps of 0.01
  Characteristic Angle: 60 to 90° in steps of 1
Time Delay: 0.000 to 65.535 s in steps of 0.001
Timing Accuracy: ±3% or 4 ms, whichever is greater
Current Supervision:
  Level: line-to-line current
  Pickup: 0.050 to 30.000 pu in steps of 0.001
  Dropout: 97 to 98%
Memory Duration: 5 to 25 cycles in steps of 1
Voltage Supervision Pickup (series compensation applications):
  0 to 5.000 pu in steps of 0.001

PHASE DISTANCE OPERATING TIME CURVES

The operating times are response times of a microprocessor part of the relay. See output contacts specifications for estimation of the total response time for a particular application. The operating times are average times including variables such as fault inception angle or type of a voltage source (magnetic VTs and CVTs).



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GROUND DISTANCE

Characteristic: Dynamic (100% memory-polarized) MHO, or QUAD, selectable individually per zone

Number of Zones: 4

Directionality: All zones reversible

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

Reach Accuracy: ±5% including the effect of CVT transients up to an SIR of 30

Distance Characteristic Angle: 30 to 90° in steps of 1

Distance Comparator Limit Angle: 30 to 90° in steps of 1

Directional Supervision:
- Characteristic Angle: 30 to 90° in steps of 1
- Limit Angle: 30 to 90° in steps of 1

Zero-Sequence Compensation
- Z0/Z1 magnitude: 0.50 to 7.00 in steps of 0.01
- Z0/Z1 angle: –90 to 90° in steps of 1

Zero-Sequence Mutual Compensation
- Z0M/Z1 magnitude: 0.00 to 7.00 in steps of 0.01
- Z0M/Z1 angle: –90 to 90° in steps of 1

Right Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Left Blinder (QUAD only):
- Reach: 0.02 to 250 Ω in steps of 0.01
- Characteristic Angle: 60 to 90° in steps of 1

Time Delay: 0.000 to 65.535 s in steps of 0.001

Timing Accuracy: ±3% or 4 ms, whichever is greater

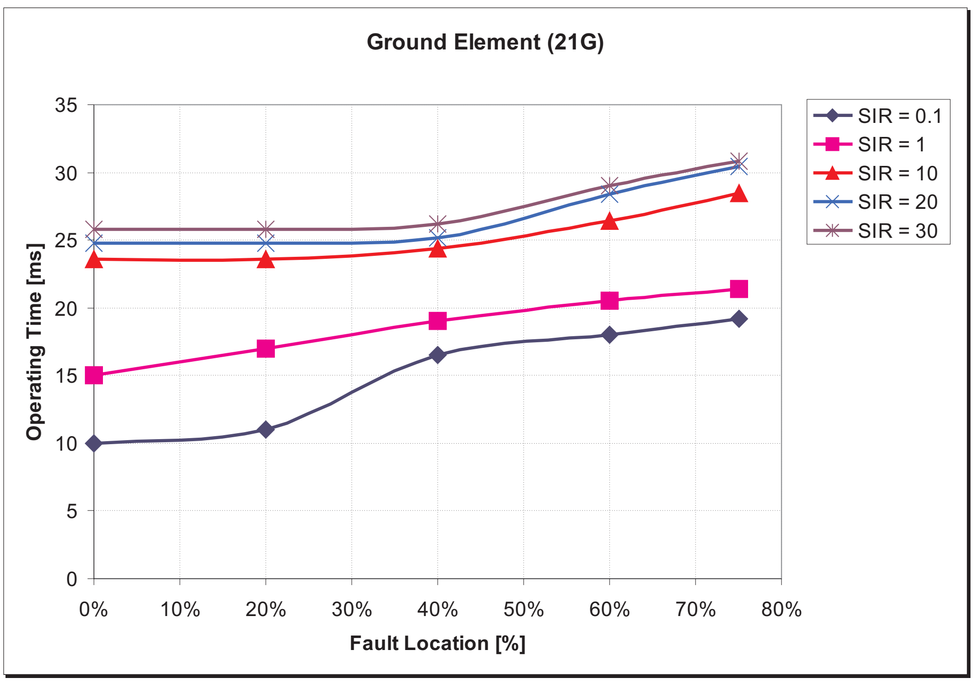
Current Supervision:
- Level: neutral current (3I_0)
- Pickup: 0.050 to 30.000 pu in steps of 0.001
- Dropout: 97 to 98%

Memory Duration: 5 to 25 cycles in steps of 1

Voltage Supervision Pickup (series compensation applications): 0 to 5.000 pu in steps of 0.001

GROUND DISTANCE OPERATING TIME CURVES

The operating times are response times of a microprocessor part of the relay. See output contacts specifications for estimation of the total response time for a particular application. The operating times are average times including variables such as fault inception angle or type of a voltage source (magnetic VTs and CVTs).



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LINE PICKUP
Phase IOC: 0.000 to 30.000 pu
Positive Sequence UV: 0.000 to 3.000 pu
Positive Seq. OV Delay: 0.000 to 65.535 s

PHASE/NEUTRAL/GROUND TOC
Current: Phasor or RMS
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97% to 98% of Pickup
Level Accuracy:
for 0.1 to 2.0 × CT: ±0.5% of reading or ±1% of rated (whichever is greater)
for > 2.0 × CT: ±1.5% of reading > 2.0 × CT rating
Curve Shapes: IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/ Extremely Inverse; I^2t; FlexCurve™ (programmable); Definite Time (0.01 s base curve)
Curve Multiplier: Time Dial = 0.00 to 600.00 in steps of 0.01
Reset Type: Instantaneous/Timed (per IEEE)
Timing Accuracy: Operate at > 1.03 × Actual Pickup ±3.5% of operate time or ±½ cycle (whichever is greater)

PHASE/NEUTRAL/GROUND IOC
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97 to 98% of Pickup
Level Accuracy:
0.1 to 2.0 × CT rating: ±0.5% of reading or ±1% of rated (whichever is greater)
> 2.0 × CT rating ±1.5% of reading
Overreach: <2%
Pickup Delay: 0.00 to 600.00 s in steps of 0.01
Reset Delay: 0.00 to 600.00 s in steps of 0.01
Operate Time: <20 ms at 3 × Pickup at 60 Hz
Timing Accuracy: Operate at 1.5 × Pickup ±3% or ±4 ms (whichever is greater)

NEGATIVE SEQUENCE TOC
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97% to 98% of Pickup
Level Accuracy: ±0.5% of reading or ±1% of rated (whichever is greater) from 0.1 to 2.0 x CT rating ±1.5% of reading > 2.0 x CT rating
Curve Shapes: IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/ Extremely Inverse; I^2t; FlexCurve™ (programmable); Definite Time (0.01 s base curve)
Curve Multiplier (Time Dial): 0.00 to 600.00 in steps of 0.01
Reset Type: Instantaneous/Timed (per IEEE) and Linear
Timing Accuracy: Operate at > 1.03 × Actual Pickup ±3.5% of operate time or ±½ cycle (whichever is greater)

NEGATIVE SEQUENCE IOC
Pickup Level: 0.000 to 30.000 pu in steps of 0.001
Dropout Level: 97 to 98% of Pickup
Level Accuracy:
0.1 to 2.0 × CT rating: ±0.5% of reading or ±1% of rated (whichever is greater)
> 2.0 × CT rating: ±1.5% of reading
Overreach: < 2 %
Pickup Delay: 0.00 to 600.00 s in steps of 0.01
Reset Delay: 0.00 to 600.00 s in steps of 0.01
Operate Time: < 20 ms at 3 × Pickup at 60 Hz
Timing Accuracy: Operate at 1.5 × Pickup ±3% or ± 4 ms (whichever is greater)

PHASE DIRECTIONAL OVERCURRENT
Relay Connection: 90° (quadrature)
Quadrature Voltage:
ABC Phase Seq.: phase A (V_{BC}), phase B (V_{CA}), phase C (V_{AB})
ACB Phase Seq.: phase A (V_{CB}), phase B (V_{AC}), phase C (V_{BA})
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°
Operation Time (FlexLogic™ Operands):
Tripping (reverse load, forward fault):< 12 ms, typically
Blocking (forward load, reverse fault):< 8 ms, typically

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 × (|I_0| – *K* × |I_1|), *K* = 0.0625; IG
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 Ω in steps of 0.01
Pickup Level: 0.05 to 30.00 pu in steps of 0.01
Dropuot Level: 97 to 98%
Operation Time: < 16 ms at 3 × Pickup at 60 Hz

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NEGATIVE SEQUENCE DIRECTIONAL OC

Directionality:	Co-existing forward and reverse
Polarizing:	Voltage
Polarizing Voltage:	V_2
Operating Current:	I_2
Level Sensing:	
Zero-sequence:	$\lvert I\_0\rvert - K \times \lvert I\_1\rvert$, $K = 0.0625$
Negative-sequence:	$\lvert I\_2\rvert - K \times \lvert I\_1\rvert$, $K = 0.125$
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 Ω in steps of 0.01
Pickup Level:	0.05 to 30.00 pu in steps of 0.01
Dropout Level:	97 to 98%
Operation Time:	< 16 ms at 3 × Pickup at 60 Hz

BREAKER FAILURE

Mode:	1-pole, 3-pole
Current Supv. Level:	Phase, Neutral
Current Supv. Pickup:	0.001 to 30.000 pu in steps of 0.001
Current Supv. DPO:	97 to 98% of Pickup
Current Supv. Accuracy:	
0.1 to 2.0 × CT rating:	±0.75% of reading or ±1% of rated (whichever is greater)
> 2 × CT rating:	±1.5% of reading

PHASE UNDERVOLTAGE

Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	102 to 103% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Curve Shapes:	GE IAV Inverse; Definite Time (0.1s base curve)
Curve Multiplier:	Time Dial = 0.00 to 600.00 in steps of 0.01
Timing Accuracy:	Operate at < 0.90 × Pickup ±3.5% of operate time 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:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0.00 to 600.00 in steps of 0.01 s
Operate Time:	< 30 ms at 1.10 × Pickup at 60 Hz
Timing Accuracy:	±3% or ±4 ms (whichever is greater)

NEUTRAL OVERVOLTAGE

Pickup Level:	0.000 to 1.250 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0.00 to 600.00 s in steps of 0.01
Reset Delay:	0.00 to 600.00 s in steps of 0.01
Timing Accuracy:	±3% or ±4 ms (whichever is greater)
Operate Time:	< 30 ms at 1.10 × Pickup at 60 Hz

AUXILIARY UNDERVOLTAGE

Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	102 to 103% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Curve Shapes:	GE IAV Inverse Definite Time
Curve Multiplier:	Time Dial = 0 to 600.00 in steps of 0.01
Timing Accuracy:	±3% of operate time or ±4 ms (whichever is greater)

NEGATIVE SEQUENCE OVERVOLTAGE

Pickup Level:	0.000 to 1.250 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0 to 600.00 s in steps of 0.01
Reset Delay:	0 to 600.00 s in steps of 0.01
Time Accuracy:	±3% or ±20 ms, whichever is greater
Operate Time:	< 30 ms at 1.10 × Pickup at 60 Hz

AUXILIARY OVERVOLTAGE

Pickup Level:	0.000 to 3.000 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Level Accuracy:	±0.5% of reading from 10 to 208 V
Pickup Delay:	0 to 600.00 s in steps of 0.01
Reset Delay:	0 to 600.00 s in steps of 0.01
Timing Accuracy:	±3% of operate time or ±4 ms (whichever is greater)
Operate Time:	< 30 ms at 1.10 × pickup at 60 Hz

SYNCHROCHECK

Max Volt Difference:	0 to 100000 V in steps of 1
Max Angle Difference:	0 to 100° in steps of 1
Max Freq Difference:	0.00 to 2.00 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)

AUTORECLOSURE

Two breakers applications
Single- and three-pole tripping schemes
Up to 2 reclose attempts before lockout
Selectable reclosing mode and breaker sequence

PILOT-AIDED SCHEMES

Direct Underreaching Transfer Trip (DUTT)
Permissive Underreaching Transfer Trip (PUTT)
Permissive Overreaching Transfer Trip (POTT)
Hybrid POTT Scheme
Directional Comparison Blocking Scheme

POWER SWING DETECT

Functions:	Power swing block, Out-of-step trip
Measured Impedance:	Positive-sequence
Blocking & Tripping Modes:	2-step or 3-step
Tripping Mode:	Early or Delayed
Current Supervision:	
Pickup Level:	0.050 to 30.000 pu in steps of 0.001
Dropout Level:	97 to 98% of Pickup
Fwd / Reverse Reach (sec. Ω):	0.10 to 500.00 Ω in steps of 0.01
Impedance Accuracy:	±5%

Fwd / Reverse Angle Impedances:	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 s in steps of 0.001
Timing Accuracy:	±3% or 4 ms, whichever is greater

LOAD ENCROACHMENT

Measured Impedance:	Positive-sequence
Minumum Voltage:	0.000 to 3.000 pu in steps of 0.001
Reach (sec. Ω):	0.02 to 250.00 Ω in steps of 0.01
Impedance Accuracy:	±5%
Angle:	5 to 50° in steps of 1
Angle Accuracy:	±2°
Pickup Delay:	0 to 65.535 s in steps of 0.001
Reset Delay:	0 to 65.535 s in steps of 0.001
Time Accuracy:	±3% or ±4 ms, whichever is greater
Operate Time:	< 30 ms at 60 Hz

TRIP OUTPUT

Collects trip and reclose input requests and issues outputs to control tripping and reclosing.

Communications Timer Delay:	0 to 65535 s in steps of 0.001
Timing Accuracy:	±3% or 4 ms, whichever is greater

OPEN POLE DETECTOR

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
Current Dropout Level:	Pickup + 3%, not less than 0.05 pu
Time Delay:	0 to 65.535 s in steps of 0.001
Timing Accuracy:	±3% or 4 ms, whichever is greater

2

2.2.2 USER-PROGRAMMABLE ELEMENTS

FLEXLOGIC™

Programming language:	Reverse Polish Notation with graphical visualization (keypad programmable)
Lines of code:	512
Number of 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, sec., min.) in steps of 1
Dropout delay:	0 to 60000 (ms, sec., min.) in steps of 1

FLEXCURVES™

Number:	2 (A and B)
Number of reset points:	40 (0 through 1 of pickup)
Number of operate points:	80 (1 through 20 of pickup)
Time delay:	0 to 65535 ms in steps of 1

FLEXELEMENTS™

Number of elements:	8
Operating signal:	any analog actual value, or two values in differential mode
Operating signal mode:	Signed or Absolute Value
Operating mode:	Level, Delta
Compensation direction:	Over, Under
Pickup Level:	–30.000 to 30.000 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 and dropout delay:	0.000 to 65.535 in steps of 0.001

FLEX STATES

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

USER-PROGRAMMABLE LEDS

Number:	48 plus Trip and Alarm
Programmability:	from any logical variable, contact, or virtual input
Reset mode:	Self-reset or Latched

USER-DEFINABLE DISPLAYS

Number of displays:	8
Lines of display:	2 × 20 alphanumeric characters
Parameters	up to 5, any Modbus register addresses

2

2.2.3 MONITORING

OSCILLOGRAPHY

Max. No. of Records:	64
Sampling Rate:	64 samples per power cycle
Triggers:	Any element pickup, dropout or operate Digital input change of state Digital output change of state FlexLogic™ equation
Data:	AC input channels Element state Digital input state Digital output state
Data Storage:	In non-volatile memory

EVENT RECORDER

Capacity:	1024 events
Time-tag:	to 1 microsecond
Triggers:	Any element pickup, dropout or operate Digital input change of state Digital output change of state Self-test events
Data Storage:	In non-volatile memory

DATA LOGGER

Number of Channels:	1 to 16
Parameters:	Any available analog Actual Value
Sampling Rate:	1 sec.; 1, 5, 10, 15, 20, 30, 60 min.
Storage Capacity:	(NN is dependent on memory)
1-second rate:	01 channel for NN days 16 channels for NN days
↓	↓
60-minute rate:	01 channel for NN days 16 channels for NN days

FAULT LOCATOR

Method:	Single-ended
Maximum accuracy if:	Fault resistance is zero or fault currents from all line terminals are in phase
Relay Accuracy:	±1.5% (V > 10 V, I > 0.1 pu)
Worst-case Accuracy:	
$VT_{\%error}$ +	(user data)
$CT_{\%error}$ +	(user data)
$Z_{Line\%error}$ +	(user data)
$METHOD_{\%error}$ +	(Chapter 6)
$RELAY\ ACCURACY_{\%error}$ +	(1.5%)

2.2.4 METERING

RMS CURRENT: PHASE, NEUTRAL, AND GROUND

Accuracy at	
0.1 to 2.0 × CT rating:	±0.25% of reading or ±0.1% of rated (whichever is greater)
> 2.0 × CT rating:	±1.0% of reading

RMS VOLTAGE

Accuracy:	±0.5% of reading from 10 to 208 V

REAL POWER WATT

Accuracy:	±1.0% of reading at –0.8 < PF ≤ –1.0 and 0.8 < PF ≤ 1.0

REACTIVE POWER VAR

Accuracy:	±1.0% of reading –0.2 ≤ PF ≤ 0.2

APPARENT POWER VA

Accuracy:	±1.0% of reading

FREQUENCY

Accuracy at	
V = 0.8 to 1.2 pu:	±0.01 Hz (when voltage signal is used for frequency measurement)
I = 0.1 to 0.25 pu:	±0.05 Hz
I > 0.25 pu	±0.02 Hz (when current signal is used for frequency measurement)

2.2.5 INPUTS

AC CURRENT

CT Rated Primary:	1 to 50000 A
CT Rated Secondary:	1 A or 5 A by connection
Nominal Frequency:	20 to 65 Hz
Relay Burden:	< 0.2 VA at rated secondary
Conversion Range:	
Standard CT Module:	0.02 to 46 × CT rating RMS symmetrical
Sensitive Ground Module:	0.002 to 4.6 × CT rating RMS symmetrical
Current Withstand:	20 ms at 250 times rated 1 sec. at 100 times rated Cont. at 3 times rated

AC VOLTAGE

VT Rated Secondary:	50.0 to 240.0 V
VT Ratio:	0.1 to 24000.0
Nominal Frequency:	20 to 65 Hz
Relay Burden:	< 0.25 VA at 120 V
Conversion Range:	1 to 275 V
Voltage Withstand:	cont. at 260 V to neutral 1 min./hr at 420 V to neutral

CONTACT INPUTS

Dry Contacts:	1000 Ω maximum
Wet Contacts:	300 V DC maximum
Selectable Thresholds:	16 V, 30 V, 80 V, 140 V
Recognition Time:	< 1 ms
Debounce Timer:	0.0 to 16.0 ms in steps of 0.5

DCMA INPUTS

Current Input (mA DC): 0 to –1, 0 to +1, –1 to +1, 0 to 5, 0 to 10, 0 to 20, 4 to 20 (programmable)

Input Impedance: 379 Ω ±10%

Conversion Range: –1 to + 20 mA DC

Accuracy: ±0.2% of full scale

Type: Passive

RTD INPUTS

Types (3-wire): 100 Ω Platinum, 100 & 120 Ω Nickel, 10 Ω Copper

Sensing Current: 5 mA

Range: –50 to +250°C

Accuracy: ±2°C

Isolation: 36 V pk-pk

IRIG-B INPUT

Amplitude Modulation: 1 to 10 V pk-pk

DC Shift: TTL

Input Impedance: 22 kΩ

2.2.6 POWER SUPPLY

LOW RANGE

Nominal DC Voltage: 24 to 48 V at 3 A

Min./Max. DC Voltage: 20 / 60 V

NOTE: Low range is DC only.

HIGH RANGE

Nominal DC Voltage: 125 to 250 V at 0.7 A

Min./Max. DC Voltage: 88 / 300 V

Nominal AC Voltage: 100 to 240 V at 50/60 Hz, 0.7 A

Min./Max. AC Voltage: 88 / 265 V at 48 to 62 Hz

ALL RANGES

Volt Withstand: 2 × Highest Nominal Voltage for 10 ms

Voltage Loss Hold-Up: 50 ms duration at nominal

Power Consumption: Typical = 35 VA; Max. = 75 VA

INTERNAL FUSE

RATINGS

Low Range Power Supply: 7.5 A / 600 V

High Range Power Supply: 5 A / 600 V

INTERRUPTING CAPACITY

AC: 100 000 A RMS symmetrical

DC: 10 000 A

2.2.7 OUTPUTS

FORM-A RELAY

Make and Carry for 0.2 sec.: 30 A as per ANSI C37.90

Carry Continuous: 6 A

Break at L/R of 40 ms: 0.25 A DC max.

Operate Time: < 4 ms

Contact Material: Silver alloy

FORM-A VOLTAGE MONITOR

Applicable Voltage: approx. 15 to 250 V DC

Trickle Current: approx. 1 to 2.5 mA

FORM-A CURRENT MONITOR

Threshold Current: approx. 80 to 100 mA

FORM-C AND CRITICAL FAILURE RELAY

Make and Carry for 0.2 sec: 10 A

Carry Continuous: 6 A

Break at L/R of 40 ms: 0.1 A DC max.

Operate Time: < 8 ms

Contact Material: Silver alloy

FAST FORM-C RELAY

Make and Carry: 0.1 A max. (resistive load)

Minimum Load Impedance:

INPUT VOLTAGE	IMPEDANCE	
	2 W RESISTOR	1 W RESISTOR
250 V DC	20 KΩ	50 KΩ
120 V DC	5 KΩ	2 KΩ
48 V DC	2 KΩ	2 KΩ
24 V DC	2 KΩ	2 KΩ

Note: values for 24 V and 48 V are the same due to a required 95% voltage drop across the load impedance.

Operate Time: < 0.6 ms

INTERNAL LIMITING RESISTOR:

Power: 2 watts

Resistance: 100 ohms

CONTROL POWER EXTERNAL OUTPUT (FOR DRY CONTACT INPUT)

Capacity: 100 mA DC at 48 V DC

Isolation: ±300 Vpk

2.2.8 COMMUNICATIONS

RS232

Front Port: 19.2 kbps, Modbus® RTU

RS485

1 or 2 Rear Ports: Up to 115 kbps, Modbus® RTU, isolated together at 36 Vpk

Typical Distance: 1200 m

ETHERNET PORT

10BaseF: 820 nm, multi-mode, supports half-duplex/full-duplex fiber optic with ST connector

Redundant 10BaseF: 820 nm, multi-mode, half-duplex/full-duplex fiber optic with ST connector

Power Budget: 10 db

Max Optical Ip Power: –7.6 dBm

Typical Distance: 1.65 km

2.2.9 ENVIRONMENTAL

Operating Temperatures:
Cold: IEC 60028-2-1, 16 h at –40°C
Dry Heat: IEC 60028-2-2, 16 h at 85°C

Humidity (noncondensing): IEC 60068-2-30, 95%, Variant 1, 6 days

Altitude: Up to 2000 m

Installation Category: II

2.2.10 TYPE TESTS

Electrical Fast Transient: ANSI/IEEE C37.90.1
IEC 61000-4-4
IEC 60255-22-4

Oscillatory Transient: ANSI/IEEE C37.90.1
IEC 61000-4-12

Insulation Resistance: IEC 60255-5

Dielectric Strength: IEC 60255-6
ANSI/IEEE C37.90

Electrostatic Discharge: EN 61000-4-2

Surge Immunity: EN 61000-4-5

RFI Susceptibility: ANSI/IEEE C37.90.2
IEC 61000-4-3
IEC 60255-22-3
Ontario Hydro C-5047-77

Conducted RFI: IEC 61000-4-6

Voltage Dips/Interruptions/Variations:
IEC 61000-4-11
IEC 60255-11

Power Frequency Magnetic Field Immunity:
IEC 61000-4-8

Vibration Test (sinusoidal): IEC 60255-21-1

Shock and Bump: IEC 60255-21-2

NOTE

Type test report available upon request.

2.2.11 PRODUCTION TESTS

THERMAL

Products go through a 12 h burn-in process at 60°C

2.2.12 APPROVALS

APPROVALS

UL approval pending

CSA approval pending

Manufactured under an ISO9000 Registered system.

CE:
LVD 73/23/EEC: IEC 1010-1
EMC 81/336/EEC: EN 50081-2
EN 50082-2

2.2.13 MAINTENANCE

Cleaning: Normally, cleaning is not required; but for situations where dust has accumulated on the faceplate display, a dry cloth can be used.

3.1.1 PANEL CUTOUT

The relay is available as a 19-inch rack horizontal mount unit or as a reduced size (¾) vertical mount unit, with a removable faceplate. The modular design allows the relay to be easily upgraded or repaired by a qualified service person. The faceplate is hinged to allow easy access to the removable modules, and is itself removable to allow mounting on doors with limited rear depth. There is also a removable dust cover that fits over the faceplate, which must be removed when attempting to access the keypad or RS232 communications port.

The vertical and horizontal case dimensions are shown below, 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.

The relay must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the keypad and the RS232 communications port. The relay is secured to the panel with the use of four screws supplied with the relay.

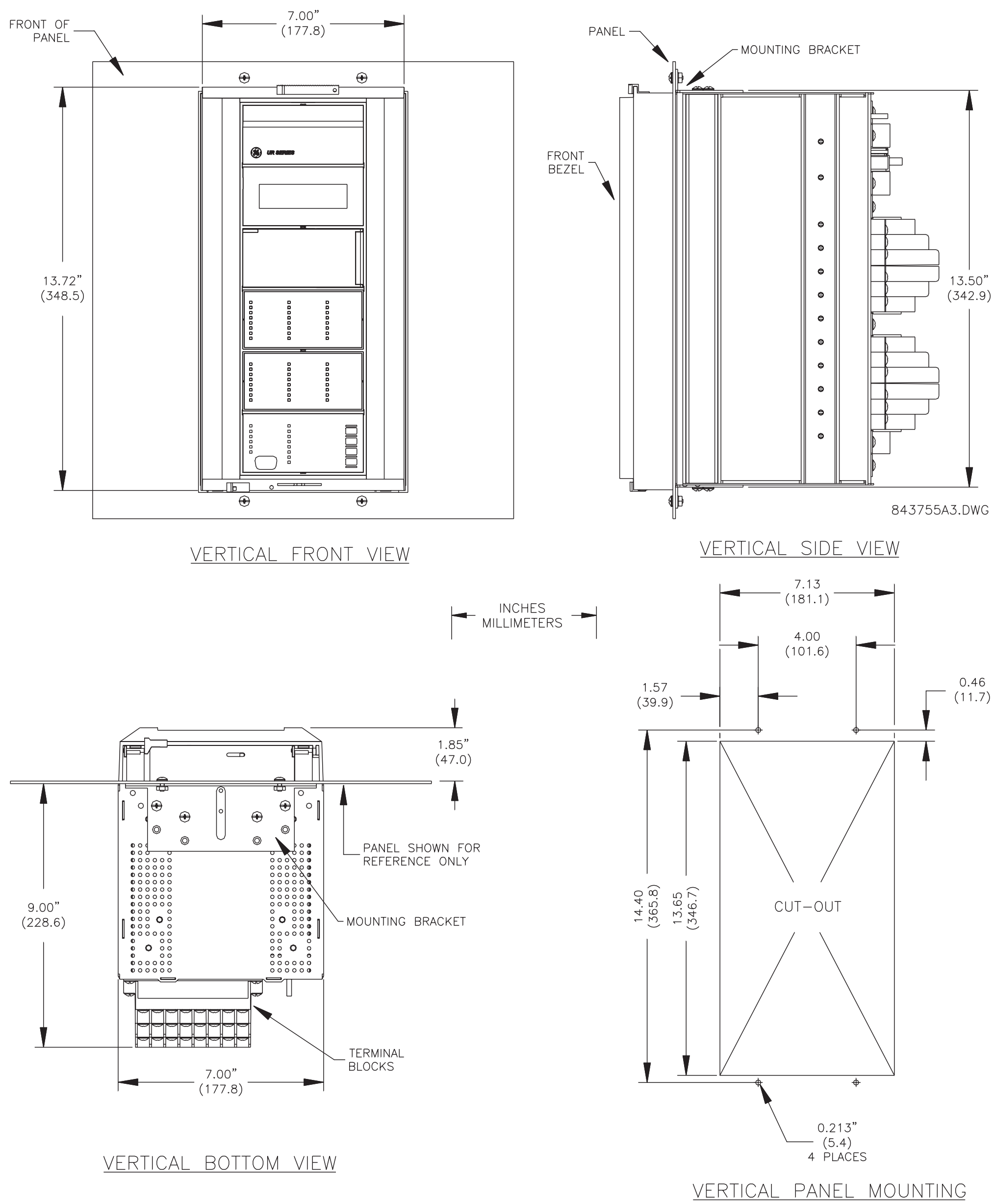


Figure 3–1: D60 VERTICAL MOUNTING AND DIMENSIONS

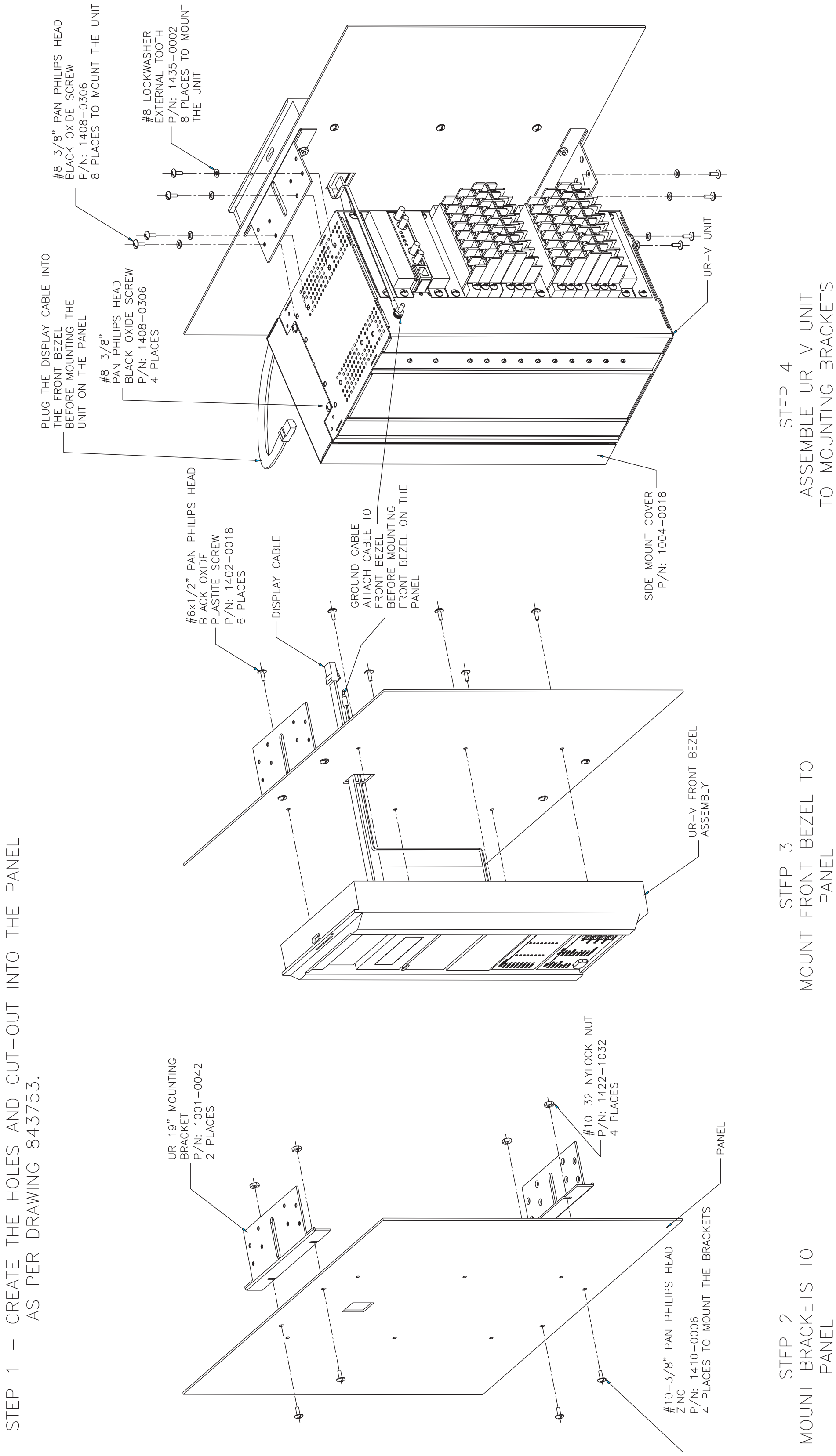


Figure 3–2: D60 VERTICAL SIDE MOUNTING INSTALLATION

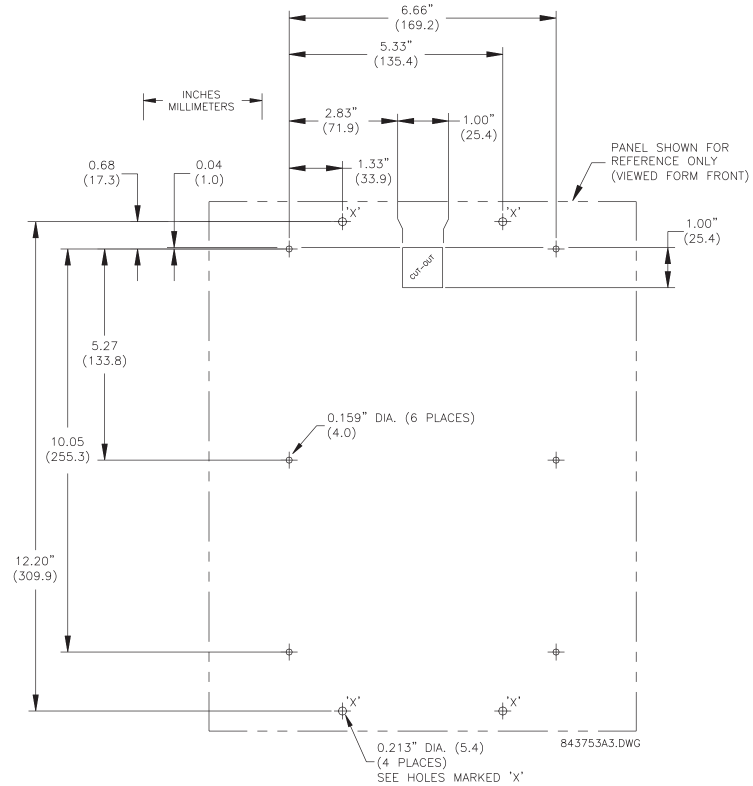


Figure 3–3: D60 VERTICAL SIDE MOUNTING REAR DIMENSIONS

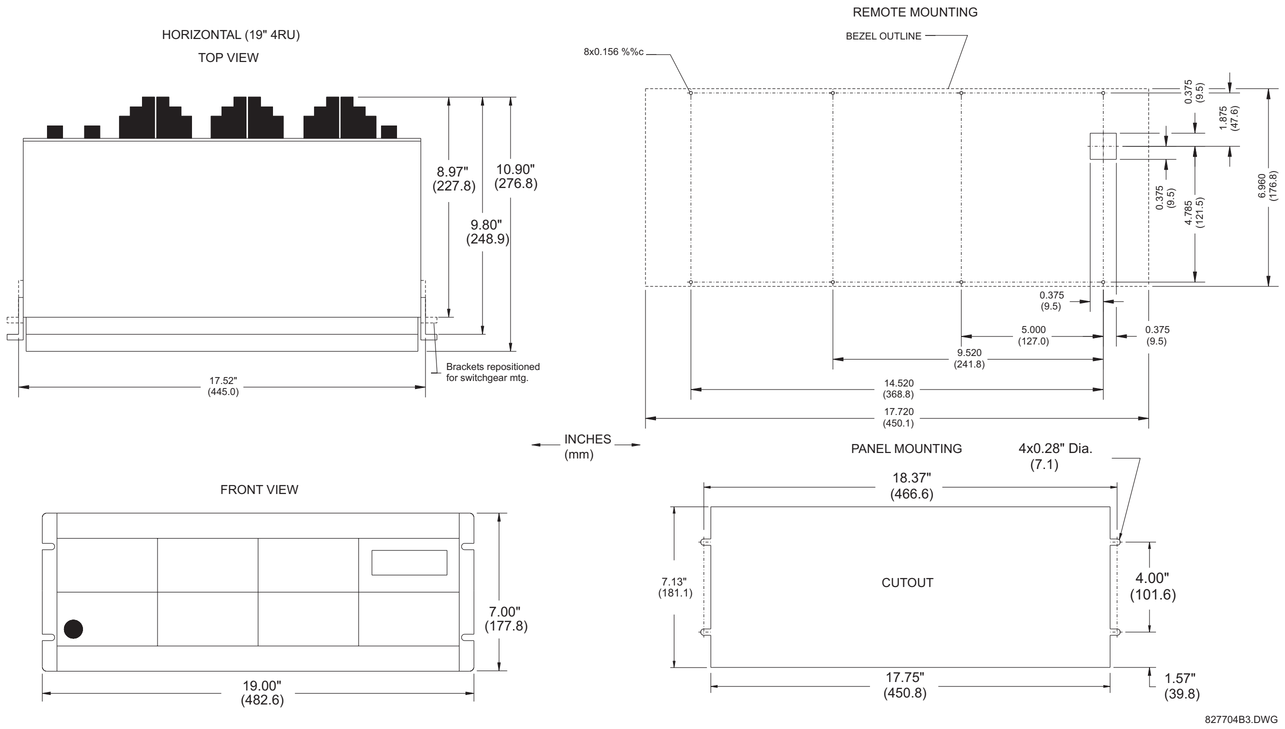


Figure 3–4: D60 HORIZONTAL MOUNTING AND DIMENSIONS

3.1.2 MODULE WITHDRAWAL / INSERTION

WARNING **Module withdrawal and insertion may only be performed when control power has been removed from the unit. Inserting an incorrect module type into a slot may result in personal injury, damage to the unit or connected equipment, or undesired operation!**

WARNING **Proper electrostatic discharge protection (i.e. a static strap) must be used when coming in contact with modules while the relay is energized!**

The relay, being modular in design, allows for the withdrawal and insertion of modules. Modules must only be replaced with like modules in their original factory configured slots.

The faceplate can be opened to the left, once the sliding latch on the right side has been pushed up, as shown in the figure below. This allows for easy accessibility of the modules for withdrawal.

Figure 3–5: UR MODULE WITHDRAWAL/INSERTION

WITHDRAWAL: The ejector/inserter clips, located at the top and bottom of each module, must be pulled simultaneously to release the module for removal. Before performing this action, **control power must be removed from the relay**. Record the original location of the module to ensure that the same or replacement module is inserted into the correct slot.

INSERTION: Ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserter clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.

NOTE Type 9C and 9D CPU modules are equipped with 10BaseT and 10BaseF Ethernet connectors for communications. These connectors must be individually disconnected from the module before the it can be removed from the chassis.

3.1.3 REAR TERMINAL LAYOUT

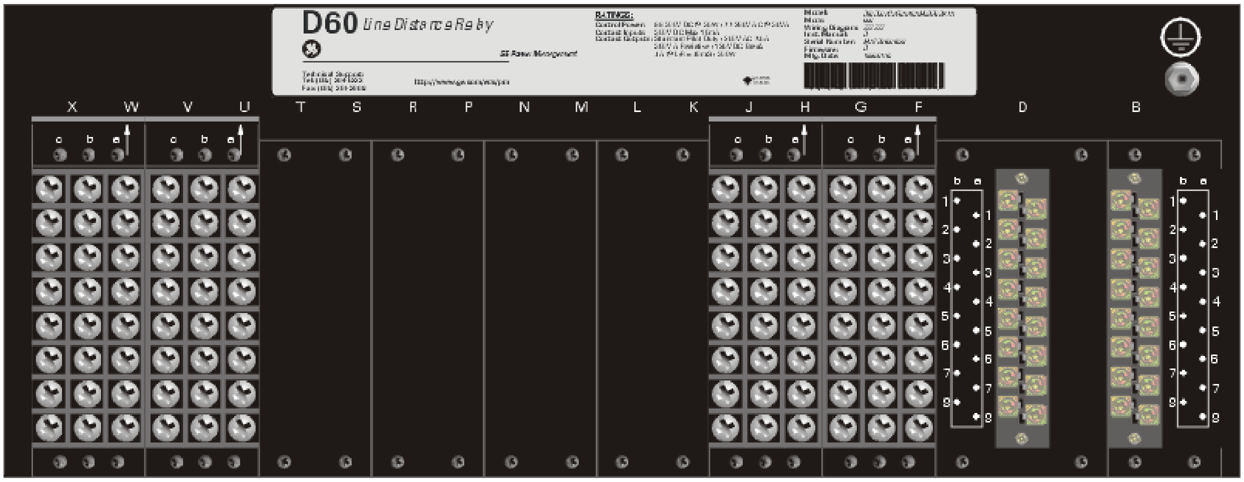


Figure 3–6: REAR TERMINAL VIEW

Do not touch any rear terminals while the relay is energized!

WARNING

The relay follows a convention with respect to terminal number assignments which are three characters long assigned in order by module slot position, row number, and column letter. Two-slot wide modules take their slot designation from the first slot position (nearest to CPU module) which is indicated by an arrow marker on the terminal block. See the following figure for an example of rear terminal assignments.

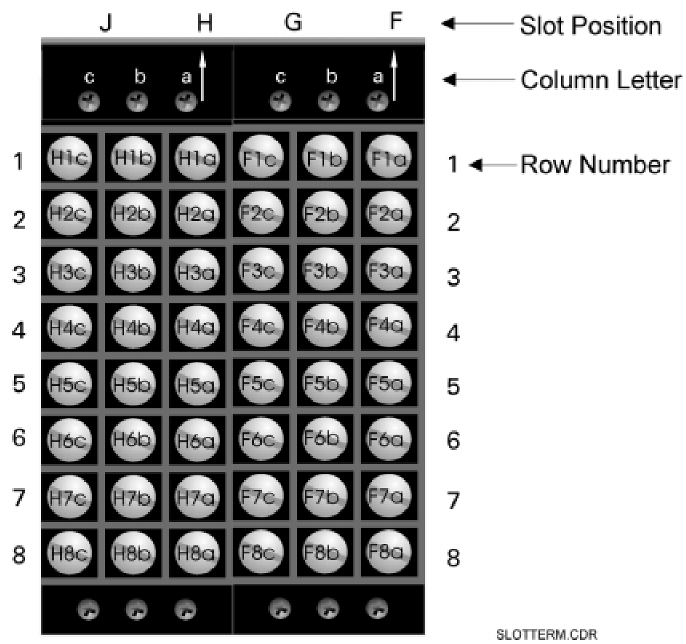
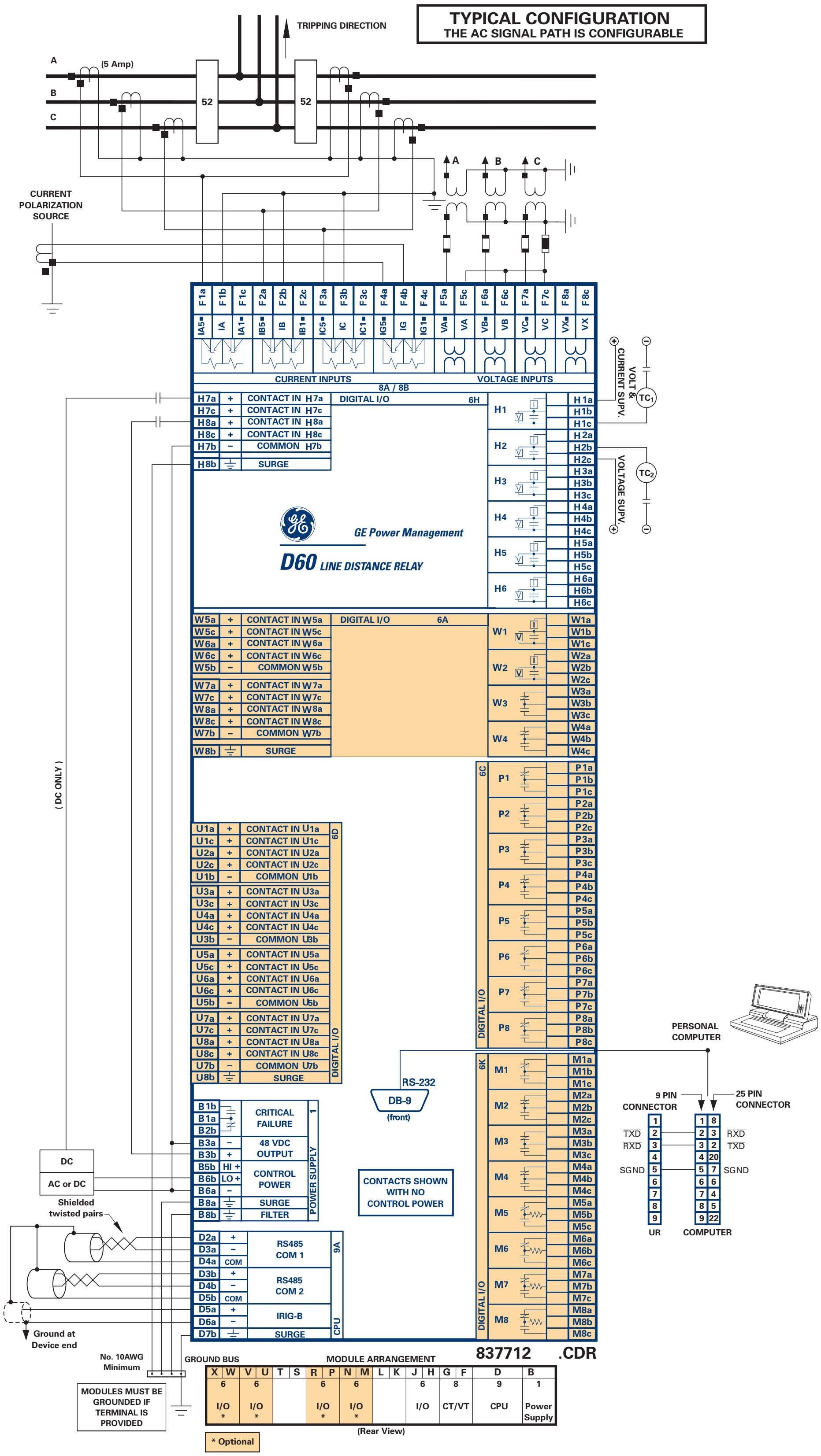


Figure 3–7: EXAMPLE OF MODULES IN F & H SLOTS

3.2.1 TYPICAL WIRING DIAGRAM



This diagram is based on the following order code: D60-A00-HCL-F8A-H6H-M6K-P6C-U6D-W6A.

The purpose of this diagram is to provide an example of how the relay is typically wired, not specifically how to wire your own relay. Please refer to the following pages for examples to help you wire your relay correctly based on your own relay configuration and order code.

CAUTION

Figure 3–8: TYPICAL WIRING DIAGRAM

3.2.2 DIELECTRIC STRENGTH

a) RATINGS

The dielectric strength of UR module hardware is shown in the following table:

Table 3–1: DIELECTRIC STRENGTH OF UR MODULE HARDWARE

MODULE TYPE	MODULE FUNCTION	TERMINALS		DIELECTRIC STRENGTH (AC)
		FROM	TO	
1	Power Supply	High (+); Low (+); (–)	Chassis	2000 V AC for 1 min. (See Precaution 1)
1	Power Supply	48 V DC (+) and (–)	Chassis	2000 V AC for 1 min. (See Precaution 1)
1	Power Supply	Relay Terminals	Chassis	2000 V AC for 1 min. (See Precaution 1)
2	Reserved for Future	N/A	N/A	N/A
3	Reserved for Future	N/A	N/A	N/A
4	Reserved for Future	N/A	N/A	N/A
5	Analog I/O	All except 8b	Chassis	< 50 V DC
6	Digital I/O	All (See Precaution 2)	Chassis	2000 V AC for 1 min.
8	CT/VT	All	Chassis	2000 V AC for 1 min.
9	CPU	All except 7b	Chassis	< 50 VDC

3

b) TESTING

Filter networks and transient protection clamps are used in module hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI) and electromagnetic interference (EMI). These protective components **can be damaged** by application of the ANSI/IEEE C37.90 specified test voltage for a period longer than the specified one minute. For testing of dielectric strength where the test interval may exceed one minute, always observe the following precautions:

Test Precautions:

1. The connection from ground to the Filter Ground (Terminal 8b) and Surge Ground (Terminal 8a) must be removed before testing.
2. Some versions of the digital I/O module have a Surge Ground connection on Terminal 8b. On these module types, this connection must be removed before testing.

3.2.3 CONTROL POWER

CAUTION

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 MAY OCCUR!

The power supply module can be ordered with either of two possible voltage ranges. Each range has a dedicated input connection for proper operation. The ranges are as shown below (see the Technical Specifications section for details).

Table 3–2: CONTROL POWER VOLTAGE RANGE

RANGE	NOMINAL VOLTAGE
LO	24 to 48 V (DC only)
HI	125 to 250 V

The power supply module provides power to the relay and supplies power for dry contact input connections.

3

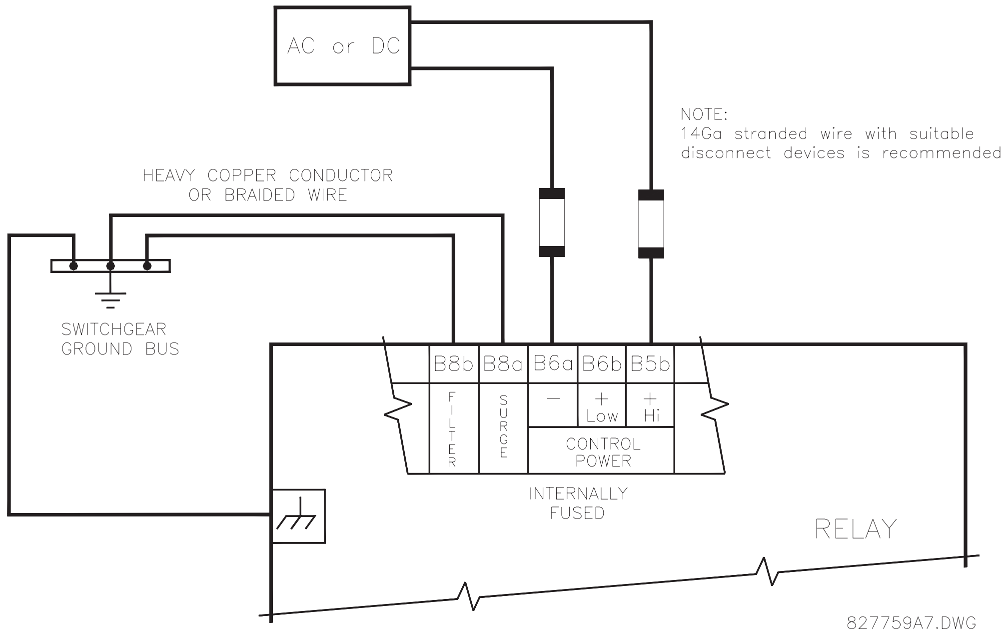


Figure 3–9: CONTROL POWER CONNECTION

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see TYPICAL WIRING DIAGRAM). The critical failure relay is a Form-C that will be energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If any of the on-going self-test features detect a critical failure or control power is lost, the relay will de-energize.

3.2.4 CT/VT MODULES

A CT/VT module may have voltage inputs on channels 1 through 4 inclusive, or channels 5 through 8 inclusive. Channels 1 and 5 are intended for connection to phase A, and are labeled as such in the relay. Channels 2 and 6 are intended for connection to phase B, and are labeled as such in the relay. Channels 3 and 7 are intended for connection to phase C and are labeled as such in the relay. Channels 4 and 8 are intended for connection to a single phase source. If voltage, this channel is labelled the auxiliary voltage (VX). If current, this channel is intended for connection to a CT between a system neutral and ground, and is labelled the ground current (IG).

a) AC CURRENT TRANSFORMER INPUTS

CAUTION

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 MAY RESULT IN EQUIPMENT DAMAGE OR INADEQUATE PROTECTION.

The CT/VT module may be ordered with a standard ground current input that is the same as the phase current inputs (type 8A) or with a sensitive ground input (type 8B) which is 10 times more sensitive (see the Technical Specifications section for more details). Each AC current input has an isolating transformer and an automatic shorting mechanism that shorts the input when the module is withdrawn from the chassis. 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 may be used.

CT connections for both ABC and ACB phase rotations are identical as shown in the TYPICAL WIRING DIAGRAM.

b) AC VOLTAGE TRANSFORMER INPUTS

The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as input for the Synchrocheck and Volts/Hertz features.

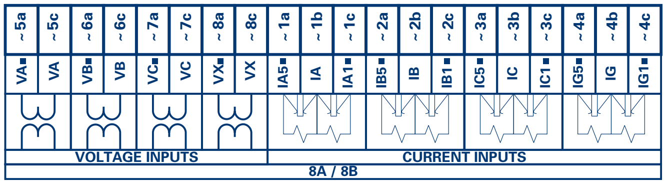


Figure 3–10: CT/VT MODULE WIRING

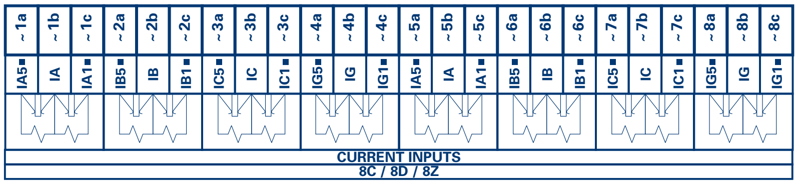


Figure 3–11: CT MODULE WIRING

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.

3.2.5 CONTACT INPUTS/OUTPUTS

Every digital input/output module has 24 terminal connections. They are arranged as 3 terminals per row, with 8 rows in total. A given row of three terminals may be used for the outputs of one relay. For example, for Form-C relay outputs, the terminals connect to the normally open (NO), normally closed (NC), and common contacts of the relay. For a Form-A output, there are options of using current or voltage detection for feature supervision, depending on the module ordered. The terminal configuration for contact inputs is different for the two applications. When a digital I/O module is ordered with contact inputs, they are arranged in groups of four and use two rows of three terminals. Ideally, each input would be totally isolated from any other input. However, this would require that every input have two dedicated terminals and limit the available number of contacts based on the available number of terminals. So, although each input is individually optically isolated, each group of four inputs uses a single common as a reasonable compromise. This allows each group of four outputs to be supplied by wet contacts from different voltage sources (if required) or a mix of wet and dry contacts.

The tables and diagrams on the following pages illustrate the module types (6A, etc.) and contact arrangements that may be ordered for the relay. Since an entire row is used for a single contact output, the name is assigned using the module slot position and row number. However, since there are two contact inputs per row, these names are assigned by module slot position, row number, and column position.

UR RELAY FORM-A OUTPUT CONTACTS

Some Form-A 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 "On = 1" when the current in the circuit is above the threshold setting. The voltage monitor is set to "On = 1" when the current is above about 1 to 2.5 mA, and the current monitor is set to "On = 1" when the current exceeds about 80 to 100 mA. 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. The block diagrams of the circuits are below above for the Form-A outputs with:

a) optional voltage monitor

b) optional current monitor

c) with no monitoring

3

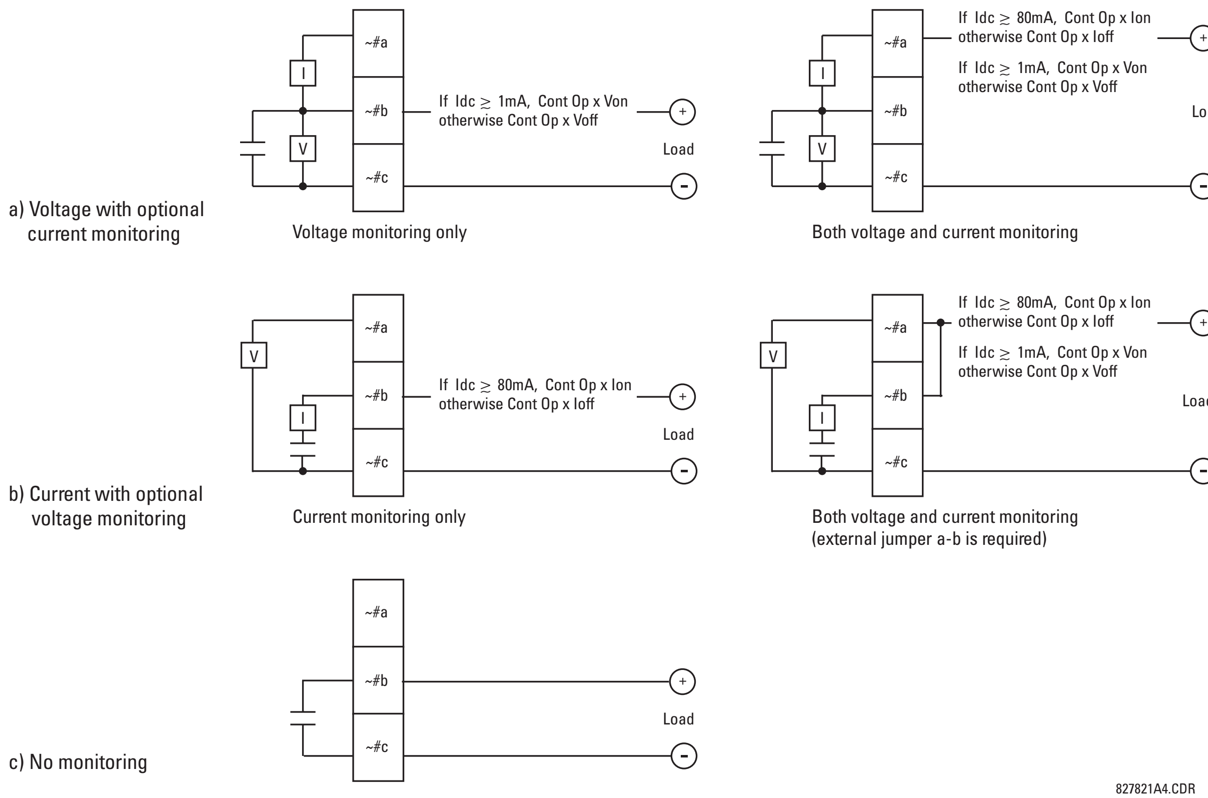


Figure 3–12: FORM-A CONTACT FUNCTIONS

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) which 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. Refer DIGITAL ELEMENTS section for an example of how Form A contacts can be applied for Breaker Trip Circuit Integrity Monitoring.

WARNING

Relay contacts must be considered 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!

NOTE

USE OF FORM-A OUTPUTS IN HIGH IMPEDANCE CIRCUITS

For Form-A output contacts internally equipped with a voltage measuring cIrcuit across the contact, the circuit has an impedance that can cause a problem when used in conjunction with external high input impedance monitoring equipment such as modern relay test set trigger circuits. These monitoring circuits may continue to read the Form-A contact as being closed after it has closed and subsequently opened, when measured as an impedance.

The solution to this problem is to use the voltage measuring trigger input of the relay test set, and connect the Form-A contact through a voltage-dropping resistor to a DC voltage source. If the 48 V DC output of the power supply is used as a source, a 500 Ω, 10 W resistor is appropriate. In this configuration, the voltage across either the Form-A contact or the resistor can be used to monitor the state of the output.

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module; wherever a number sign "#" appears, substitute the contact number

NOTE

When current monitoring is used to seal-in the Form-A contact outputs, the FlexLogic™ Operand driving the contact output should be given 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).

Table 3–3: DIGITAL I/O MODULE ASSIGNMENTS

~6A I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6B I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6C I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7	Form-C
~8	Form-C

3

~6D I/O MODULE	
TERMINAL ASSIGNMENT	INPUT
~1a, ~1c	2 Inputs
~2a, ~2c	2 Inputs
~3a, ~3c	2 Inputs
~4a, ~4c	2 Inputs
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6E I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6F I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Fast Form-C
~2	Fast Form-C
~3	Fast Form-C
~4	Fast Form-C
~5	Fast Form-C
~6	Fast Form-C
~7	Fast Form-C
~8	Fast Form-C

~6G I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6H I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6K I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT
~1	Form-C
~2	Form-C
~3	Form-C
~4	Form-C
~5	Fast Form-C
~6	Fast Form-C
~7	Fast Form-C
~8	Fast Form-C

~6L I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6M I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6N I/O MODULE	
TERMINAL ASSIGNMENT	OUTPUT OR INPUT
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

3

~6P I/O MODULE	
TERMINAL ASSIGNMENT	**OUTPUT OR INPUT**
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6R I/O MODULE	
TERMINAL ASSIGNMENT	**OUTPUT OR INPUT**
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6S I/O MODULE	
TERMINAL ASSIGNMENT	**OUTPUT OR INPUT**
~1	Form-A
~2	Form-A
~3	Form-C
~4	Form-C
~5	Form-C
~6	Form-C
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6T I/O MODULE	
TERMINAL ASSIGNMENT	**OUTPUT OR INPUT**
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5a, ~5c	2 Inputs
~6a, ~6c	2 Inputs
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

~6U I/O MODULE	
TERMINAL ASSIGNMENT	**OUTPUT OR INPUT**
~1	Form-A
~2	Form-A
~3	Form-A
~4	Form-A
~5	Form-A
~6	Form-A
~7a, ~7c	2 Inputs
~8a, ~8c	2 Inputs

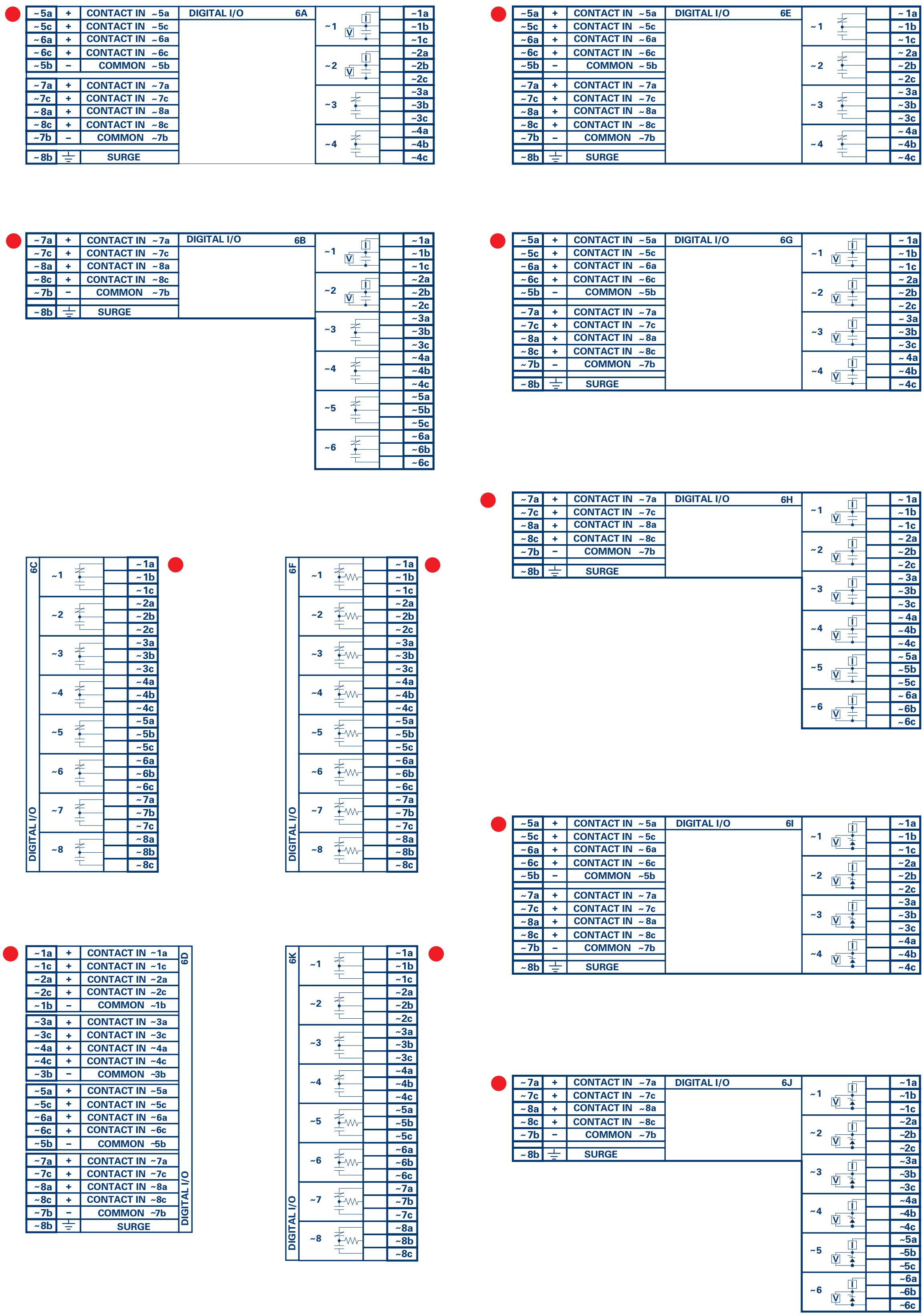


Figure 3–13: DIGITAL I/O MODULE WIRING (SHEET 1 OF 2)

3

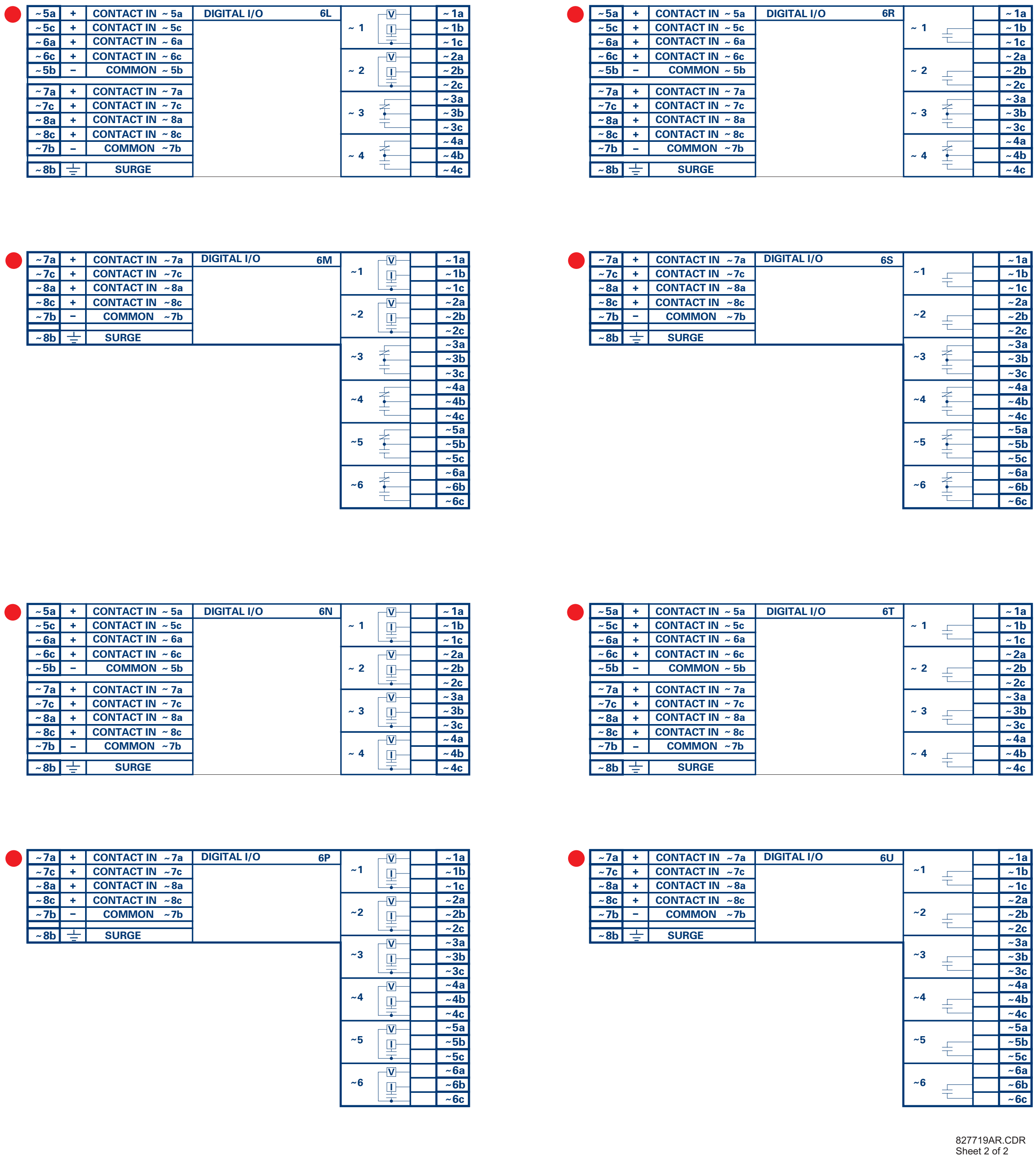


Figure 3–14: DIGITAL I/O MODULE WIRING (SHEET 2 OF 2)

CAUTION

CORRECT POLARITY MUST BE OBSERVED FOR ALL CONTACT INPUT CONNECTIONS OR EQUIPMENT DAMAGE MAY RESULT.

A dry contact has one side connected to terminal B3b. 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 the required contact input terminal. Each contact input group has its own common (negative) terminal which must be connected to the DC negative terminal (B3a) of the power supply module. When a dry contact closes, a current of 1 to 3 mA will flow through the associated circuit.

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 required contact input terminal. In addition, the negative side of the external source must be connected to the relay common (negative) terminal of each contact input group. 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 16 V DC for 24 V sources, 30 V DC for 48 V sources, 80 V DC for 110 to 125 V sources, and 140 V DC for 250 V sources.

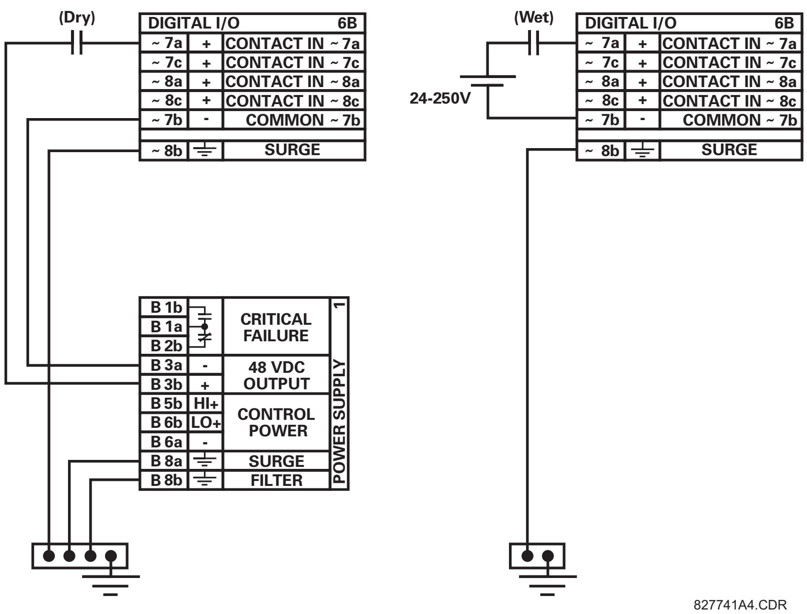


Figure 3–15: DRY AND WET CONTACT INPUT CONNECTIONS

NOTE

Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.

Contact outputs may be ordered as Form-A or Form-C. The Form A contacts may 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.

3.2.6 TRANSDUCER INPUTS/OUTPUTS

Transducer input/output modules can receive input signals from external dcmA output transducers (dcmA In) or resistance temperature detectors (RTD). Hardware and software is provided to receive signals from these external transducers and convert these signals into a digital format for use as required.

Every transducer input/output module has a total of 24 terminal connections. These connections are arranged as three terminals per row with a total of eight rows. A given row may be used for either inputs or outputs, with terminals in column "a" having positive polarity and terminals in column "c" having negative polarity. Since an entire row is used for a single input/output channel, the name of the channel is assigned using the module slot position and row number.

Each module also requires that a connection from an external ground bus be made to Terminal 8b. The figure below illustrates the transducer module types (5C, 5E, and 5F) and channel arrangements that may be ordered for the relay.

3

NOTE **Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.**

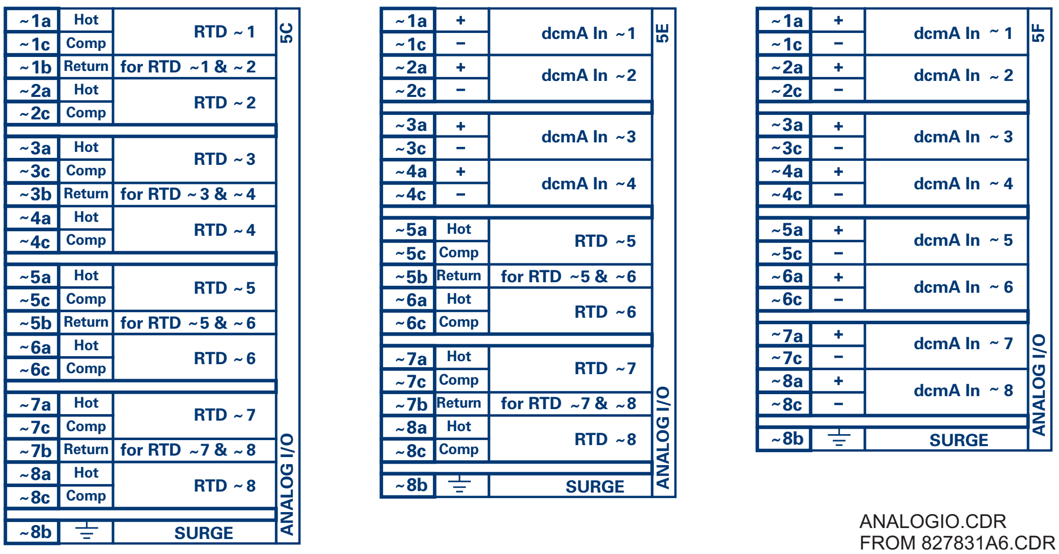


Figure 3–16: TRANSDUCER I/O MODULE WIRING

3.2.7 RS232 FACEPLATE PROGRAM PORT

A 9 pin RS232C serial port is located on the relay's faceplate for programming with a portable (personal) computer. All that is required to use this interface is a personal computer running the URPC software provided with the relay. Cabling for the RS232 port is shown in the following figure for both 9 pin and 25 pin connectors.

Note that the baud rate for this port is fixed at **19200 bps**.

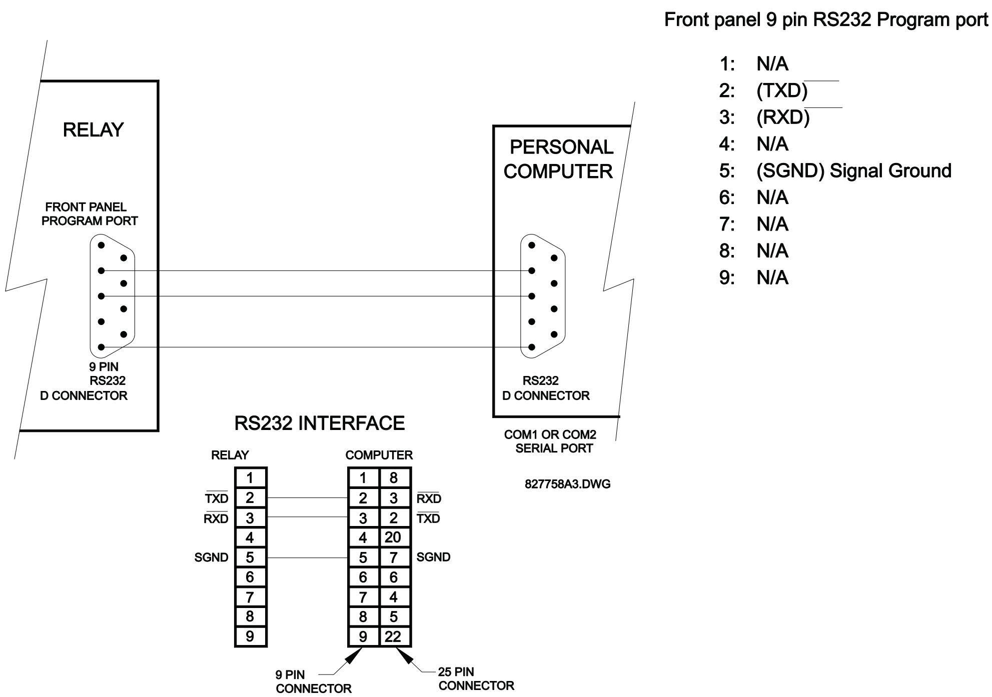


Figure 3–17: RS232 FACEPLATE PORT CONNECTION

3.2.8 CPU COMMUNICATION PORTS

In addition to the RS232 port on the faceplate, the relay provides the user with two additional communication port(s) depending on the CPU module installed.

Table 3–4: CPU COMMUNICATION PORT OPTIONS

CPU TYPE	COM 1	COM 2
9A	RS485	RS485
9C	10BASE-F	RS485
9D	Redundant 10BASE-F	RS485

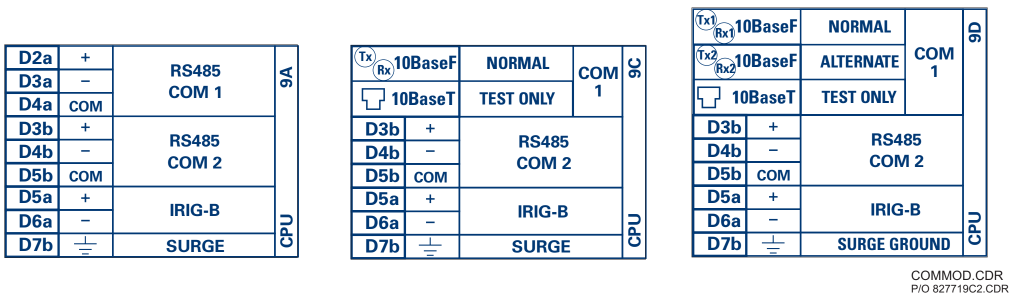


Figure 3–18: CPU MODULE COMMUNICATIONS WIRING

a) RS485 PORTS

RS485 data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. Through the use of these port(s), continuous monitoring and control from a remote computer, SCADA system or 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. The COM terminal should be connected to the common wire inside the shield, when provided. To avoid loop currents, the shield should be grounded at one point only. Each relay should also be daisy chained to the next one in the link. A maximum of 32 relays 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 increase the number of relays on a single channel to more than 32. Star or stub connections should be avoided 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 internally provided at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

Both ends of the RS485 circuit should also be terminated with an impedance as shown below.

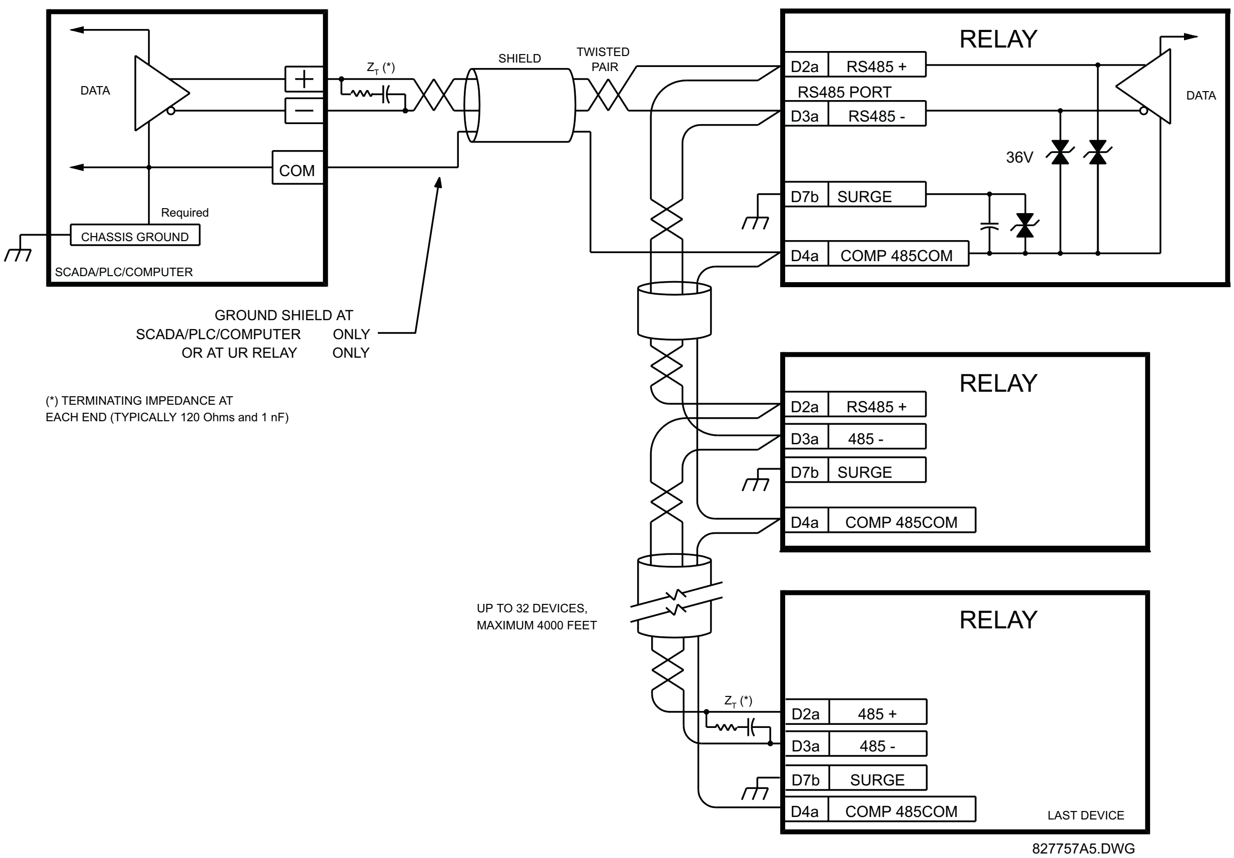


Figure 3–19: RS485 SERIAL CONNECTION

b) 10BASE-F FIBER OPTIC PORT

CAUTION **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.**

CAUTION **OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.**

The fiber optic communication ports allow for fast and efficient communications between relays at 10 Mbps. Optical fiber may be connected to the relay supporting a wavelength of 820 nanometers in multimode. Optical fiber is only available for CPU types 9C and 9D. The 9D CPU has a 10BaseF transmitter and receiver for optical fiber communications and a second pair of identical optical fiber transmitter and receiver for redundancy.

The optical fiber sizes supported include 50/125 µm, 62.5/125 µm and 100/140 µm. The fiber optic port is designed such that the response times will not vary for any core that is 100 µm or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter/receiver pair (the ST type connector contributes for a connector loss of 0.2 dB). 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.

3

3.2.9 IRIG-B

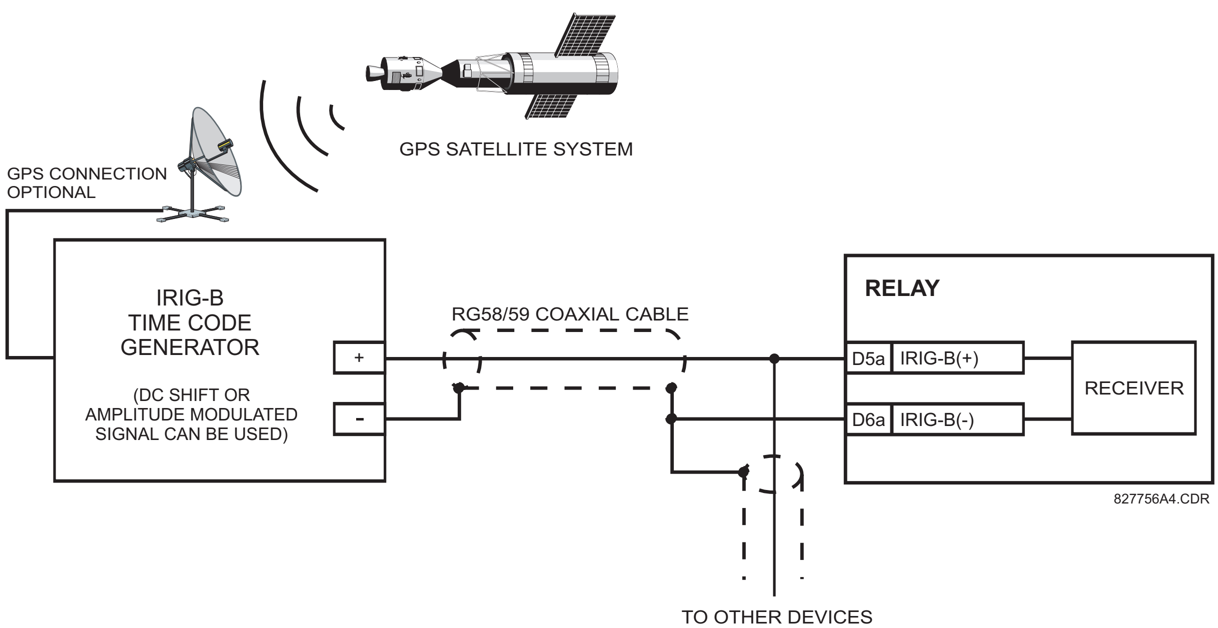


Figure 3–20: IRIG-B CONNECTION

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within 1 millisecond. The IRIG time code formats are serial, width-modulated codes which can be either DC level shifted or amplitude modulated (AM). Third party equipment is available for generating the IRIG-B signal; this equipment may use a GPS satellite system to obtain the time reference so that devices at different geographic locations can also be synchronized.

4.1.1 GRAPHICAL USER INTERFACE

The URPC software provides a graphical user interface (GUI) as one of two human interfaces to a UR device. The alternate human interface is implemented via the device's faceplate keypad and display (see FACEPLATE INTERFACE section in this chapter).

URPC provides a single facility to configure, monitor, maintain, and trouble-shoot the operation of relay functions, connected over local or wide area communication networks. It can be used while disconnected (i.e. off-line) or connected (i.e. on-line) to a UR device. In off-line mode, settings files can be created for eventual downloading to the device. In on-line mode, you can communicate with the device in real-time.

The URPC software, provided with every D60 relay, can be run from any computer supporting Microsoft Windows® 95, 98, or NT. This chapter provides a summary of the basic URPC software interface features. The URPC Help file provides details for getting started and using the URPC software interface.

4.1.2 CREATING A SITE LIST

To start using the URPC program, a Site List must first be created. See the instructions in the URPC Help program under the topic "Creating a Site List".

4.1.3 URPC® SOFTWARE OVERVIEW

a) ENGAGING A COMMUNICATING DEVICE

The URPC software may be used in on-line mode (relay connected) to directly communicate with a UR relay. Communicating relays are organized and grouped by communication interfaces and into sites. Sites may contain any number of relays selected from the UR product series.

b) USING SETTINGS FILES

The URPC software interface supports three ways of handling changes to relay settings:

- In off-line mode (relay disconnected) to create or edit relay settings files for later download to communicating relays.
- While connected to a communicating relay to directly modify any relay settings via relay data view windows, and then save the settings to the relay.
- You can create/edit settings files and then write them to the relay while the interface is connected to the relay.

Settings files are organized on the basis of file names assigned by the user. A settings file contains data pertaining to the following types of relay settings:

- Device Definition
- Product Setup
- System Setup
- FlexLogic™
- Grouped Elements
- Control Elements
- Inputs/Outputs
- Testing

Factory default values are supplied and can be restored after any changes.

c) CREATING / EDITING FLEXLOGIC™ EQUATIONS

You can create or edit a FlexLogic™ equation in order to customize the relay. You can subsequently view the automatically generated logic diagram.

d) VIEWING ACTUAL VALUES

You can view real-time relay data such as input/output status and measured parameters.

e) VIEWING TRIGGERED EVENTS

While the interface is in either on-line or off-line mode, you can view and analyze data generated by triggered specified parameters, via:

- **Event Recorder facility**

  The event recorder captures contextual data associated with the last 1024 events, listed in chronological order from most recent to oldest.

- **Oscillography facility**

  The oscillography waveform traces and digital states are used to provide a visual display of power system and relay operation data captured during specific triggered events.

f) CREATING INTERACTIVE SINGLE LINE DIAGRAMS

The URPC® software provides an icon-based interface facility for designing and monitoring electrical schematic diagrams of sites employing UR relays.

g) FILE SUPPORT

- **Execution**

  Any URPC file which is double clicked or opened will launch the application, or provide focus to the already opened application. If the file was a settings file (*.urs) which had been removed from the Settings List tree menu, it will be added back to the Settings List tree menu.

- **Drag and Drop**

  The Site List and Settings List control bar windows are each mutually a drag source and a drop target for device-order-code-compatible files or individual menu items. Also, the Settings List control bar window and any Windows Explorer directory folder are each mutually a file drag source and drop target.

  New files which are dropped into the Settings List window are added to the tree which is automatically sorted alphabetically with respect to settings file names. Files or individual menu items which are dropped in the selected device menu in the Site List window will automatically be sent to the on-line communicating device.

h) UR FIRMWARE UPGRADES

The firmware of a UR device can be upgraded, locally or remotely, via the URPC® software. The corresponding instructions are provided by the URPC® Help program under the topic “Upgrading Firmware”.

NOTE

Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (i.e. default values, min/max values, data type, and item size) may 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.

4.1.4 URPC® SOFTWARE MAIN WINDOW

The URPC software main window supports the following primary display components:

a. Title bar which shows the pathname of the active data view

b. Main window menu bar

c. Main window tool bar

d. Site List control bar window

e. Settings List control bar window

f. Device data view window(s), with common tool bar

g. Settings File data view window(s), with common tool bar

h. Workspace area with data view tabs

i. Status bar

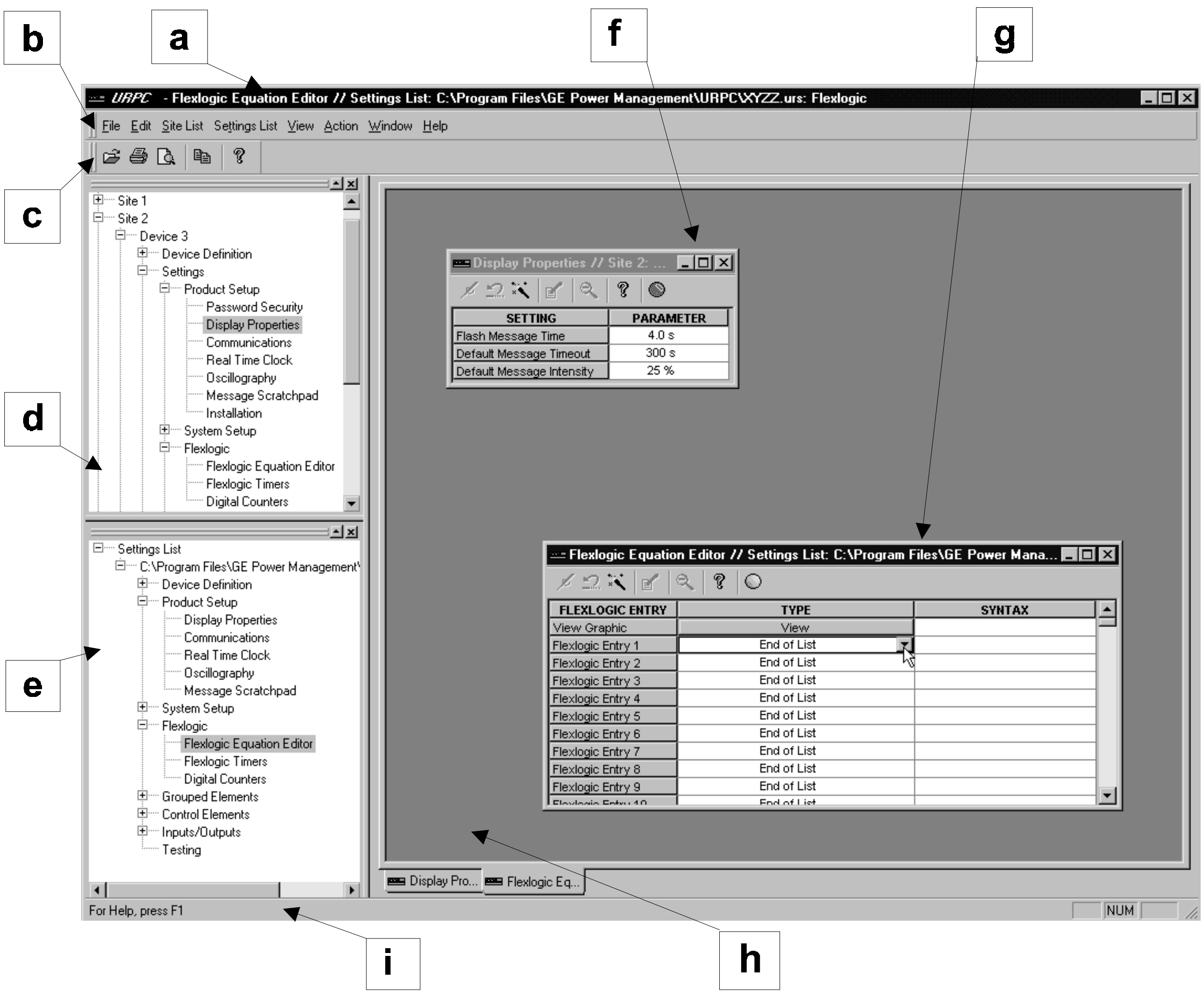


Figure 4–1: URPC SOFTWARE MAIN WINDOW

4.2.1 FACEPLATE

The keypad/display/LED interface is one of two alternate human interfaces supported. The other alternate human interface is implemented via the URPC software. The UR faceplate interface is available in two configurations: horizontal or vertical. The faceplate interface consists of several functional panels.

The faceplate is hinged to allow easy access to the removable modules. There is also a removable dust cover that fits over the faceplate which must be removed in order to access the keypad panel. The following two figures show the horizontal and vertical arrangement of faceplate panels.

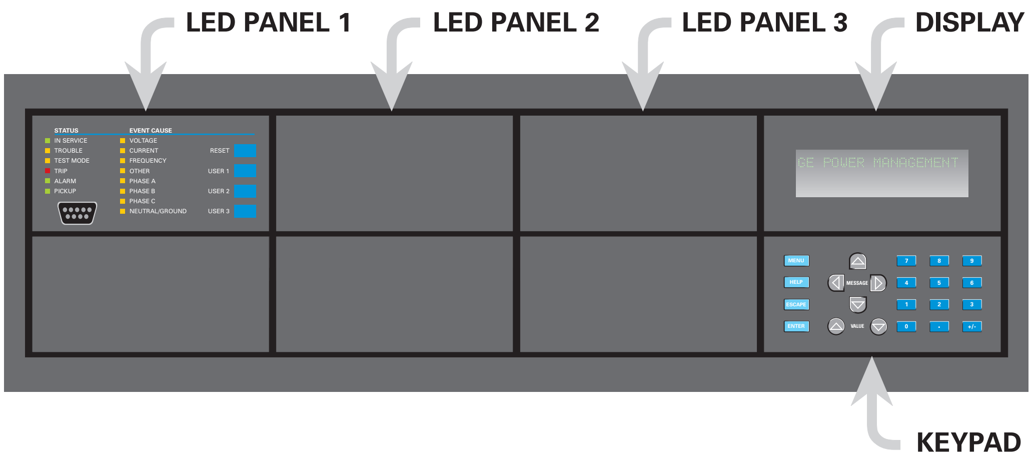


Figure 4–2: UR HORIZONTAL FACEPLATE PANELS

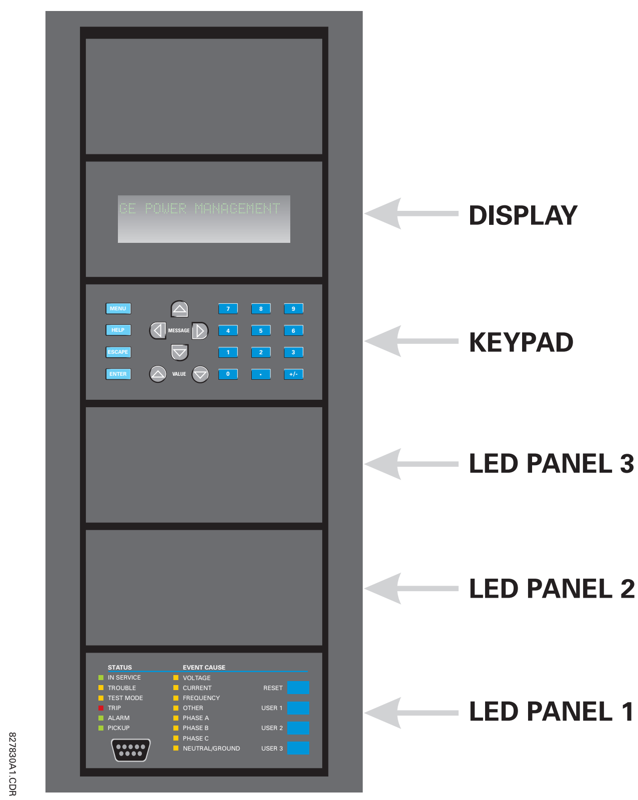


Figure 4–3: UR VERTICAL FACEPLATE PANELS

4.2.2 LED INDICATORS

a) LED PANEL 1

This panel provides several LED indicators, several keys, and a communications port. The RESET key is used to reset any latched LED indicator or target message, once the condition has been cleared (these latched conditions can also be reset via the **SETTINGS ⇨⇩ INPUT/OUTPUTS ⇨⇩ RESETTING** menu). The USER keys are used by the Breaker Control feature. The RS232 port is intended for connection to a portable PC.

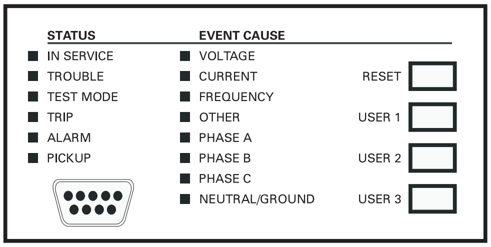


Figure 4–4: LED PANEL 1

STATUS INDICATORS:

- **IN SERVICE**: Indicates that control power is applied; all monitored I/O and internal systems are OK; the relay has been programmed.
- **TROUBLE**: Indicates that the relay has detected an internal problem.
- **TEST MODE**: Indicates that the relay is in test mode.
- **TRIP**: Indicates that the selected FlexLogic™ operand serving as a Trip switch has operated. This indicator always latches; the RESET command must be initiated to allow the latch to be reset.
- **ALARM**: Indicates that the selected FlexLogic™ operand serving as an Alarm switch has operated. This indicator is never latched.
- **PICKUP**: Indicates that an element is picked up. This indicator is never latched.

EVENT CAUSE INDICATORS:

These indicate the input type that was involved in a condition detected by an element that is operated or has a latched flag waiting to be reset.

- **VOLTAGE**: Indicates voltage was involved.
- **CURRENT**: Indicates current was involved.
- **FREQUENCY**: Indicates frequency was involved.
- **OTHER**: Indicates a composite function was involved.
- **PHASE A**: Indicates Phase A was involved.
- **PHASE B**: Indicates Phase B was involved.
- **PHASE C**: Indicates Phase C was involved.
- **NEUTRAL/GROUND**: Indicates neutral or ground was involved.

b) LED PANELS 2 & 3

These panels provide 48 amber LED indicators whose operation is controlled by the user. Support for applying a customized label beside every LED is provided.

User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. Refer to the USER-PROGRAMMABLE LEDs section in Chapter 5 for the settings used to program the operation of the LEDs on these panels.

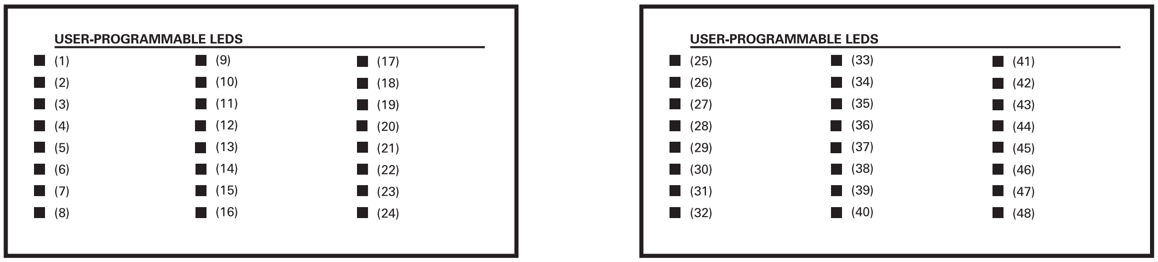


Figure 4–5: LED PANELS 2 AND 3 (INDEX TEMPLATE)

c) DEFAULT LABELS FOR LED PANEL 2

The default labels are meant to represent:

- **GROUP 1...8**: The illuminated GROUP is the active settings group.
- **BREAKER n OPEN**: The breaker is open.
- **BREAKER n CLOSED**: The breaker is closed.
- **BREAKER n TROUBLE**: A problem related to the breaker has been detected.
- **SYNCHROCHECK NO n IN-SYNCH**: Voltages have satisfied the synchrocheck element.
- **RECLOSE ENABLED**: The recloser is operational.
- **RECLOSE DISABLED**: The recloser is not operational.
- **RECLOSE IN PROGRESS**: A reclose operation is in progress.
- **RECLOSE LOCKED OUT**: The recloser is not operational and requires a reset.

The relay is shipped with the default label for the LED panel 2. The LEDs, however, are not pre-programmed. To match the pre-printed label, the LED settings must be entered as shown in the USER-PROGRAMMABLE LEDs section of the SETTINGS chapter. The LEDs are fully user-programmable. The default labels can be replaced by user-printed labels for both LED panels 2 and 3 as explained in the next section.

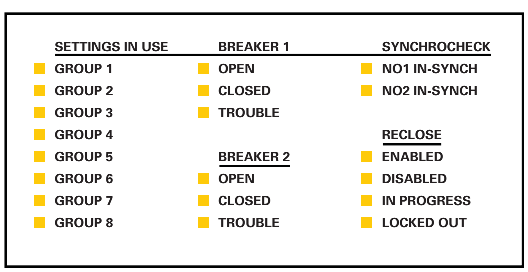


Figure 4–6: LED PANEL 2 (DEFAULT LABELS)

4.2.3 CUSTOM LABELING OF LEDs

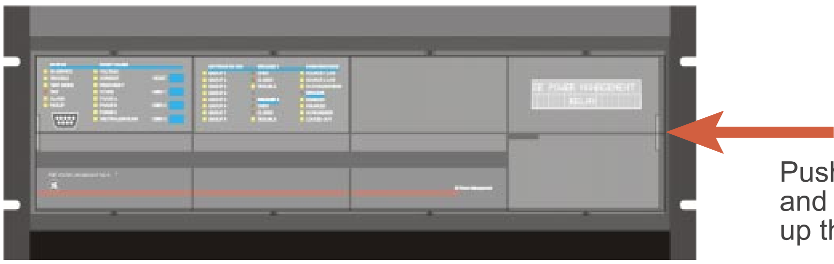
a) INSTALLING CUSTOMIZED DISPLAY MODULE

Custom labeling of an LED-only panel is facilitated by downloading a ‘zip’ file from

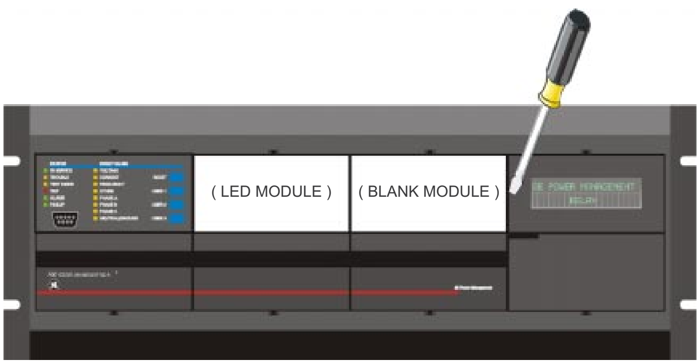
http://www.ge.com/indsys/pm/drawings/ur/custmod.zip.

This file provides templates and instructions for creating appropriate labeling for the LED panel. The following procedures are contained in the downloadable file. The CorelDRAW panel-templates provide relative LED locations and located example-text (x) edit boxes. The following procedure demonstrates how to install/uninstall the custom panel labeling.

1. Remove the clear LEXAN FRONT COVER (P/N: 1501-0014).



2. Pop out the LED MODULE and/or BLANK MODULE with a screwdriver as shown below. Be careful not to damage the plastic.



3. Place the left side of the customized module back to the front panel frame, then snap back the right side.
4. Put the clear LEXAN FRONT COVER back into place.

4.2.4 CUSTOMIZING THE DISPLAY MODULE

The following items are required to customize the UR display module:

- Black and white or color printer (color preferred)
- CorelDRAW version 5.0 or later software
- 1 each of: 8.5 x 11 white paper, exacto knife, ruler, custom display module (P/N: 1516-0069), custom module cover (P/N: 1502-0015)

1. Open the LED panel customization template in CorelDRAW. Add text in places of the Xs on the template(s) with the **Edit > Text** menu command. Delete the X place holders as required.Setup the print copy by selecting the **File > Print** menu command and pressing the "Properties" button.
2. On the **Page Setup** tab, choose **Paper Size**: "Letter" and **Orientation**: "Landscape" and press "OK".
3. Click the "Options" button and select the **Layout** tab.
4. For **Position and Size** enable the "Center image" and "Maintain aspect ratio" check boxes and press "OK", then "OK" once more to print.
5. From the printout, cut-out the BACKGROUND TEMPLATE from the three windows (use the cropmarks as a guide).

6. Put the BACKGROUND TEMPLATE on top of the custom display module (P/N: 1513-0069) and snap the clear cutome module cover (P/N: 1502-0015) over it and the templates.

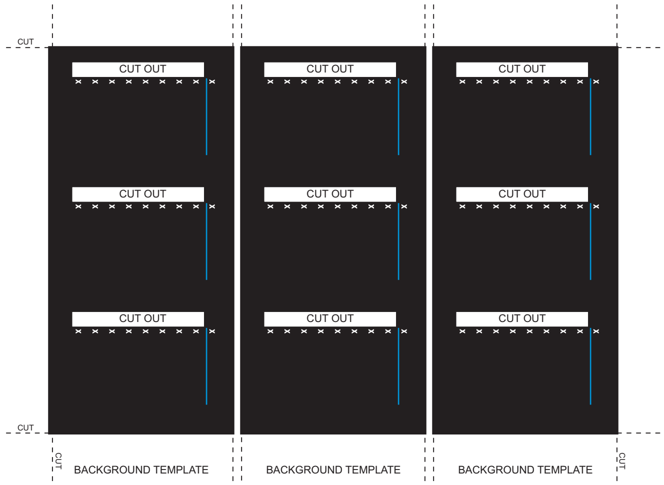


Figure 4–7: LED PANEL CUSTOMIZATION TEMPLATES (EXAMPLE)

4

4.2.5 DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

4.2.6 KEYPAD

Display messages are organized into 'pages' under the following headings: Actual Values, Settings, Commands, and Targets. The MENU key navigates through these pages. Each heading page is broken down further into logical subgroups.

The ▲ ◄ MESSAGE ► ▼ keys navigate through the subgroups. The ▲ VALUE ▼ keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The . key initiates and advance to the next character in text edit mode or enters a decimal point. The HELP key may be pressed at any time for context sensitive help messages. The ENTER key stores altered setting values.

4.2.7 BREAKER CONTROL

The D60 can interface with associated circuit breakers. In many cases the application monitors the state of the breaker, which can be presented on faceplate LEDs, along with a breaker trouble indication. Breaker operations can be manually initiated from faceplate keypad or automatically initiated from a FlexLogic™ operand. A setting is provided to assign names to each breaker; this user-assigned name is used for the display of related flash messages. These features are provided for two breakers; the user may use only those portions of the design relevant to a single breaker, which must be breaker No. 1.

For the following discussion it is assumed the SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER n ⇨ BREAKER FUNCTION setting is "Enabled" for each breaker.

a) CONTROL MODE SELECTION & MONITORING

Installations may require that a breaker is operated in the three-pole only mode (3-Pole), or in the one and three-pole (1-Pole) mode, selected by setting. If the mode is selected as 3-pole, a single input tracks the breaker open or closed position. If the mode is selected as 1-Pole, all three breaker pole states must be input to the relay. These inputs must be in agreement to indicate the position of the breaker.

For the following discussion it is assumed the SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER n ⇨⇩ BREAKER PUSH BUTTON CONTROL setting is "Enabled" for each breaker. The D60 has features required for single-pole operation. Inputs that trip individual breaker poles and cause a breaker reclose are passed directly to this element.

b) FACEPLATE PUSHBUTTON (USER KEY) CONTROL

After the 30 minute interval during which command functions are permitted after a correct command password, the user cannot open or close a breaker via the keypad. The following discussions begin from the not-permitted state.

c) CONTROL OF TWO BREAKERS

NOTE

For the following example setup, the symbol "(Name)" represents the user-programmed variable name.

For this application (setup shown below), the relay is connected and programmed for both breaker No. 1 and breaker No. 2. The USER 1 key performs the selection of which breaker is to be operated by the USER 2 and USER 3 keys. The USER 2 key is used to manually close the breaker and the USER 3 key is used to manually open the breaker.

```
ENTER COMMAND
PASSWORD
```

This message appears when the USER 1, USER 2, or USER 3 key is pressed and a COMMAND PASSWORD is required; i.e. if COMMAND PASSWORD is enabled and no commands have been issued within the last 30 minutes.

```
   Press USER 1
 To Select Breaker
```

This message appears if the correct password is entered or if none is required. This message will be maintained for 30 seconds or until the USER 1 key is pressed again.

```
BKR1-(Name) SELECTED
USER 2=CLS/USER 3=OP
```

This message is displayed after the USER 1 key is pressed for the second time. Three possible actions can be performed from this state within 30 seconds as per items **(1)**, **(2)** and **(3)** below:

(1)

```
  USER 2 OFF/ON
To Close BKR1-(Name)
```

If the USER 2 key is pressed, this message appears for 20 seconds. If the USER 2 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to close breaker No. 1.

(2)

```
  USER 3 OFF/ON
To Open BKR1-(Name)
```

If the USER 3 key is pressed, this message appears for 20 seconds. If the USER 3 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to open breaker No. 1.

(3)

```
BKR2-(Name) SELECTED
USER 2=CLS/USER 3=OP
```

If the USER 1 key is pressed at this step, this message appears showing that a different breaker is selected. Three possible actions can be performed from this state as per **(1)**, **(2)** and **(3)**. Repeatedly pressing the USER 1 key alternates between available breakers. Pressing keys other than USER 1, 2 or 3 at any time aborts the breaker control function.

d) CONTROL OF ONE BREAKER

For this application the relay is connected and programmed for breaker No. 1 only. Operation for this application is identical to that described for two breakers.

4.2.8 MENUS

a) NAVIGATION

Press the MENU key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the MENU key advances through the main heading pages as illustrated below.

```
MENU              ⇨  MENU              ⇨  MENU              ⇨  MENU
ACTUAL VALUES        SETTINGS             COMMANDS             TARGETS
      ⇩                  ⇩                    ⇩                    ⇩
■■ ACTUAL VALUES     ■■ SETTINGS          ■■ COMMANDS          No Active
■■ STATUS            ■■ PRODUCT SETUP     ■■ VIRTUAL INPUTS    Targets

⇨ MENU
USER DISPLAYS
(when in use)
      ⇩
User Display 1
```

b) HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE ▲ and ▼ keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE ▶ key from a header display displays specific information for the header category. Conversely, continually pressing the ◀ MESSAGE key from a setting value or actual value display returns to the header display.

```
HIGHEST LEVEL                  LOWEST LEVEL (SETTING VALUE)

■■ SETTINGS        ◀▶  ■ PASSWORD     ◀▶  ACCESS LEVEL:
■■ PRODUCT SETUP       ■ SECURITY         Restricted
       ▲▼
■■ SETTINGS
■■ SYSTEM SETUP
```

c) EXAMPLE MENU NAVIGATION SCENARIO

■■ ACTUAL VALUES ■■ STATUS	Press the MENU key until the header for the first Actual Values page appears. This page contains system and relay status information. Repeatedly press the ▲ ◄ MESSAGE ► ▼ keys to display the other actual value headers.
⇩	
■■ SETTINGS ■■ PRODUCT SETUP	Press the MENU key until the header for the first page of Settings appears. This page contains settings to configure the relay.
⇩	
■■ SETTINGS ■■ SYSTEM SETUP	Press the MESSAGE ▼ key to move to the next Settings page. This page contains settings for system setup. Repeatedly press the ▲ MESSAGE ▼ keys to display the other setting headers and then back to the first Settings page header.
⇩	
■ PASSWORD ■ SECURITY	From the Settings page one header (Product Setup), press the MESSAGE ► key once to display the first sub-header (Password Security).
⇩	
ACCESS LEVEL: Restricted	Press the MESSAGE ► key once more and this will display the first setting for Password Security. Pressing the MESSAGE ▼ key repeatedly will display the remaining setting messages for this sub-header.
⇩	
■ PASSWORD ■ SECURITY	Press the MESSAGE ◄ key once to move back to the first sub-header message.
⇩	
■ DISPLAY ■ PROPERTIES	Pressing the MESSAGE ▼ key will display the second setting sub-header associated with the Product Setup header.
⇩	
FLASH MESSAGE TIME: 1.0 s	Press the MESSAGE ► key once more and this will display the first setting for Display Properties.
⇩	
DEFAULT MESSAGE INTENSITY: 25%	To view the remaining settings associated with the Display Properties subheader, repeatedly press the MESSAGE ▼ key. The last message appears as shown.

4.2.9 CHANGING SETTINGS

a) ENTERING NUMERICAL DATA

Each numerical setting has its own minimum, maximum, and increment value associated with it. These parameters define what values are acceptable for a setting.

FLASH MESSAGE TIME: 1.0 s	For example, select the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES ⇨ FLASH MESSAGE TIME** setting.
⇩	
MINIMUM: 0.5 MAXIMUM: 10.0	Press the HELP key to view the minimum and maximum values. Press the HELP key again to view the next context sensitive help message.

Two methods of editing and storing a numerical setting value are available.

- **0 to 9** and **·** (decimal point): The relay numeric keypad works the same as that of any electronic calculator. A number is entered one digit at a time. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the MESSAGE ◄ key or pressing the ESCAPE key, returns the original value to the display.
- ▲ **VALUE** ▼: The VALUE ▲ key increments the displayed value by the step value, up to the maximum value allowed. While at the maximum value, pressing the VALUE ▲ key again will allow the setting selection to continue upward from the minimum value. The VALUE ▼ key decrements the displayed value by the step value, down to the

4

minimum value. While at the minimum value, pressing the VALUE ▼ key again will allow the setting selection to continue downward from the maximum value.

```
FLASH MESSAGE
TIME:  2.5 s
```
⇩

As an example, set the flash message time setting to 2.5 seconds. Press the appropriate numeric keys in the sequence "2 . 5". The display message will change as the digits are being entered.

```
NEW SETTING
HAS BEEN STORED
```

Until the ENTER key is pressed, editing changes are not registered by the relay. Therefore, press the ENTER key to store the new value in memory. This flash message will momentarily appear as confirmation of the storing process. Numerical values which contain decimal places will be rounded-off if more decimal place digits are entered than specified by the step value.

b) ENTERING ENUMERATION DATA

Enumeration settings have data values which are part of a set, whose members are explicitly defined by a name. A set is comprised of two or more members.

4

```
ACCESS LEVEL:
Restricted
```

For example, the selections available for **ACCESS LEVEL** are "Restricted", "Command", "Setting", and "Factory Service".

Enumeration type values are changed using the ▲ VALUE ▼ keys. The VALUE ▲ key displays the next selection while the VALUE ▼ key displays the previous selection.

```
ACCESS LEVEL:
Setting
```

If the **ACCESS LEVEL** needs to be "Setting", press the ▲ VALUE ▼ keys until the proper selection is displayed. Press the HELP key at any time for the context sensitive help messages.

⇩

```
NEW SETTING
HAS BEEN STORED
```

Changes are not registered by the relay until the ENTER key is pressed. Pressing ENTER stores the new value in memory. This flash message momentarily appears as confirmation of the storing process.

c) ENTERING ALPHANUMERIC TEXT

Text settings have data values which are fixed in length, but user-defined in character. They may be comprised of upper case letters, lower case letters, numerals, and a selection of special characters.

In order to allow the relay to be customized for specific applications, there are several places where text messages may be programmed. One example is the MESSAGE SCRATCHPAD. To enter alphanumeric text messages, the following procedure should be followed:

Example: to enter the text, “Breaker #1”

1. Press [•] to enter text edit mode.
2. Press the VALUE ▲ or VALUE ▼ key until the character 'B' appears; press [•] to advance the cursor to the next position.
3. Repeat step 2 for the remaining characters: r,e,a,k,e,r, ,#,1.
4. Press ENTER to store the text.
5. If you have any problem, press the HELP key to view the context sensitive help. Flash messages will sequentially appear for several seconds each. For the case of a text setting message, the HELP key displays how to edit and store a new value.

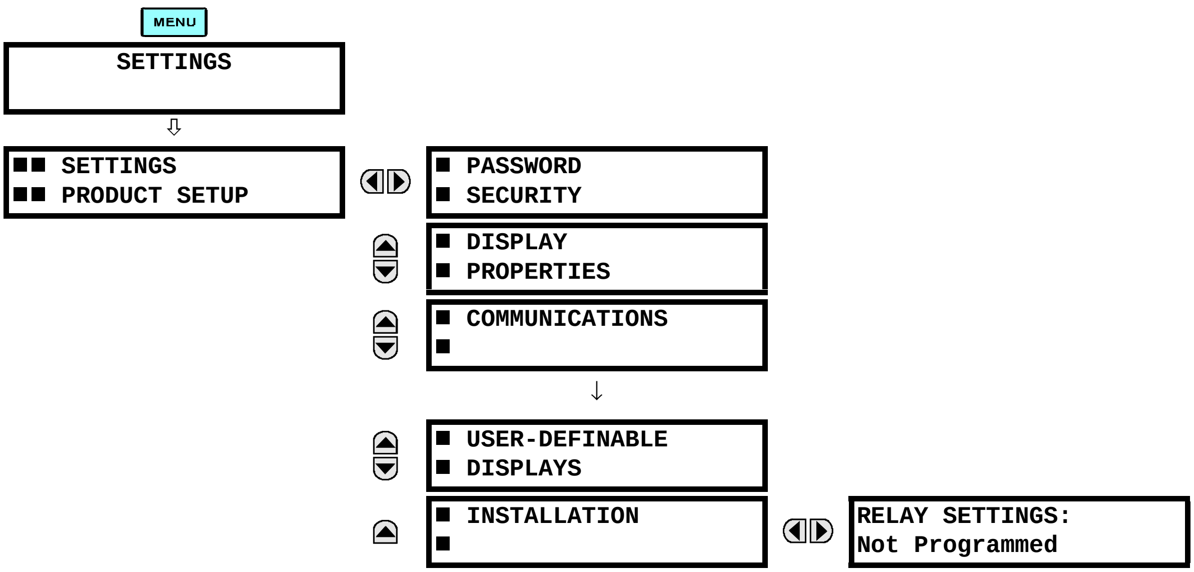
d) ACTIVATING THE RELAY

```
RELAY SETTINGS:
Not Programmed
```

When the relay is powered up, the TROUBLE indicator will be on, the IN SERVICE indicator off, and this message displayed. This indicates that the relay is in the "Not Programmed" state and is safeguarding (output relays blocked) against the installation of a relay whose settings have not been entered. This message will remain until the relay is explicitly put in the "Programmed" state.

To change the **RELAY SETTINGS:** "Not Programmed" mode to "Programmed", proceed as follows:

1. Press the MENU key until the **SETTINGS** header flashes momentarily and the **SETTINGS PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE ▶ key until the **PASSWORD SECURITY** message appears on the display.
3. Press the MESSAGE ▼ key until the **INSTALLATION** message appears on the display.
4. Press the MESSAGE ▶ key until the **RELAY SETTINGS: Not Programmed** message is displayed.



5. After the **RELAY SETTINGS: Not Programmed** message appears on the display, press the VALUE ▲ key or the VALUE ▼ key to change the selection to "Programmed".
6. Press the ENTER key.

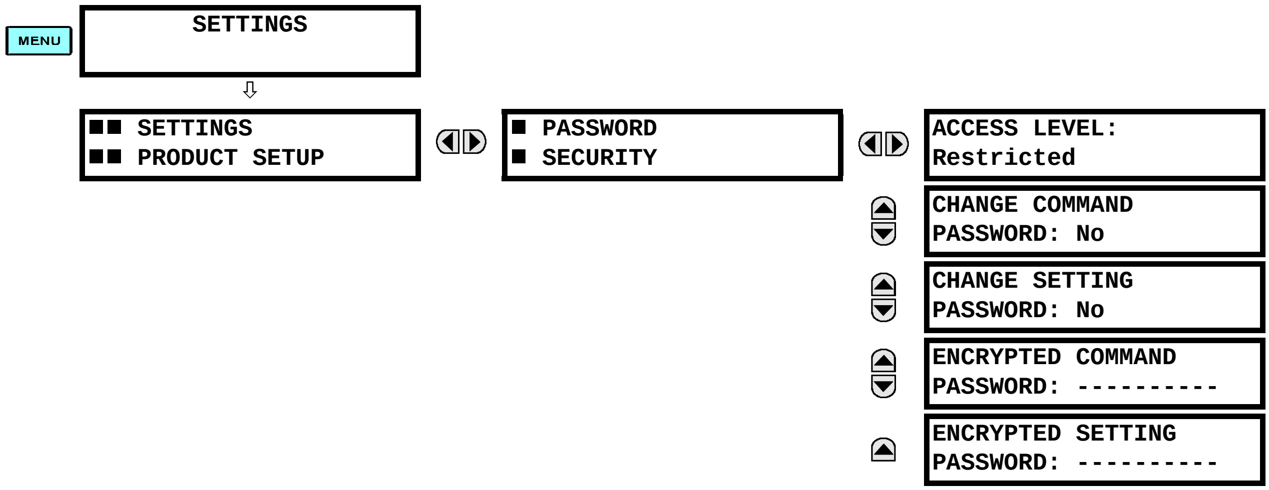
7. When the "NEW SETTING HAS BEEN STORED" message appears, the relay will be in "Programmed" state and the IN SERVICE indicator will turn on.

e) ENTERING INITIAL PASSWORDS

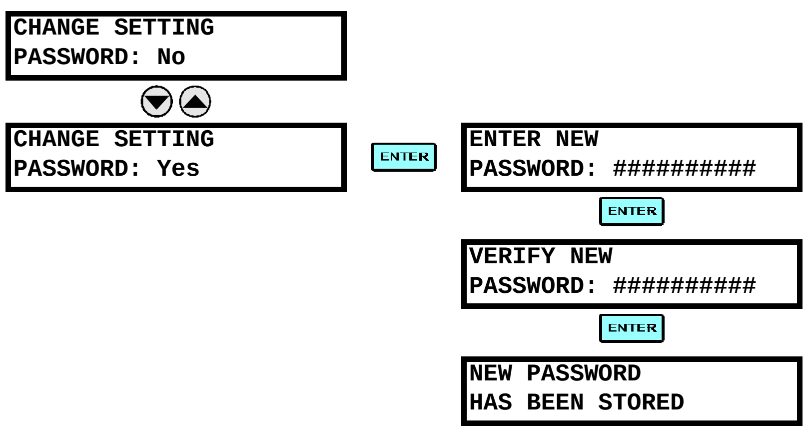
To enter the initial SETTING (or COMMAND) PASSWORD, proceed as follows:

1. Press the MENU key until the 'SETTINGS' header flashes momentarily and the 'SETTINGS PRODUCT SETUP' message appears on the display.
2. Press the MESSAGE ▶ key until the 'ACCESS LEVEL:' message appears on the display.

3. Press the MESSAGE ▼ key until the 'CHANGE SETTING (or COMMAND) PASSWORD:' message appears on the display.



4. After the 'CHANGE...PASSWORD' message appears on the display, press the VALUE ▲ key or the VALUE ▼ key to change the selection to Yes.
5. Press the ENTER key and the display will prompt you to 'ENTER NEW PASSWORD'.
6. Type in a numerical password (up to 10 characters) and press the ENTER key.
7. When the 'VERIFY NEW PASSWORD' is displayed, re-type in the same password and press ENTER.



8. When the 'NEW PASSWORD HAS BEEN STORED' message appears, your new SETTING (or COMMAND) PASSWORD will be active.

f) CHANGING EXISTING PASSWORD

To change an existing password, follow the instructions in the previous section with the following exception. A message will prompt you to type in the existing password (for each security level) before a new password can be entered.

In the event that a password has been lost (forgotten), submit the corresponding Encrypted Password from the PASSWORD SECURITY menu to the Factory for decoding.

5.1.1 SETTINGS MAIN MENU

■■ SETTINGS ■■ PRODUCT SETUP	■ PASSWORD ■ SECURITY	See page 5-7.
	■ DISPLAY ■ PROPERTIES	See page 5-8.
	■ COMMUNICATIONS ■	See page 5-8.
	■ MODBUS USER MAP ■	See page 5-15.
	■ REAL TIME ■ CLOCK	See page 5-15.
	■ FAULT REPORT ■	See page 5-15.
	■ OSCILLOGRAPHY ■	See page 5-16.
	■ DATA LOGGER ■	See page 5-18.
	■ USER-PROGRAMMABLE ■ LEDS	See page 5-19.
	■ FLEX STATE ■ PARAMETERS	See page 5-20.
	■ USER-DEFINABLE ■ DISPLAYS	See page 5-20.
	■ INSTALLATION ■	See page 5-22.
■■ SETTINGS ■■ SYSTEM SETUP	■ AC INPUTS ■	See page 5-23.
	■ POWER SYSTEM ■	See page 5-24.
	■ SIGNAL SOURCES ■	See page 5-25.
	■ LINE ■	See page 5-27.
	■ BREAKERS ■	See page 5-28.
	■ FLEXCURVES ■	See page 5-31.
■■ SETTINGS ■■ FLEXLOGIC	■ FLEXLOGIC ■ EQUATION EDITOR	See page 5-46.
	■ FLEXLOGIC ■ TIMERS	See page 5-46.
	■ FLEXELEMENTS ■	See page 5-47.

■■ SETTINGS ■■ GROUPED ELEMENTS	■ SETTING GROUP 1 ■	See page 5-51.
	■ SETTING GROUP 2 ■	
	↓ ↓	
	■ SETTING GROUP 8 ■	
■■ SETTINGS ■■ CONTROL ELEMENTS	■ SETTING GROUPS ■	See page 5-119.
	■ TRIP OUTPUT ■	See page 5-120.
	■ SYNCHROCHECK ■	See page 5-124.
	■ AUTORECLOSE ■	See page 5-128.
	■ DIGITAL ELEMENTS ■	See page 5-139.
	■ DIGITAL COUNTERS ■	See page 5-142.
	■ MONITORING ■ ELEMENTS	See page 5-144.
	■ PILOT SCHEMES ■	See page 5-149.
■■ SETTINGS ■■ INPUTS / OUTPUTS	■ CONTACT INPUTS ■	See page 5-165.
	■ VIRTUAL INPUTS ■	See page 5-167.
	■ CONTACT OUTPUTS ■	See page 5-168.
	■ VIRTUAL OUTPUTS ■	See page 5-168.
	■ REMOTE DEVICES ■	See page 5-169.
	■ REMOTE INPUTS ■	See page 5-170.
	■ REMOTE OUTPUTS ■ DNA BIT PAIRS	See page 5-171.
	■ REMOTE OUTPUTS ■ UserSt BIT PAIRS	See page 5-172.
	■ RESETTING ■	See page 5-172.

```
■■ SETTINGS              ■ DCMA INPUTS             See page 5-173.
■■ TRANSDUCER I/O        ■

                         ■ RTD INPUTS              See page 5-174.
                         ■

■■ SETTINGS              TEST MODE                 See page 5-175.
■■ TESTING               FUNCTION:

                         ■ FORCE CONTACT           See page 5-175.
                         ■ INPUTS

                         ■ FORCE CONTACT           See page 5-175.
                         ■ OUTPUTS
```

5.1.2 INTRODUCTION TO ELEMENTS

In the design of UR relays, the term “element” is used to describe a feature that is 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 will set the output to logic 1, also referred to as “setting the flag”. A single comparator may 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, except the Digital Element which uses a logic state as the input, use analog parameter actual values as the input.

Elements are arranged into two classes, GROUPED and CONTROL. Each element classed as a GROUPED element is provided with eight alternate sets of settings, in setting groups numbered 1 through 8. 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 the element scheme logic diagram. This includes the input(s), settings, fixed logic, and the output operands that are generated (abbreviations used on scheme logic diagrams are defined in Appendix F).

Some settings for current and voltage elements are specified in per-unit (pu) calculated quantities:

pu quantity = (actual quantity) / (base quantity)

- 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’ will be the common secondary or primary current to which the sum is scaled (i.e. normalized to the larger of the 2 rated CT inputs). For example, if CT1 = 300 / 5 A and CT2 = 100 / 5 A, then in order to sum these, CT2 is scaled to the CT1 ratio. In this case, the ‘base quantity’ will be 5 A secondary or 300 A primary.
- For voltage elements, the ‘base quantity’ is the nominal secondary or primary voltage of the VT.

Some settings are common to most elements and are discussed below:

FUNCTION Setting

This setting programs the element to be operational when selected as "Enabled". The factory default is "Disabled". Once programmed to "Enabled", any element associated with the Function becomes active and all options become available.

NAME Setting

This setting is used to uniquely identify the element.

SOURCE Setting

This setting is used to select the parameter or set of parameters to be monitored.

PICKUP Setting

For simple elements, this setting is 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 may be provided to define the range of the measured parameters which will 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.

TARGET Setting

This setting is used to define the operation of an element target message. When set to Disabled, no target message or illumination of a faceplate LED indicator is issued upon operation of the element. When set to Self-Reset, the target message and LED indication follow the Operate state of the element, and self-resets once the operate element condition clears. When set to Latched, the target message and LED indication will remain visible after the element output returns to logic 0 - until a RESET command is received by the relay.

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, an event is 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 could happen when the element is in the operate state if the reset delay time is not ‘0’.

5.1.3 INTRODUCTION TO AC SOURCES

a) BACKGROUND

The D60 may 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 3I_0 residual currents may be required for the circuit relaying and metering functions. For a three-winding transformer application, it may be required to calculate watts and vars for each of three windings, using voltage from different sets of VTs. All these requirements can be satisfied with a single UR relay, equipped with sufficient CT and VT input channels, by selecting the parameter to be measured. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to protection/control comparators and some metering elements.

Selection of the parameter(s) to be measured is partially performed 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, etc.) to be measured. The user completes the selection process by selecting the instrument transformer input channels to be used 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 currents of phase, 3I_0 and ground current, current from CTs with different ratios are adjusted to a single ratio before the summation.

A mechanism called a "Source" configures the routing of input CT and VT channels to measurement sub-systems. Sources, in the context of the UR family of relays, refer to the logical grouping of current and voltage signals such that one Source contains all of the signals required to measure the load or fault in a particular power apparatus. A given Source may 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 as illustrated in the following figure. In this application, the current flows as shown by the labeled 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 winding 1 of the power transformer 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 same considerations apply to transformer winding 2. The protection elements need access to the net current for the protection of the transformer, but some elements may need access to the individual currents from CT1 and CT2.

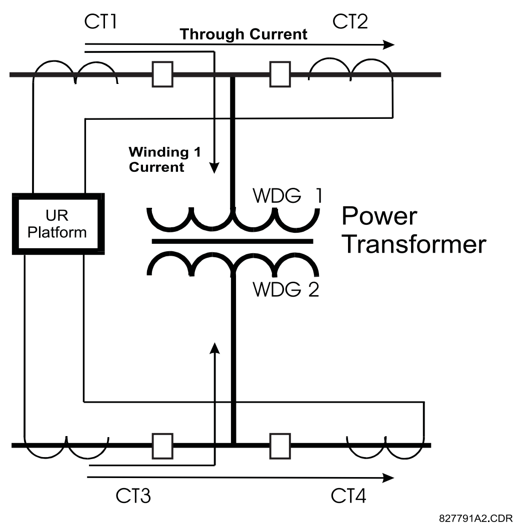


Figure 5–1: BREAKER-AND-A-HALF SCHEME

In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all the CTs through which any portion of the current for the element being protected could flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the UR platform, provisions have been included for all the current signals to be brought to the UR 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, as additional information to calculate a restraint current, for example, 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 will be 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 protection and metering elements in the UR platform. Individual names can be given to each Source to help identify them more clearly for later use. For example, in the scheme shown in the BREAKER-AND-A-HALF SCHEME above, the user would configure one Source to be the sum of CT1 and CT2 and could name this Source as 'Wdg 1 Current'.

Once the Sources have been configured, the user has them available as selections for the choice of input signal for the protection elements and as metered quantities.

b) CT/VT MODULE CONFIGURATIONS

CT and VT input channels are contained in CT/VT modules in UR products. The type of input channel can be phase/neutral/other voltage, phase/ground current, or sensitive ground current. The CT/VT modules calculate total waveform RMS levels, fundamental frequency phasors, symmetrical components and harmonics for voltage or current, as allowed by the hardware in each channel. These modules may calculate other parameters as directed by the CPU module.

A CT/VT module can contain up to eight input channels numbered 1 through 8. The numbering of channels in a CT/VT module corresponds to the module terminal numbering of 1 through 8 and is arranged as follows; channels 1, 2, 3 and 4 are always provided as a group, hereafter called a "bank," and all four are either current or voltage, as are channels 5, 6, 7 and 8. Channels 1, 2, 3 and 5, 6, 7 are arranged as phase A, B and C respectively. Channels 4 and 8 are either another current or voltage.

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the CT/VT module with the lowest slot position letter to the module with the highest slot position letter, as follows:

INCREASING SLOT POSITION LETTER -->		
CT/VT MODULE 1	**CT/VT MODULE 2**	**CT/VT MODULE 3**
< bank 1 >	< bank 3 >	< bank 5 >
< bank 2 >	< bank 4 >	< bank 6 >

The UR platform allows for a maximum of three sets of three-phase voltages and six sets of three-phase currents. The result of these restrictions leads to the maximum number of CT/VT modules in a chassis to three. The maximum number of Sources is six. A summary of CT/VT module configurations is shown below.

ITEM	**MAXIMUM NUMBER**
CT/VT Module	3
CT Bank (3 phase channels, 1 ground channel)	6
VT Bank (3 phase channels, 1 auxiliary channel)	3

c) CT/VT INPUT CHANNEL CONFIGURATION SETTINGS

Upon startup of the relay, configuration settings for every bank of current or voltage input channels in the relay are automatically generated, as determined from the order code. Within each bank, a channel identification label is automatically assigned to each bank of channels in a given product. The 'bank' naming convention is based on the physical location of the channels, required by the user to know how to connect the relay to external circuits. Bank identification consists of the letter designation of the slot in which the CT/VT module is mounted as the first character, followed by numbers indicating the channel, either 1 or 5.

For three-phase channel sets, the number of the lowest numbered channel identifies the set. For example, F1 represents the three-phase channel set of F1/F2/F3, where F is the slot letter and 1 is the first channel of the set of three channels.

Upon startup, the CPU configures the settings required to characterize the current and voltage inputs, and will display them in the appropriate section in the sequence of the banks (as described above) as shown below for a maximum configuration:

F1, F5, M1, M5, U1, U5.

The above section explains how the input channels are identified and configured to the specific application instrument 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 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.

5.2.1 PASSWORD SECURITY

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ PASSWORD SECURITY

■ PASSWORD ■ SECURITY	◄►	ACCESS LEVEL: Restricted	*Range: Restricted, Command, Setting, Factory Service (for factory use only)*
MESSAGE	▲▼	CHANGE COMMAND PASSWORD: No	*Range: No, Yes*
MESSAGE	▲▼	CHANGE SETTING PASSWORD: No	*Range: No, Yes*
MESSAGE	▲▼	ENCRYPTED COMMAND PASSWORD: ----------	*Range: 0 to 9999999999* *Note: ---------- indicates no password*
MESSAGE	▲	ENCRYPTED SETTING PASSWORD: ----------	*Range: 0 to 9999999999* *Note: ---------- indicates no password*

The D60 provides two user levels of password security: Command and Setting. Operations under password supervision are as follows:

COMMAND:

- Operating the breakers via faceplate keypad
- Changing the state of virtual inputs
- Clearing the event records
- Clearing the oscillography records

SETTING:

- Changing any setting.

The Command and Setting passwords are defaulted to "Null" when the relay is shipped from the factory. When a password is set to "Null", the password security feature is disabled.

Programming a password code is required to enable each access level. A password consists of 1 to 10 numerical characters. When a **CHANGE ... PASSWORD** setting is set to "Yes", the following message sequence is invoked:

1. ENTER NEW PASSWORD: ____________
2. VERIFY NEW PASSWORD: ____________
3. NEW PASSWORD HAS BEEN STORED

To gain write access to a "Restricted" setting, set **ACCESS LEVEL** to "Setting" and then change the setting, or attempt to change the setting and follow the prompt to enter the programmed password. If the password is correctly entered, access will be allowed. If no keys are pressed for longer than 30 minutes or control power is cycled, accessibility will automatically revert to the "Restricted" level.

If an entered password is lost (or forgotten), consult the factory service department with the corresponding **ENCRYPTED PASSWORD**.

NOTE

If the SETTING password and COMMAND password are set the same, the one password will allow access to commands and settings.

5.2.2 DISPLAY PROPERTIES

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ DISPLAY PROPERTIES

■ DISPLAY ■ PROPERTIES	FLASH MESSAGE TIME: 1.0 s	Range: 0.5 to 10.0 s in steps of 0.1
MESSAGE	DEFAULT MESSAGE TIMEOUT: 300 s	Range: 10 to 900 s in steps of 1
MESSAGE	DEFAULT MESSAGE INTENSITY: 25 %	Range: 25%, 50%, 75%, 100%

Some relay messaging characteristics can be modified to suit different situations using the display properties settings.

Flash messages are status, warning, error, or information messages displayed for several seconds in response to certain key presses during setting programming. These messages override any normal messages. The time a flash message remains on the display can be changed to accommodate different reading rates. If no keys are pressed for a period of time, the relay automatically displays a default message. This time can be modified to ensure messages remain on the screen long enough during programming or reading of actual values.

To extend the life of the phosphor in the vacuum fluorescent display, the brightness can be attenuated when displaying default messages. When interacting with the display using the keypad, the display always operates at full brightness.

5.2.3 COMMUNICATIONS

a) SERIAL PORTS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨ SERIAL PORTS

■ COMMUNICATIONS ■		
	■ SERIAL PORTS ■	
MESSAGE	RS485 COM1 BAUD RATE: 19200	Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200. Only active if CPU 9A is ordered.
MESSAGE	RS485 COM1 PARITY: None	Range: None, Odd, Even Only active if CPU Type 9A is ordered
MESSAGE	RS485 COM1 RESPONSE MIN TIME: 0 ms	Range: 0 to 1000 ms in steps of 10 Only active if CPU Type 9A is ordered
MESSAGE	RS485 COM2 BAUD RATE: 19200	Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200
MESSAGE	RS485 COM2 PARITY: None	Range: None, Odd, Even
MESSAGE	RS485 COM2 RESPONSE MIN TIME: 0 ms	Range: 0 to 1000 ms in steps of 10

The D60 is equipped with up to 3 independent serial communication ports. The faceplate RS232 port is intended for local use and has fixed parameters of 19200 baud and no parity. The rear COM1 port type will depend on the CPU ordered: it may be either an Ethernet or an RS485 port. The rear COM2 port is RS485. The RS485 ports have 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. Any of these ports may be connected to a personal computer running URPC. This software is used for downloading or uploading setting files, viewing measured parameters, and upgrading the relay firmware to the latest version. A maximum of 32 relays can be daisy-chained and connected to a DCS, PLC or PC using the RS485 ports.

NOTE

For each RS485 port, the minimum time before the port will transmit after receiving data from a host can be set. This feature allows operation with hosts which hold the RS485 transmitter active for some time after each transmission.

b) NETWORK

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK

		■ COMMUNICATIONS ■	
		■ NETWORK ■	
MESSAGE		IP ADDRESS: 0.0.0.0	Range: Standard IP address format Only active if CPU Type 9C or 9D is ordered.
MESSAGE		SUBNET IP MASK: 0.0.0.0	Range: Standard IP address format Only active if CPU Type 9C or 9D is ordered.
MESSAGE		GATEWAY IP ADDRESS: 0.0.0.0	Range: Standard IP address format Only active if CPU Type 9C or 9D is ordered.
MESSAGE		■ OSI NETWORK ■ ADDRESS (NSAP)	Note: Press the MESSAGE ⇨ key to enter the OSI NETWORK ADDRESS. Only active if CPU Type 9C or 9D is ordered.
MESSAGE		ETHERNET OPERATION MODE: Half-Duplex	Range: Half-Duplex, Full-Duplex Only active if CPU Type 9C or 9D is ordered.
MESSAGE		ETHERNET PRI LINK MONITOR: Disabled	Range: Disabled, Enabled Only active if CPU Type 9C or 9D is ordered.
MESSAGE		ETHERNET SEC LINK MONITOR: Disabled	Range: Disabled, Enabled Only active if CPU Type 9C or 9D is ordered.

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The Network setting messages will appear only if the UR is ordered with an Ethernet card. The Ethernet Primary and Secondary Link Monitor settings allow internal self test targets to be triggered when either the Primary or Secondary ethernet fibre link status indicates a connection loss. The IP addresses are used with DNP/Network, Modbus/TCP, MMS/UCA2, IEC 60870-5-104, TFTP, and HTTP (web server) protocols. The NSAP address is used with the MMS/UCA2 protocol over the OSI (CLNP/TP4) stack only. Each network protocol has a setting for the **TCP/UDP PORT NUMBER**. These settings are used only in advanced network configurations. They should normally be left at their default values, but may be changed if required; for example, to allow access to multiple URs behind a router. By setting a different TCP/UCP Port Number for a given protocol on each UR, the router can map the URs to the same external IP address. The client software (URPC, for example) must be configured to use the correct port number if these settings are used.

WARNING

Do not set more than one protocol to use the same TCP/UDP Port Number, as this will result in unreliable operation of those protocols.

NOTE

When the NSAP address, any TCP/UDP Port Number, or any User Map setting (when used with DNP) is changed, it will not become active until power to the relay has been cycled (OFF/ON).

c) MODBUS PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ MODBUS PROTOCOL

		■ COMMUNICATIONS ■	
		■ MODBUS PROTOCOL ■	
MESSAGE		MODBUS SLAVE ADDRESS: 254	Range: 1 to 254 in steps of 1
MESSAGE		MODBUS TCP PORT NUMBER: 502	Range: 1 to 65535 in steps of 1

The serial communication ports utilize the Modbus protocol, unless configured for DNP operation (see DNP PROTOCOL below). This allows the URPC program to be used. UR relays operate as Modbus slave devices only. When using Modbus protocol on the RS232 port, the D60 will respond regardless of the **MODBUS SLAVE ADDRESS** programmed. For the RS485 ports each D60 must have a unique address from 1 to 254. Address 0 is the broadcast address which all Modbus slave devices listen to. Addresses do not have to be sequential, but no two devices can have the same address or conflicts resulting in errors will occur. Generally, each device added to the link should use the next higher address starting at 1. Refer to Appendix B for more information on the Modbus protocol.

d) DNP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL

5

		■ COMMUNICATIONS ■	
		■ DNP PROTOCOL ■	
MESSAGE		DNP PORT: NONE	Range: NONE, COM1 - RS485, COM2 - RS485, FRONT PANEL - RS232, NETWORK
MESSAGE		DNP ADDRESS: 255	Range: 0 to 65519 in steps of 1
MESSAGE		■ DNP NETWORK ■ CLIENT ADDRESSES	Note: Press the MESSAGE ⇨ key to enter the DNP NETWORK CLIENT ADDRESSES
MESSAGE		DNP TCP/UDP PORT NUMBER: 20000	Range: 1 to 65535 in steps of 1
MESSAGE		DNP UNSOL RESPONSE FUNCTION: Disabled	Range: Enabled, Disabled
MESSAGE		DNP UNSOL RESPONSE TIMEOUT: 5 s	Range: 0 to 60 s in steps of 1
MESSAGE		DNP UNSOL RESPONSE MAX RETRIES: 10	Range: 1 to 255 in steps of 1
MESSAGE		DNP UNSOL RESPONSE DEST ADDRESS: 1	Range: 0 to 65519 in steps of 1
MESSAGE		USER MAP FOR DNP ANALOGS: Disabled	Range: Enabled, Disabled
MESSAGE		NUMBER OF SOURCES IN ANALOG LIST: 1	Range: 1 to 6 in steps of 1

MESSAGE	DNP CURRENT SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP VOLTAGE SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP CURRENT SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP POWER SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP ENERGY SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP OTHER SCALE FACTOR: 1	Range: 0.01. 0.1, 1, 10, 100, 1000
MESSAGE	DNP CURRENT DEFAULT DEADBAND: 30000	Range: 0 to 65535 in steps of 1
MESSAGE	DNP VOLTAGE DEFAULT DEADBAND: 30000	Range: 0 to 65535 in steps of 1
MESSAGE	DNP POWER DEFAULT DEADBAND: 30000	Range: 0 to 65535 in steps of 1
MESSAGE	DNP ENERGY DEFAULT DEADBAND: 30000	Range: 0 to 65535 in steps of 1
MESSAGE	DNP OTHER DEFAULT DEADBAND: 30000	Range: 0 to 65535 in steps of 1
MESSAGE	DNP TIME SYNC IIN PERIOD: 1440 min	Range: 1 to 10080 min. in steps of 1
MESSAGE	DNP MESSAGE FRAGMENT SIZE: 240	Range: 30 to 2048 in steps of 1
MESSAGE	■ DNP BINARY INPUTS ■ USER MAP	

The D60 supports the Distributed Network Protocol (DNP) version 3.0. The D60 can be used as a DNP slave device connected to a single DNP master (usually either an RTU or a SCADA master station). Since the D60 maintains one set of DNP data change buffers and connection information, only one DNP master should actively communicate with the D60 at one time. The DNP PORT setting is used to select the communications port assigned to the DNP protocol. DNP can be assigned to a single port only. Once DNP is assigned to a serial port, the Modbus protocol is disabled on that port. Note that COM1 can be used only in non-ethernet UR relays. When this setting is set to NETWORK, the DNP protocol can be used over either TCP/IP or UDP/IP. Refer to Appendix E for more information on the DNP protocol.

The **DNP ADDRESS** setting is the DNP slave address. This number identifies the D60 on a DNP communications link. Each DNP slave should be assigned a unique address.

The **DNP NETWORK CLIENT ADDRESS** settings can force the D60 to respond to a maximum of five specific DNP masters.

The **DNP UNSOL RESPONSE FUNCTION** should be set to "Disabled" for RS485 applications since there is no collision avoidance mechanism.

The **DNP UNSOL RESPONSE TIMEOUT** sets the time the D60 waits for a DNP master to confirm an unsolicited response.

The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the D60 will retransmit an unsolicited response without receiving a confirmation from the master. A value of 255 allows infinite re-tries.

The **DNP UNSOL RESPONSE DEST ADDRESS** setting is the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the D60 from either the current DNP TCP connection or the most recent UDP message.

The **USER MAP FOR DNP ANALOGS** setting allows the large pre-defined Analog Inputs points list to be replaced by the much smaller Modbus User Map. This can be useful for users wishing to read only selected Analog Input points from the D60. See Appendix E for more information

The **NUMBER OF SOURCES IN ANALOG LIST** setting allows the selection of the number of current/voltage source values that are included in the Analog Inputs points list. This allows the list to be customized to contain data for only the sources that are configured. This setting is relevant only when the User Map is not used.

The **DNP SCALE FACTOR** settings are numbers used to scale Analog Input point values. These settings group the D60 Analog Input data into types: current, voltage, power, energy, and other. Each setting represents the scale factor for all Analog Input points of that type. For example, if the **DNP VOLTAGE SCALE FACTOR** setting is set to a value of 1000, all DNP Analog Input points that are voltages will be returned with values 1000 times smaller (e.g. a value of 72000 V on the D60 will be returned as 72). These settings are useful when Analog Input values must be adjusted to fit within certain ranges in DNP masters. Note that a scale factor of 0.1 is equivalent to a multiplier of 10 (i.e. the value will be 10 times larger).

The **DNP DEFAULT DEADBAND** settings are the values used by the D60 to determine when to trigger unsolicited responses containing Analog Input data. These settings group the D60 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, in order to trigger unsolicited responses from the D60 when any current values change by 15 A, the **DNP CURRENT DEFAULT DEADBAND** setting should be set to 15. Note that these settings are the default values of the deadbands. 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 D60, the default deadbands will be in effect.

The **DNP TIME SYNC IIN PERIOD** setting determines how often the "Need Time" Internal Indication (IIN) bit is set by the D60. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

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The **DNP MESSAGE FRAGMENT SIZE** 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 can provide for more robust data transfer over noisy communication channels.

The **DNP BINARY INPUTS USER MAP** setting allows for the creation of a custom DNP Binary Inputs points list. The default DNP Binary Inputs list on the D60 contains 928 points representing various binary states (contact inputs and outputs, virtual inputs and outputs, protection element states, etc.). If not all of these points are required in the DNP master, a custom Binary Inputs points list can be created by selecting up to 58 blocks of 16 points. Each block represents 16 Binary Input points. Block 1 represents Binary Input points 0 to 15, block 2 represents Binary Input points 16 to 31, block 3 represents Binary Input points 32 to 47, etc. The minimum number of Binary Input points that can be selected is 16 (1 block). If all of the **BIN INPUT BLOCK X** settings are set to "Not Used", the standard list of 928 points will be in effect. The D60 will form the Binary Inputs points list from the **BIN INPUT BLOCK X** settings up to the first occurrence of a setting value of "Not Used".

NOTE

When using either of the User Maps for DNP data points (Analog Inputs and/or Binary Inputs), for UR relays with the ethernet option installed, check the "DNP Points Lists" D60 web page to ensure the desired points lists have been created. This web page can be viewed using Internet Explorer or Netscape Navigator by entering the D60 IP address to access the D60 "Main Menu", then by selecting the "Device Information Menu", and then selecting the "DNP Points Lists".

e) UCA/MMS PROTCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ UCA/MMS PROTOCOL

```
■ COMMUNICATIONS
■
```

```
■ UCA/MMS PROTOCOL
■
```

MESSAGE	DEFAULT GOOSE UPDATE TIME: 60 s	Range:	1 to 60 s in steps of 1 See UserSt BIT PAIRS in the REMOTE OUTPUTS section.
MESSAGE	UCA LOGICAL DEVICE: UCADevice	Range:	Up to 16 alphanumeric characters representing the name of the UCA logical device.
MESSAGE	UCA/MMS TCP PORT NUMBER: 102	Range:	1 to 65535 in steps of 1

The D60 supports the Manufacturing Message Specification (MMS) protocol as specified by the Utility Communication Architecture (UCA). UCA/MMS is supported over two protocol stacks: TCP/IP over ethernet and TP4/CLNP (OSI) over ethernet. The D60 operates as a UCA/MMS server. Appendix C describes the UCA/MMS protocol implementation in more detail. The REMOTE INPUTS and REMOTE OUTPUT sections of Chapter 5: SETTINGS describes the peer-to-peer GOOSE message scheme.

The UCA LOGICAL DEVICE setting represents the name of the MMS domain (UCA logical device) in which all UCA objects are located.

f) WEB SERVER HTTP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ WEB SERVER HTTP PROTOCOL

```
■ COMMUNICATIONS
■

        ■ WEB SERVER
        ■ HTTP PROTOCOL

MESSAGE     HTTP TCP PORT          Range: 1 to 65535 in steps of 1
            NUMBER:    80
```

The D60 contains an embedded web server. That is, the D60 is capable of transferring web pages to a web browser such as Microsoft Internet Explorer or Netscape Navigator. This feature is available only if the D60 has the ethernet option installed. The web pages are organized as a series of menus that can be accessed starting at the D60 "Main Menu". Web pages are available showing DNP and IEC 60870-5-104 points lists, Modbus registers, Event Records, Fault Reports, etc. The web pages can be accessed by connecting the UR and a computer to an ethernet network. The Main Menu will be displayed in the web browser on the computer simply by entering the IP address of the D60 into the "Address" box on the web browser.

g) TFTP PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ TFTP PROTOCOL

```
■ COMMUNICATIONS
■

        ■ TFTP PROTOCOL
        ■

MESSAGE     TFTP MAIN UDP PORT     Range: 1 to 65535 in steps of 1
            NUMBER:    69

MESSAGE     TFTP DATA UDP PORT 1   Range: 0 to 65535 in steps of 1
            NUMBER:    0

MESSAGE     TFTP DATA UDP PORT 2   Range: 0 to 65535 in steps of 1
            NUMBER:    0
```

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the UR over a network. The D60 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The file "dir.txt" is an ASCII text file that can be transferred from the D60. This file contains a list and description of all the files available from the UR (event records, oscillography, etc.).

h) IEC 60870-5-104 PROTOCOL

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ IEC 60870-5-104 PROTOCOL

```
■ COMMUNICATIONS
■
```

```
■ IEC 60870-5-104
■ PROTOCOL
```

MESSAGE	IEC 60870-5-104 FUNCTION: Disabled	*Range: Enabled, Disabled*
MESSAGE	IEC TCP PORT NUMBER: 2404	*Range: 1 to 65535 in steps of 1*
MESSAGE	IEC COMMON ADDRESS OF ASDU: 0	*Range: 0 to 65535 in steps of 1*
MESSAGE	IEC CYCLIC DATA PERIOD: 60 s	*Range: 1 to 65535 s in steps of 1*
MESSAGE	NUMBER OF SOURCES IN MMENC1 LIST: 1	*Range: 1 to 6 in steps of 1*
MESSAGE	IEC CURRENT DEFAULT THRESHOLD: 30	*Range: 0 to 65535 in steps of 1*
MESSAGE	IEC VOLTAGE DEFAULT THRESHOLD: 30000	*Range: 0 to 65535 in steps of 1*
MESSAGE	IEC POWER DEFAULT THRESHOLD: 30000	*Range: 0 to 65535 in steps of 1*
MESSAGE	IEC ENERGY DEFAULT THRESHOLD: 30000	*Range: 0 to 65535 in steps of 1*
MESSAGE	IEC OTHER DEFAULT THRESHOLD: 30000	*Range: 0 to 65535 in steps of 1*

The D60 supports the IEC 60870-5-104 protocol. The D60 can be used as an IEC 60870-5-104 slave device connected to a single master (usually either an RTU or a SCADA master station). Since the D60 maintains one set of IEC 60870-5-104 data change buffers, only one master should actively communicate with the D60 at one time. For situations where a second master is active in a "hot standby" configuration, the UR supports a second IEC 60870-5-104 connection providing the standby master sends only IEC 60870-5-104 Test Frame Activation messages for as long as the primary master is active.

The **NUMBER OF SOURCES IN MMENC1 LIST** setting allows the selection of the number of current/voltage source values that are included in the M_ME_NC_1 (Measured value, short floating point) Analog points list. This allows the list to be customized to contain data for only the sources that are configured.

The **IEC ------- DEFAULT THRESHOLD** settings are the values used by the UR to determine when to trigger spontaneous responses containing M_ME_NC_1 analog data. These settings group the UR 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, in order to trigger spontaneous responses from the UR when any current values change by 15 A, the **IEC CURRENT DEFAULT THRESHOLD** setting should be set 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 UR, the default thresholds will be in effect.

NOTE

The IEC 60870-5-104 and DNP protocols can not be used at the same time. When the IEC 60870-5-104 FUNCTION setting is set to Enabled, the DNP protocol will not be operational. When this setting is changed it will not become active until power to the relay has been cycled (OFF/ON).

5.2.4 MODBUS USER MAP

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ MODBUS USER MAP

■ MODBUS USER MAP ■	◀▶	ADDRESS 1: 0 VALUE: 0	Range: 0 to 65535 in steps of 1
		↓ ↓	
MESSAGE	▲	ADDRESS 256: 0 VALUE: 0	Range: 0 to 65535 in steps of 1

The Modbus® User Map provides up to 256 registers with read only access. To obtain a value for a memory map address, enter the desired location in the **ADDRESS** line (the value must be converted from hex to decimal format). The corresponding value from the is displayed in the **VALUE** line. A value of "0" in subsequent register **ADDRESS** lines automatically return values for the previous **ADDRESS** lines incremented by "1". An address value of "0" in the initial register means "none" and values of "0" will be displayed for all registers.

Different **ADDRESS** values can be entered as required in any of the register positions.

NOTE

These settings can also be used with the DNP protocol. See the DNP ANALOG INPUT POINTS section in Appendix E for details.

5.2.5 REAL TIME CLOCK

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ REAL TIME CLOCK

■ REAL TIME ■ CLOCK	◀▶	IRIG-B SIGNAL TYPE: None	Range: None, DC Shift, Amplitude Modulated

The date and time for the relay clock can be synchronized to other relays using an IRIG-B signal. It has the same accuracy as an electronic watch, approximately ±1 minute per month.

An IRIG-B signal may be connected to the relay to synchronize the clock to a known time base and to other relays. If an IRIG-B signal is used, only the current year needs to be entered.

See also the **COMMANDS ⇩ SET DATE AND TIME** menu for manually setting the relay clock.

5.2.6 FAULT REPORT

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT

■ FAULT REPORT ■	◀▶	FAULT REPORT SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	▲	FAULT REPORT TRIG: Off	Range: FlexLogic™ operand

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data will include:

- Name of the relay, programmed by the user
- Date and time of trigger
- Name of trigger (specific operand)
- Active setting group
- Pre-fault current and voltage phasors (one-quarter cycle before the trigger)
- Fault current and voltage phasors (three-quarter cycle after the trigger)
- Target Messages that are set at the time of triggering
- Events (9 before trigger and 7 after trigger)

The captured data also includes the fault type and the distance to the fault location, as well as the reclose shot number.

The trigger can be any FlexLogic™ operand, but in most applications it is expected to be the same operand, usually a virtual output, that is used to drive an output relay to trip a breaker. To prevent the over-writing of fault events, the disturbance detector should not be used to trigger a fault report.

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. As the fault report must capture a usable amount of pre and post-fault data, it can not be triggered faster than every 20 ms.

Each fault report is stored as a file; the relay capacity is ten files. An eleventh trigger overwrites the oldest file. The operand selected as the fault report trigger automatically triggers an oscillography record which can also be triggered independently.

URPC is required to view all captured data. The relay faceplate display can be used to view the date and time of trigger, the fault type, the distance location of the fault, and the reclose shot number

The **FAULT REPORT SOURCE** setting selects the Source for input currents and voltages and disturbance detection. The **FAULT REPORT TRIG** setting assigns the FlexLogic™ operand representing the protection element/elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal.

See also **SETTINGS ⇩ SYSTEM SETUP ⇨⇩ LINE** menu for specifying line characteristics and the **ACTUAL VALUES ⇩ RECORDS ⇨ FAULT REPORTS** menu.

5.2.7 OSCILLOGRAPHY

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ OSCILLOGRAPHY

■ OSCILLOGRAPHY ■	
NUMBER OF RECORDS: 15	Range: 1 to 64 in steps of 1
TRIGGER MODE: Automatic Overwrite	Range: Automatic Overwrite, Protected
TRIGGER POSITION: 50%	Range: 0 to 100 in steps of 1
TRIGGER SOURCE: Off	Range: FlexLogic™ operand
AC INPUT WAVEFORMS: 16 samples/cycle	Range: Off; 8, 16, 32, 64 samples/cycle
■ DIGITAL CHANNELS ■	Range: 2 to 63 channels
DIGITAL CHANNEL 2: Off	Range: FlexLogic™ operand
↓	
DIGITAL CHANNEL 63: Off	Range: FlexLogic™ operand
■ ANALOG CHANNELS ■	Range: 1 to 16 channels
ANALOG CHANNEL 1: Off	Range: Off, any analog Actual Value parameter
↓	
ANALOG CHANNEL 16: Off	Range: Off, any analog Actual Value parameter

Oscillography records contain waveforms captured at the sampling rate as well as other relay data at the point of trigger. Oscillography records are triggered by a programmable FlexLogic™ operand. Multiple oscillography records may be captured simultaneously.

The **NUMBER OF RECORDS** is selectable, but the number of cycles captured in a single record varies considerably based on other factors such as sample rate and the number of operational CT/VT modules. There is a fixed amount of data storage for oscillography; the more data captured, the less the number of cycles captured per record. See the **ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY** menu to view the number of cycles captured per record. The following table provides sample configurations with corresponding cycles/record.

Table 5–1: OSCILLOGRAPHY CYCLES/RECORD EXAMPLE

# RECORDS	# CT/VTS	SAMPLE RATE	# DIGITALS	# ANALOGS	CYCLES/ RECORD
1	1	8	0	0	1872.0
1	1	16	16	0	1685.0
8	1	16	16	0	266.0
8	1	16	16	4	219.5
8	2	16	16	4	93.5
8	2	16	64	16	93.5
8	2	32	64	16	57.6
8	2	64	64	16	32.3
32	2	64	64	16	9.5

A new record may automatically overwrite an older record if **TRIGGER MODE** is set to "Automatic Overwrite".

The **TRIGGER POSITION** is programmable as a percent of the total buffer size (e.g. 10%, 50%, 75%, etc.). A trigger position of 25% consists of 25% pre- and 75% post-trigger data.

The **TRIGGER SOURCE** is always captured in oscillography and may be any FlexLogic™ parameter (element state, contact input, virtual output, etc.). The relay sampling rate is 64 samples per cycle.

The **AC INPUT WAVEFORMS** setting determines the sampling rate at which AC input signals (i.e. current and voltage) are stored. Reducing the sampling rate allows longer records to be stored. This setting has no effect on the internal sampling rate of the relay which is always 64 samples per cycle, i.e. it has no effect on the fundamental calculations of the device.

An **ANALOG CHANNEL** setting selects the metering actual value recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to 'Off' are ignored. The parameters available in a given relay are dependent on: (a) the type of relay, (b) the type and number of CT/VT hardware modules installed, and (c) the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. Tables of all possible analog metering actual value parameters are presented in Appendix A: FLEXANALOG PARAMETERS. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display - entering this number via the relay keypad will cause the corresponding parameter to be displayed.

All eight CT/VT module channels are stored in the oscillography file. The CT/VT module channels are named as follows:

<slot_letter><terminal_number>—<I or *V><phase A*, *B*, or *C*, or *4th input>*

The fourth current input in a bank is called IG, and the fourth voltage input in a bank is called VX. For example, F2-IB designates the IB signal on terminal 2 of the CT/VT module in slot F. If there are no CT/VT modules and Analog Input modules, no analog traces will appear in the file; only the digital traces will appear.

WARNING **When the NUMBER OF RECORDS setting is altered, all oscillography records will be CLEARED.**

5.2.8 DATA LOGGER

PATH: SETTINGS ⇨⇩ PRODUCT SETUP ⇨⇩ DATA LOGGER

■ DATA LOGGER ■		DATA LOGGER RATE: 1 min	*Range: 1 sec; 1 min, 5 min, 10 min, 15 min, 20 min, 30 min, 60 min*
MESSAGE		DATA LOGGER CHNL 1: Off	*Range: Off, any analog Actual Value parameter*
MESSAGE		DATA LOGGER CHNL 2: Off	*Range: Off, any analog Actual Value parameter*
		↓	
MESSAGE		DATA LOGGER CHNL 16: Off	*Range: Off, any analog Actual Value parameter*
MESSAGE		DATA LOGGER CONFIG: 0 CHNL x 0.0 DAYS	*Range: Not applicable - shows computed data only*

The data logger samples and records up to 16 analog parameters at a user-defined sampling rate. This recorded data may be downloaded to the URPC 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 the information is retained when power to the relay is lost.

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 between the channels in use.

5

NOTE **Changing any setting affecting Data Logger operation will clear any data that is currently in the log.**

DATA LOGGER RATE:

This setting selects the time interval at which the actual value data will be recorded.

DATA LOGGER CHNL 1 (to 16):

This setting selects the metering actual value that is to be recorded in Channel 1(16) of the data log. The parameters available in a given relay are dependent on: the type of relay, the type and number of CT/VT hardware modules installed, and the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. Tables of all possible analog metering actual value parameters are presented in Appendix A: FLEXANALOG PARAMETERS. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display – entering this number via the relay keypad will cause the corresponding parameter to be displayed.

DATA LOGGER CONFIG:

This display presents the total amount of time the Data Logger can record the channels not selected to "Off" without overwriting old data.

5.2.9 USER-PROGRAMMABLE LEDS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-PROGRAMMABLE LEDS

```
■ USER-PROGRAMMABLE
■ LEDS

    ■ TRIP & ALARM
    ■ LEDS

        TRIP LED INPUT:          Range: FlexLogic™ operand
        OFF

        ALARM LED INPUT:         Range: FlexLogic™ operand
        OFF

    ■ USER-PROGRAMMABLE
    ■ LED 1

        LED 1 OPERAND:           Range: FlexLogic™ operand
        Off

        LED 1 TYPE:              Range: Self-Reset, Latched
        Self-Reset

    ■ USER-PROGRAMMABLE
    ■ LED 2
            ↓
    ■ USER-PROGRAMMABLE
    ■ LED 48
```

The TRIP and ALARM LEDs are on LED panel 1. Each indicator can be programmed to become illuminated when the selected FlexLogic™ operand is in the logic 1 state. There are 48 amber LEDs across the relay faceplate LED panels. Each of these indicators can be programmed to illuminate when the selected FlexLogic™ operand is in the logic 1 state.

- LEDs 1 through 24 inclusive are on LED panel 2; LEDs 25 through 48 inclusive are on LED panel 3.

Refer to the LED INDICATORS section in the HUMAN INTERFACES chapter for the locations of these indexed LEDs. This menu selects the operands to control these LEDs. Support for applying user-customized labels to these LEDs is provided. If the **LED X TYPE** setting is "Self-Reset" (default setting), the LED illumination will track the state of the selected LED operand. If the **LED X TYPE** setting is ‘Latched’, the LED, once lit, remains so until reset by the faceplate RESET button, from a remote device via a communications channel, or from any programmed operand, even if the LED operand state de-asserts.

Table 5–3: RECOMMENDED SETTINGS FOR LED PANEL 2 LABELS)

SETTING	PARAMETER	SETTING	PARAMETER
LED 1 Operand	SETTING GROUP ACT 1	LED 13 Operand	Off
LED 2 Operand	SETTING GROUP ACT 2	LED 14 Operand	BREAKER 2 OPEN
LED 3 Operand	SETTING GROUP ACT 3	LED 15 Operand	BREAKER 2 CLOSED
LED 4 Operand	SETTING GROUP ACT 4	LED 16 Operand	BREAKER 2 TROUBLE
LED 5 Operand	SETTING GROUP ACT 5	LED 17 Operand	SYNC 1 SYNC OP
LED 6 Operand	SETTING GROUP ACT 6	LED 18 Operand	SYNC 2 SYNC OP
LED 7 Operand	SETTING GROUP ACT 7	LED 19 Operand	Off
LED 8 Operand	SETTING GROUP ACT 8	LED 20 Operand	Off
LED 9 Operand	BREAKER 1 OPEN	LED 21 Operand	AR ENABLED
LED 10 Operand	BREAKER 1 CLOSED	LED 22 Operand	AR DISABLED
LED 11 Operand	BREAKER 1 TROUBLE	LED 23 Operand	AR RIP
LED 12 Operand	Off	LED 24 Operand	AR LO

Refer to the CONTROL OF SETTINGS GROUPS example in the CONTROL ELEMENTS section for group activation.

5.2.10 FLEX STATE PARAMETERS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FLEX STATE PARAMETERS

■ FLEX STATE ■ PARAMETERS		PARAMETER 1: Off	Range: FlexLogic™ Operand
MESSAGE		PARAMETER 2: Off	Range: FlexLogic™ Operand
		↓ ↓	
MESSAGE		PARAMETER 256: Off	Range: FlexLogic™ Operand

This 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 relay. The state bits are packed so that 16 states may be read out in a single Modbus register. The state bits can be configured so that all of the states which are of interest to the user are available in a minimum number of Modbus registers.

The state bits may be read out in the "Flex States" register array beginning at Modbus address 900 hex. 16 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.

5.2.11 USER-DEFINABLE DISPLAYS

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ USER-DEFINABLE DISPLAYS

■ USER-DEFINABLE ■ DISPLAYS				
		■ USER DISPLAY 1 ■		
MESSAGE		DISP 1 TOP LINE:		Range: up to 20 alphanumeric characters
MESSAGE		DISP 1 BOTTOM LINE:		Range: up to 20 alphanumeric characters
MESSAGE		DISP 1 ITEM 1 0		Range: 0 to 65535 in steps of 1
MESSAGE		DISP 1 ITEM 2 0		Range: 0 to 65535 in steps of 1
MESSAGE		DISP 1 ITEM 3 0		Range: 0 to 65535 in steps of 1
MESSAGE		DISP 1 ITEM 4 0		Range: 0 to 65535 in steps of 1
MESSAGE		DISP 1 ITEM 5: 0		Range: 0 to 65535 in steps of 1
		■ USER DISPLAY 2 ■		
		↓		
		■ USER DISPLAY 8 ■		

This menu provides a mechanism for manually creating up to 8 user-defined information displays in a convenient viewing sequence in the USER DISPLAYS menu (between the TARGETS and ACTUAL VALUES top-level menus). The sub-menus facilitate text entry and Modbus Register data pointer options for defining the User Display content.

Also, any existing system display can be automatically copied into an available User Display by selecting the existing display and pressing the ENTER key. The display will then prompt "ADD TO USER DISPLAY LIST?". After selecting 'Yes', a message will indicate that the selected display has been added to the user display list. When this type of entry occurs, the sub-menus are automatically configured with the proper content - this content may subsequently be edited.

This menu is used **to enter** user-defined text and/or user-selected Modbus-registered data fields into the particular User Display. Each User Display consists of two 20-character lines (TOP & BOTTOM). The Tilde (~) character is used to mark the start of a data field - the length of the data field needs to be accounted for. Up to 5 separate data fields (ITEM 1...5) can be entered in a User Display - the nth Tilde (~) refers to the nth ITEM.

A User Display may be entered from the faceplate keypad or the URPC interface (preferred for convenience).

To enter text characters in the TOP LINE and BOTTOM LINE from the faceplate keypad:

1. Select the line to be edited.
2. Press the [.] key to enter text edit mode.
3. Use either VALUE key to scroll through the characters. A space is selected like a character.
4. Press the [.] key to advance the cursor to the next position.
5. Repeat step 3 and continue entering characters until the desired text is displayed.
6. The HELP key may be pressed at any time for context sensitive help information.
7. Press the ENTER key to store the new settings.

To enter a numerical value for any of the 5 ITEMs (the *decimal form* of the selected Modbus Register Address) from the faceplate keypad, use the number keypad. Use the value of '0' for any ITEMs not being used. Use the HELP key at any selected system display (Setting, Actual Value, or Command) which has a Modbus address, to view the *hexadecimal form* of the Modbus Register Address, then manually convert it to decimal form before entering it (URPC usage would conveniently facilitate this conversion).

Use the MENU key to go to the USER DISPLAYS menu **to view** the user-defined content. The current user displays will show in sequence, changing every 4 seconds. While viewing a User Display, press the ENTER key and then select the 'Yes' option **to remove** the display from the user display list. Use the MENU key again **to exit** the USER DISPLAYS menu.

EXAMPLE USER DISPLAY SETUP AND RESULT:

■ USER DISPLAY 1 ■	◀▶	DISP 1 TOP LINE: Current X ~ A	Shows user-defined text with first Tilde marker.
MESSAGE	▲▼	DISP 1 BOTTOM LINE: Current Y ~ A	Shows user-defined text with second Tilde marker.
MESSAGE	▲▼	DISP 1 ITEM 1: 6016	Shows decimal form of user-selected Modbus Register Address, corresponding to first Tilde marker.
MESSAGE	▲▼	DISP 1 ITEM 2: 6357	Shows decimal form of user-selected Modbus Register Address, corresponding to 2nd Tilde marker.
MESSAGE	▲▼	DISP 1 ITEM 3: 0	This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.
MESSAGE	▲▼	DISP 1 ITEM 4: 0	This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.
MESSAGE	▲	DISP 1 ITEM 5: 0	This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.
USER DISPLAYS	→	Current X 0.850 A Current Y 0.327 A	Shows the resultant display content.

5.2.12 INSTALLATION

PATH: SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION

■ INSTALLATION ■	◁▷	RELAY SETTINGS: Not Programmed	Range: Not Programmed, Programmed
MESSAGE	△	RELAY NAME: Relay-1	Range: up to 20 alphanumeric characters

To safeguard against the installation of a relay whose settings have not been entered, the unit will not allow signaling of any output relay until **RELAY SETTINGS** is set to "Programmed". This setting is defaulted to "Not Programmed" when the relay leaves the factory. The UNIT NOT PROGRAMMED self-test error message is displayed automatically until the relay is put into the Programmed state.

The **RELAY NAME** setting allows the user to uniquely identify a relay. This name will appear on generated reports. This name is also used to identify specific devices which are engaged in automatically sending/receiving data over the Ethernet communications channel using the UCA2/MMS protocol.

5.3.1 AC INPUTS

a) CURRENT BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨ CURRENT BANK X1

■ CURRENT BANK X1 ■	◁▷	PHASE CT X1 PRIMARY: 1 A	*Range: 1 to 65000 A in steps of 1*
MESSAGE	△▽	PHASE CT X1 SECONDARY: 1 A	*Range: 1 A, 5 A*
MESSAGE	△▽	GROUND CT X1 PRIMARY: 1 A	*Range: 1 to 65000 A in steps of 1*
MESSAGE	△	GROUND CT X1 SECONDARY: 1 A	*Range: 1 A, 5 A*

'X' = F, M, or U. 'F', 'M', and 'U' are module slot position letters. See also the section INTRODUCTION TO AC SOURCES.

Up to 6 banks of phase/ground CTs can be set.

These settings are critical for all features that have settings dependent on current measurements. When the relay is ordered, the CT module must be specified to include a standard or sensitive ground input. As the phase CTs are connected in Wye (star), the calculated phasor sum of the three phase currents (IA + IB + IC = Neutral Current = 3Io) is used as the input for the neutral overcurrent elements. In addition, a zero sequence (core balance) CT which senses current in all of the circuit primary conductors, or a CT in a neutral grounding conductor may also be used. For this configuration, the ground CT primary rating must be entered. To detect low level ground fault currents, the sensitive ground input may be used. In this case, the sensitive ground CT primary rating must be entered. For more details on CT connections, refer to the HARDWARE chapter.

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Enter the rated CT primary current values. For both 1000:5 and 1000:1 CTs, the entry would be 1000. For correct operation, the CT secondary rating must match the setting (which must also correspond to the specific CT connections used).

If CT inputs (banks of current) are to be summed as one source current, the following rule applies:

EXAMPLE:

SRC1 = F1 + F5 + U1

Where *F1*, *F5*, and *U1* are banks of CTs with ratios of 500:1, 1000:1 and 800:1 respectively.

1 pu is the highest primary current. In this case, 1000 is entered and the secondary current from the 500:1 and 800:1 ratio CTs will be adjusted to that which would be created by a 1000:1 CT before summation. If a protection element is set up to act on SRC1 currents, then PKP level of 1 pu will operate on 1000 A primary.

The same rule will apply for sums of currents from CTs with different secondary taps (5 A and 1 A).

b) VOLTAGE BANKS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK X1

■ VOLTAGE BANK X5 ■	◀▶	PHASE VT X5 CONNECTION: Wye	Range: Wye, Delta
MESSAGE	▲▼	PHASE VT X5 SECONDARY: 66.4 V	Range: 50.0 to 240.0 V in steps of 0.1
MESSAGE	▲▼	PHASE VT X5 RATIO: 1.00 :1	Range: 1.00 to 24000.00 in steps of 1.00
MESSAGE	▲▼	AUXILIARY VT X5 CONNECTION: Vag	Range: Vn, Vag, Vbg, Vcg, Vab, Vbc, Vca
MESSAGE	▲▼	AUXILIARY VT X5 SECONDARY: 66.4 V	Range: 50.0 to 240.0 V in steps of 0.1
MESSAGE	▲	AUXILIARY VT X5 RATIO: 1.00 :1	Range: 1.00 to 24000.00 in steps of 1.00

'X' = F, M, or U. 'F', 'M', and 'U' are module slot position letters. See also the INTRODUCTION TO AC SOURCES section.

Up to 3 banks of phase/auxiliary VTs can be set.

With VTs installed, the relay can be used to perform voltage measurements as well as power calculations. Enter the **PHASE VT xx CONNECTION** made to the system as "Wye" or "Delta". An open-delta source VT connection would be entered as "Delta". See the typical wiring diagram in the HARDWARE chapter for details.

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NOTE

The nominal Phase VT Secondary Voltage setting is the voltage across 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 Volt VT in a Delta connection, the secondary voltage would be 115, i.e. (13800 / 14400) × 120. For a Wye connection, the voltage value entered must be the phase to neutral voltage which would be $115 / \sqrt{3} = 66.4$.

On a 14.4 kV system with a Delta connection and a VT primary to secondary turns ratio of 14400:120, the voltage value entered would be 120, i.e. 14400 / 120.

5.3.2 POWER SYSTEM

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM

■ POWER SYSTEM ■	◀▶	NOMINAL FREQUENCY: 60 Hz	Range: 25 to 60 Hz in steps of 1
MESSAGE	▲▼	PHASE ROTATION: ABC	Range: ABC, ACB
MESSAGE	▲▼	FREQUENCY AND PHASE REFERENCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	▲	FREQUENCY TRACKING: Enabled	Range: Disabled, Enabled

The power system **NOMINAL FREQUENCY** value is used as a default to set the digital sampling rate if the system frequency cannot be measured from available signals. This may 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.

The phase sequence of the power system is required to properly calculate sequence components and power parameters. The **PHASE ROTATION** setting matches the power system phase sequence. Note that this setting informs the relay of the actual system phase sequence, either ABC or ACB. CT and VT inputs on the relay, labeled as A, B, and C, must be connected to system phases A, B, and C for correct operation.

The **FREQUENCY AND PHASE REFERENCE** 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 that are 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 Clarke transformation of the phase signals is used for frequency metering and tracking ($V_{\text{FREQUENCY}} = (2V_A - V_B - V_C)/3$) 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.

Phase angle of the reference signal will always display zero degrees and all other phase angles will be 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 relays if they have the same AC signal reference. These results in very precise correlation of time tagging in the event recorder between different UR relays provided the relays have an IRIG-B connection.

NOTE

FREQUENCY TRACKING should only be set to "Disabled" in very unusual circumstances; consult the factory for special variable-frequency applications.

5.3.3 SIGNAL SOURCES

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES ⇨ SOURCE 1(6)

■ SOURCE 1 ■		SOURCE 1 NAME: SRC 1	*Range: up to 6 alphanumeric characters*
	MESSAGE	SOURCE 1 PHASE CT: None	*Range: None, F1, F5, F1+F5,..., F1+F5+M1+M5+U1+U5* *Only phase current inputs will be displayed.*
	MESSAGE	SOURCE 1 GROUND CT: None	*Range: None, F1, F5, F1+F5,..., F1+F5+M1+M5+U1+U5* *Only ground current inputs will be displayed.*
	MESSAGE	SOURCE 1 PHASE VT: None	*Range: None, F1, F5, M1, M5, U1, U5* *Only phase voltage inputs will be displayed.*
	MESSAGE	SOURCE 1 AUX VT: None	*Range: None, F1, F5, M1, M5, U1, U5* *Only auxiliary voltage inputs will be displayed.*

There are up to 6 identical Source setting menus available, numbered from 1 to 6.

"SRC 1" can be replaced by whatever name is defined by the user for the associated source.

'F', 'U', and 'M' are module slot position letters. The number following the letter represents either the first bank of four channels (1, 2, 3, 4) called '1' or the second bank of four channels (5, 6, 7, 8) called '5' in a particular CT/VT module. Refer to the INTRODUCTION TO AC SOURCES section at the beginning of this chapter for additional details.

It is possible to select the sum of any combination of CTs. The first channel displayed is the CT to which all others will be referred. For example, the selection "F1+F5" indicates the sum of each phase from channels "F1" and "F5", scaled to whichever CT has the higher ratio. Selecting "None" hides the associated actual values.

The approach used to configure the AC Sources consists of several steps; first step is to specify the information about each CT and VT input. For CT inputs, this is the nominal primary and secondary current. For VTs, this is the connection type, ratio and nominal secondary voltage. Once the inputs have been specified, the configuration for each Source is entered, including specifying which CTs will be summed together.

USER SELECTION OF AC PARAMETERS FOR COMPARATOR ELEMENTS:

CT/VT modules automatically calculate all current and voltage parameters that can be calculated from the inputs available. Users will have to select the specific input parameters that are to be measured by every element, as selected in the element settings. The internal design of the element specifies which type of parameter to use and provides a setting for selection of the Source. In some elements where the parameter may be either fundamental or RMS magnitude, such as phase time overcurrent, two settings are provided. One setting specifies the Source, the second selects between fundamental phasor and RMS.

AC INPUT ACTUAL VALUES:

The calculated parameters associated with the configured voltage and current inputs are displayed in the current and voltage input sections of Actual Values. Only the phasor quantities associated with the actual AC physical input channels will be displayed here. All parameters contained within a configured Source are displayed in the Sources section of Actual Values.

DISTURBANCE DETECTORS (Internal):

The 50DD element is a sensitive current disturbance detector that is used to detect any disturbance on the protected system. 50DD 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 every Source.

The 50DD function responds to the changes in magnitude of the sequence currents.

The disturbance detector scheme logic is as follows:

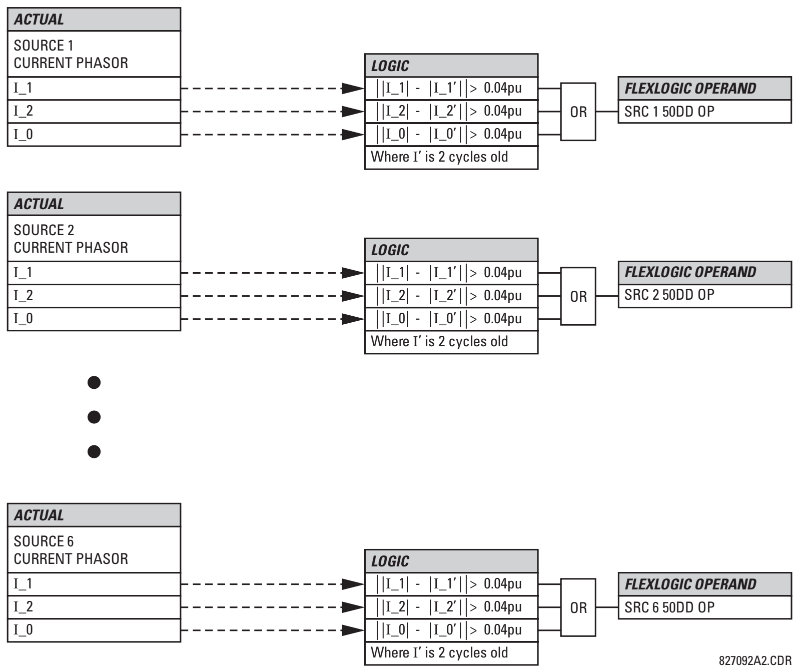

Figure 5–2: DISTURBANCE DETECTOR LOGIC DIAGRAM

EXAMPLE USE OF SOURCES:

An example of the use of Sources, with a relay with three CT/VT modules, is shown in the diagram below. A relay could have the following hardware configuration:

INCREASING SLOT POSITION LETTER -->		
CT/VT MODULE 1	**CT/VT MODULE 2**	**CT/VT MODULE 3**
CTs	CTs	VTs
CTs	VTs	---

This configuration could be used on a two winding transformer, with one winding connected into a breaker-and-a-half system. The following figure shows the arrangement of Sources used to provide the functions required in this application, and the CT/VT inputs that are used to provide the data.

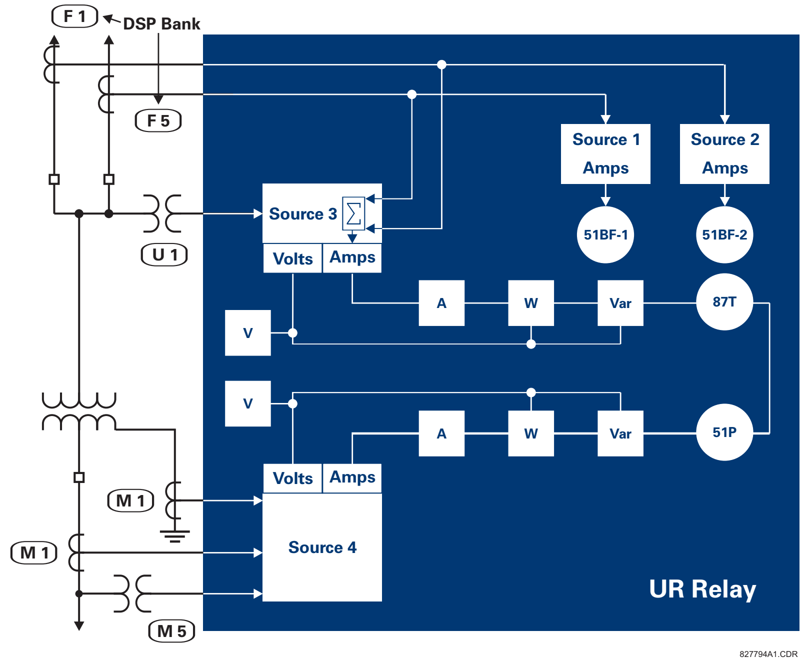

Figure 5–3: EXAMPLE USE OF SOURCES

5.3.4 LINE

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ LINE

■ LINE ■		POS SEQ IMPEDANCE MAGNITUDE: 3.00 Ω	*Range: 0.01 to 250.00 Ω in steps of 0.01*
MESSAGE		POS SEQ IMPEDANCE ANGLE: 75°	*Range: 25 to 90° in steps of 1*
MESSAGE		ZERO SEQ IMPEDANCE MAGNITUDE: 9.00 Ω	*Range: 0.01 to 650.00 Ω in steps of 0.01*
MESSAGE		ZERO SEQ IMPEDANCE ANGLE: 75°	*Range: 25 to 90° in steps of 1°*
MESSAGE		LINE LENGTH UNITS: km	*Range: km, miles*
MESSAGE		LINE LENGTH (km): 100.0	*Range: 0.0 to 2000.0 in steps of 0.1*

These settings specify the characteristics of the line. The line impedance value should be entered as secondary ohms.

This data is used for fault location calculations. See the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT** menu for assigning the Source and Trigger for fault calculations.

5.3.5 BREAKERS

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ BREAKERS ⇨ BREAKER 1(2)

Menu		Setting	Range
■ BREAKER 1 ■		BREAKER 1 FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	BREAKER1 PUSH BUTTON CONTROL: Disabled	Range: Disabled, Enabled
	MESSAGE	BREAKER 1 NAME: Bkr 1	Range: up to 6 alphanumeric characters
	MESSAGE	BREAKER 1 MODE: 3-Pole	Range: 3-Pole, 1-Pole
	MESSAGE	BREAKER 1 OPEN: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 CLOSE: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 ϕA/3-POLE: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 ϕB: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 ϕC: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 EXT ALARM: Off	Range: FlexLogic™ operand
	MESSAGE	BREAKER 1 ALARM DELAY: 0.000 s	Range: 0.000 to 1 000 000.000 s in steps of 0.001
	MESSAGE	BREAKER 1 OUT OF SV: Off	Range: FlexLogic™ operand
	MESSAGE	MANUAL CLOSE RECAL1 TIME: 0.000 s	Range: 0.000 to 1 000 000.000 s in steps of 0.001
■ BREAKER 2 ■		As for Breaker 1 above	
■ UCA SBO TIMER ■		UCA SBO TIMEOUT: 30 s	Range: 1 to 60 s in steps of 1

A description of the operation of the breaker control and status monitoring features is provided in the HUMAN INTERFACES chapter. Only information concerning programming of the associated settings is covered here. These features are provided for two breakers; a user may use only those portions of the design relevant to a single breaker, which must be breaker No. 1.

BREAKER 1 FUNCTION:

Set to "Enable" to allow the operation of any breaker control feature.

BREAKER1 PUSH BUTTON CONTROL:

Set to "Enable" to allow faceplate push button operations.

BREAKER 1 NAME:

Assign a user-defined name (up to 6 characters) to the breaker. This name will be used in flash messages related to Breaker No. 1.

BREAKER 1 MODE:

Selects "3-pole" mode, where all breaker poles are operated simultaneously, or "1-pole" mode where all breaker poles are operated either independently or simultaneously.

BREAKER 1 OPEN:

Selects an operand that creates a programmable signal to operate an output relay to open Breaker No. 1.

BREAKER 1 CLOSE:

Selects an operand that creates a programmable signal to operate an output relay to close Breaker No. 1.

BREAKER 1 ΦA/3-POLE:

Selects an operand, usually a contact input connected to a breaker auxiliary position tracking mechanism. This input can be either a 52/a or 52/b contact, or a combination the 52/a and 52/b contacts, that must be programmed to create a logic 0 when the breaker is open. If **BREAKER 1 MODE** is selected as "3-Pole", this setting selects a single input as the operand used to track the breaker open or closed position. If the mode is selected as "1-Pole", the input mentioned above is used to track phase A and settings **BREAKER 1 ΦB** and **BREAKER 1 ΦC** select operands to track phases B and C, respectively.

BREAKER 1 ΦB:

If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase B as above for phase A.

BREAKER 1 ΦC:

If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase C as above for phase A.

BREAKER 1 EXT ALARM:

Selects an operand, usually an external contact input, connected to a breaker alarm reporting contact.

BREAKER 1 ALARM DELAY:

Sets the delay interval during which a disagreement of status among the three pole position tracking operands will not declare a pole disagreement, to allow for non-simultaneous operation of the poles. If single-pole tripping and reclosing is used, the breaker may trip unsymmetrically for faults. In this case, the minimum alarm delay setting must exceed the maximum time required for fault clearing and reclosing by a suitable margin.

BREAKER 1 OUT OF SV:

Selects an operand indicating that Breaker No. 1 is out-of-service.

MANUAL CLOSE RECAL1 TIME:

Sets the interval required to maintain setting changes in effect after an operator has initiated a manual close command to operate a circuit breaker.

UCA SBO TIMEOUT:

The Select-Before-Operate timer specifies an interval from the receipt of the Breaker Control Select signal (pushbutton USER 1 on the relay faceplate) until the automatic de-selection of the breaker, so that the breaker does not remain selected indefinitely. This setting is active only if **BREAKER PUSHBUTTON CONTROL** is "Enabled".

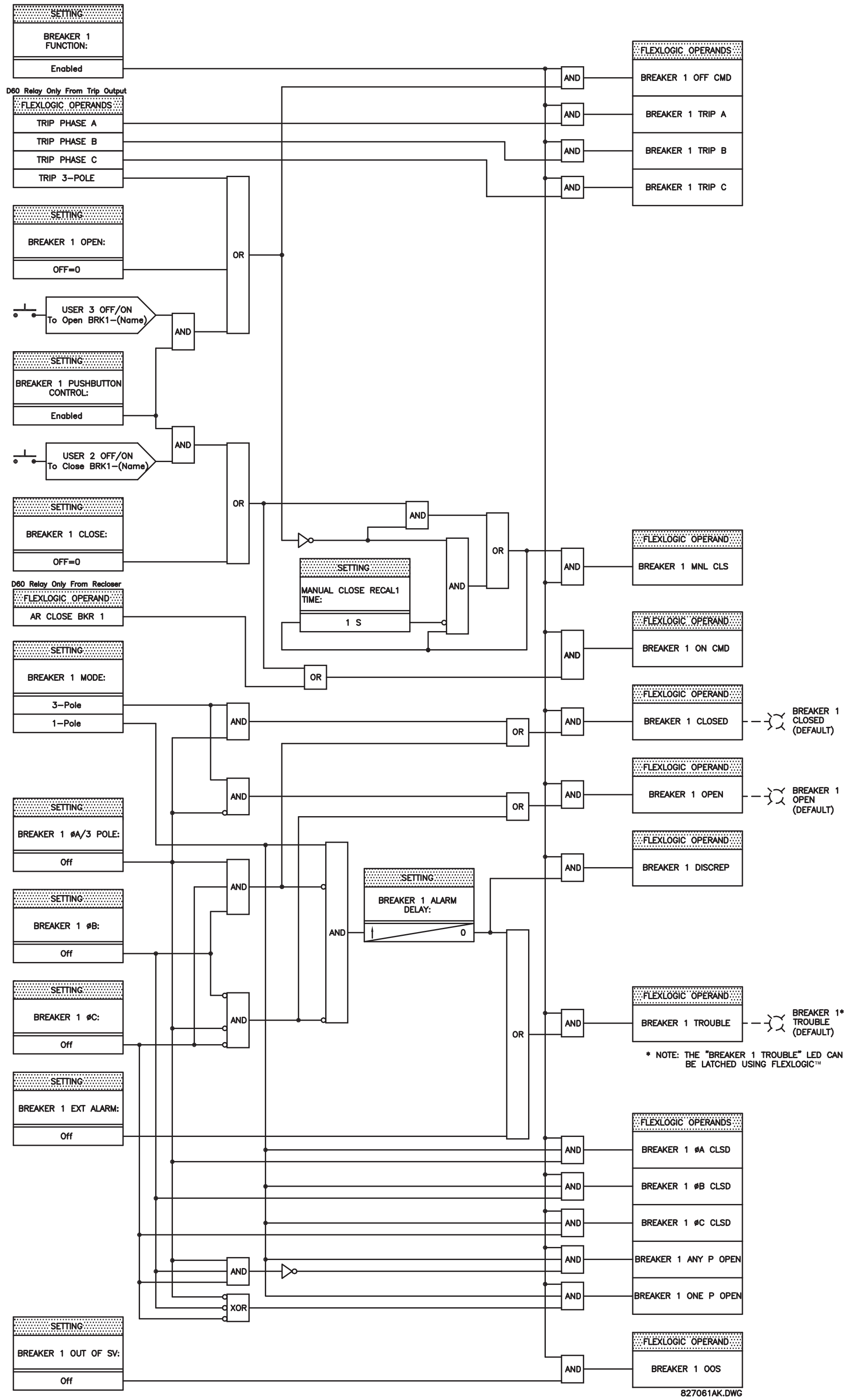

Figure 5–4: DUAL BREAKER CONTROL SCHEME LOGIC

5.3.6 FLEXCURVES™

PATH: SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ FLEXCURVES ⇨ FLEXCURVE A

```
■ FLEXCURVE A        ◁▷   FLEXCURVE A TIME AT
■                         0.00 xPKP:       0 ms
```

Range: 0 to 65535 ms in steps of 1

FlexCurves™ A and B have settings for entering times to Reset/Operate at the following pickup levels: 0.00 to 0.98 / 1.03 to 20.00. This data is converted into 2 continuous curves by linear interpolation between data points. To enter a custom FlexCurve™, enter the Reset/Operate time (using the ▲ VALUE ▼ keys) for each selected pickup point (using the ▲ MESSAGE ▼ keys) for the desired protection curve (A or B).

Table 5–9: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS
0.00		0.68	
0.05		0.70	
0.10		0.72	
0.15		0.74	
0.20		0.76	
0.25		0.78	
0.30		0.80	
0.35		0.82	
0.40		0.84	
0.45		0.86	
0.48		0.88	
0.50		0.90	
0.52		0.91	
0.54		0.92	
0.56		0.93	
0.58		0.94	
0.60		0.95	
0.62		0.96	
0.64		0.97	
0.66		0.98	

OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
1.03		2.9		4.9		10.5	
1.05		3.0		5.0		11.0	
1.1		3.1		5.1		11.5	
1.2		3.2		5.2		12.0	
1.3		3.3		5.3		12.5	
1.4		3.4		5.4		13.0	
1.5		3.5		5.5		13.5	
1.6		3.6		5.6		14.0	
1.7		3.7		5.7		14.5	
1.8		3.8		5.8		15.0	
1.9		3.9		5.9		15.5	
2.0		4.0		6.0		16.0	
2.1		4.1		6.5		16.5	
2.2		4.2		7.0		17.0	
2.3		4.3		7.5		17.5	
2.4		4.4		8.0		18.0	
2.5		4.5		8.5		18.5	
2.6		4.6		9.0		19.0	
2.7		4.7		9.5		19.5	
2.8		4.8		10.0		20.0	

NOTE

The relay using a given FlexCurve™ applies linear approximation for times between the user-entered points. Special care must be applied when setting the two points that are close to the multiple of pickup of 1, i.e. 0.98 pu and 1.03 pu. It is recommended to set the two times to a similar value; otherwise, the linear approximation may result in undesired behavior for the operating quantity the is close to 1.00 pu.

5.4.1 INTRODUCTION TO FLEXLOGIC™

To provide maximum flexibility to the user, the arrangement of internal digital logic combines fixed and user-programmed parameters. 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 which it uses to produce analog and digital outputs. The major sub-systems of a generic UR relay involved in this process are shown below.

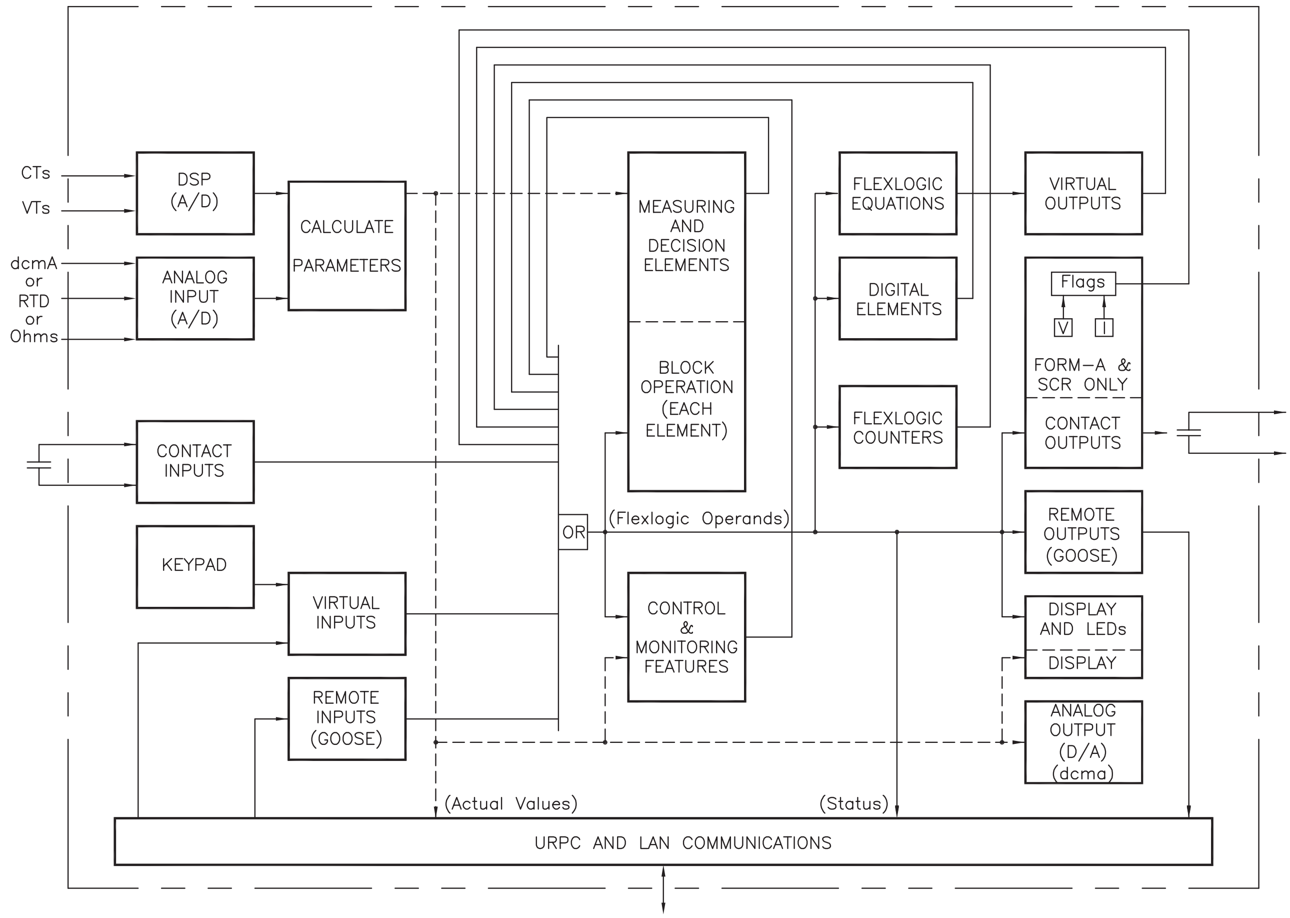

Figure 5–5: UR ARCHITECTURE OVERVIEW

The states of all digital signals used in the UR are represented by flags (or FlexLogic™ operands, which are described later in this section). A digital "1" 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 than presented above is required, it is implemented via FlexLogic™. For example, if it is desired 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 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 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 1 (= ON, i.e. flag set) or 0 (= OFF, i.e. flag not set). Each equation is evaluated at least 4 times every power system cycle.

Some types of operands are present in the relay in multiple instances; e.g. 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 listed in the table: FLEXLOGIC™ OPERAND TYPES.

Table 5–10: UR FLEXLOGIC™ OPERAND TYPES

OPERAND TYPE	STATE	EXAMPLE FORMAT	CHARACTERISTICS [INPUT IS '1' (= ON) IF...]
Contact Input	On	Cont Ip On	Voltage is presently applied to the input (external contact closed).
	Off	Cont Ip Off	Voltage is presently not applied to the input (external contact open).
Contact Output (type Form-A contact only)	Voltage On	Cont Op 1 VOn	Voltage exists across the contact.
	Voltage Off	Cont Op 1 VOff	Voltage does not exists across the contact.
	Current On	Cont Op 1 IOn	Current is flowing through the contact.
	Current Off	Cont Op 1 IOff	Current is not flowing through the contact.
Element (Analog)	Pickup	PHASE TOC1 PKP	The tested parameter is presently above the pickup setting of an element which responds to rising values or below the pickup setting of an element which responds to falling values.
	Dropout	PHASE TOC1 DPO	This operand is the logical inverse of the above PKP 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	PH DIR1 BLK	The output of the comparator is set to the block function.
Element (Digital)	Pickup	Dig Element 1 PKP	The input operand is at logic 1.
	Dropout	Dig Element 1 DPO	This operand is the logical inverse of the above PKP operand.
	Operate	Dig Element 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.
Element (Digital Counter)	Higher 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.
	Lower than	Counter 1 LO	The number of pulses counted is below the set number.
Fixed	On	On	Logic 1
	Off	Off	Logic 0
Remote Input	On	REMOTE INPUT 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 set state (i.e. evaluation of the equation which produces this virtual output results in a "1").

The operands available for this relay are listed alphabetically by types in the following table.

Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 1 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Autoreclose (1P/3P)	AR ENABLED AR DISABLED AR RIP AR 1-P RIP AR 3-P/1 RIP AR 3-P/2 RIP AR LO AR BKR1 BLK AR BKR2 BLK AR CLOSE BKR1 AR CLOSE BKR2 AR FORCE 3-P TRIP AR SHOT CNT > 0 AR ZONE 1 EXTENT AR INCOMPLETE SEQ AR RESET	Autoreclosure is enabled and ready to perform Autoreclosure is disabled Autoreclosure is in "Reclose in Progress" state A single-pole reclosure is in progress A three-pole reclosure is in progress, via DEAD TIME 1 A three-pole reclosure is in progress, via DEAD TIME 2 Autoreclosure is in lockout state Reclosure of Breaker 1 is blocked Reclosure of Breaker 2 is blocked Reclose Breaker 1 signal Reclose Breaker 2 signal Force any trip to a three-phase trip The first "CLOSE BKR X" signal has been issued The Zone 1 Distance function must be set to the extended overreach value The incomplete sequence timer timed out AR has been reset either manually or by the reset timer
ELEMENT: Auxiliary OV	AUX OV1 PKP AUX OV1 DPO AUX OV1 OP	Auxiliary Overvoltage element has picked up Auxiliary Overvoltage element has dropped out Auxiliary Overvoltage element has operated
ELEMENT: Auxiliary UV	AUX UV1 PKP AUX UV1 DPO AUX UV1 OP	Auxiliary Undervoltage element has picked up Auxiliary Undervoltage element has dropped out Auxiliary Undervoltage element has operated
ELEMENT: Blocking Scheme	DIR BLOCK TX INIT DIR BLOCK TX1 STOP DIR BLOCK TX2 STOP DIR BLOCK TX3 STOP DIR BLOCK TX4 STOP DIR BLOCK TRIP A DIR BLOCK TRIP B DIR BLOCK TRIP C DIR BLOCK TRIP 3P DIR BLOCK OP	Directional blocking signal is initiated Directional blocking scheme de-asserts transmit bit no. 1 Directional blocking scheme de-asserts transmit bit no. 2 Directional blocking scheme de-asserts transmit bit no. 3 Directional blocking scheme de-asserts transmit bit no. 4 Directional blocking scheme has operated to trip phase A Directional blocking scheme has operated to trip phase B Directional blocking scheme has operated to trip phase C Directional blocking scheme has tripped all 3 phases Directional blocking scheme has operated
ELEMENT: Breaker Arcing	BKR ARC 1 OP BKR ARC 2 OP	Breaker Arcing 1 is operated Breaker Arcing 2 is operated
ELEMENT (Breaker Failure)	BKR FAIL 1 RETRIPA BKR FAIL 1 RETRIPB BKR FAIL 1 RETRIPC BKR FAIL 1 RETRIP BKR FAIL 1 T1 OP BKR FAIL 1 T2 OP BKR FAIL 1 T3 OP BKR FAIL 1 TRIP OP	Breaker Failure 1 re-trip phase A (only for 1-pole schemes) Breaker Failure 1 re-trip phase B (only for 1-pole schemes) Breaker Failure 1 re-trip phase C (only for 1-pole schemes) Breaker Failure 1 re-trip 3-phase Breaker Failure 1 Timer 1 is operated Breaker Failure 1 Timer 2 is operated Breaker Failure 1 Timer 3 is operated Breaker Failure 1 trip is operated
	BKR FAIL 2...	Same set of operands as shown for BKR FAIL 1
ELEMENT: Breaker Control	BREAKER 1 OFF CMD BREAKER 1 ON CMD BREAKER 1 ϕA CLSD BREAKER 1 ϕB CLSD BREAKER 1 ϕC CLSD BREAKER 1 CLOSED BREAKER 1 OPEN BREAKER 1 DISCREP BREAKER 1 TROUBLE BREAKER 1 MNL CLS BREAKER 1 TRIP A BREAKER 1 TRIP B BREAKER 1 TRIP C BREAKER 1 ANY P OPEN BREAKER 1 ONE P OPEN BREAKER 1 OOS	Breaker 1 OFF command Breaker 1 ON command Breaker 1 phase A is closed Breaker 1 phase B is closed Breaker 1 phase C is closed Breaker 1 is closed Breaker 1 is open Breaker 1 has discrepancy Breaker 1 trouble alarm Breaker 1 manual close Breaker 1 trip phase A command Breaker 1 trip phase B command Breaker 1 trip phase C command At least one pole of Breaker 1 is open Only one pole of Breaker 1 is open Breaker 1 is out of service
	BREAKER 2	Same set of operands as shown for BREAKER 1
ELEMENT: Digital Counter	Counter 1 HI Counter 1 EQL Counter 1 LO ↓ Counter 8 HI Counter 8 EQL Counter 8 LO	Digital Counter 1 output is 'more than' comparison value Digital Counter 1 output is 'equal to' comparison value Digital Counter 1 output is 'less than' comparison value ↓ Digital Counter 8 output is 'more than' comparison value Digital Counter 8 output is 'equal to' comparison value Digital Counter 8 output is 'less than' comparison value

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Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 2 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Digital Element	Dig Element 1 PKP Dig Element 1 OP Dig Element 1 DPO ↓ Dig Element 16 PKP Dig Element 16 OP Dig Element 16 DPO	Digital Element 1 is picked up Digital Element 1 is operated Digital Element 1 is dropped out ↓ Digital Element 16 is picked up Digital Element 16 is operated Digital Element 16 is dropped out
ELEMENT: Disturbance Detector	SRCx 50DD OP	Source x Disturbance Detector is operated
ELEMENT: DUTT	DUTT TX1 DUTT TX2 DUTT TX3 DUTT TX4 DUTT TRIP A DUTT TRIP B DUTT TRIP C DUTT TRIP 3P DUTT OP	Direct under-reaching transfer trip asserts transmit bit no. 1 Direct under-reaching transfer trip asserts transmit bit no. 2 Direct under-reaching transfer trip asserts transmit bit no. 3 Direct under-reaching transfer trip asserts transmit bit no. 4 Direct under-reaching transfer trip has operated to trip phase A Direct under-reaching transfer trip has operated to trip phase B Direct under-reaching transfer trip has operated to trip phase C Direct under-reaching transfer trip has operated to trip all three phases Direct under-reaching transfer trip has operated
ELEMENT: FlexElements™	FLEXELEMENT 1 PKP FLEXELEMENT 1 OP FLEXELEMENT 1 DPO ↓ FLEXELEMENT 8 PKP FLEXELEMENT 8 OP FLEXELEMENT 8 DPO	FlexElement 1 has picked up FlexElement 1 has operated FlexElement 1 has dropped out ↓ FlexElement 8 has picked up FlexElement 8 has operated FlexElement 8 has dropped out
ELEMENT: Ground Distance	GND DIST Zx PKP GND DIST Zx OP GND DIST Zx OP A GND DIST Zx OP B GND DIST Zx OP C GND DIST Zx PKP A GND DIST Zx PKP B GND DIST Zx PKP C GND DIST Zx SUPN IN GND DIST Zx DIR SUPN GND DIST Zx DPO A GND DIST Zx DPO B GND DIST Zx DPO C	Ground Distance Zone x has picked up Ground Distance Zone x has operated Ground Distance Zone x phase A has operated Ground Distance Zone x phase B has operated Ground Distance Zone x phase C has operated Ground Distance Zone x phase A has picked up Ground Distance Zone x phase B has picked up Ground Distance Zone x phase C has picked up Ground Distance Zone x neutral is supervising Ground Distance Zone x Directional is supervising Ground Distance Zone x phase A has dropped out Ground Distance Zone x phase B has dropped out Ground Distance Zone x phase C has dropped out
	GND DIST Z2	Same set of operands as shown for GND DIST Z1
ELEMENT: Ground IOC	GROUND IOC1 PKP GROUND IOC1 OP GROUND IOC1 DPO	Ground Instantaneous Overcurrent 1 has picked up Ground Instantaneous Overcurrent 1 has operated Ground Instantaneous Overcurrent 1 has dropped out
	GROUND IOC2	Same set of operands as shown for GROUND IOC 1
ELEMENT: Ground TOC	GROUND TOC1 PKP GROUND TOC1 OP GROUND TOC1 DPO	Ground Time Overcurrent 1 has picked up Ground Time Overcurrent 1 has operated Ground Time Overcurrent 1 has dropped out
	GROUND TOC2	Same set of operands as shown for GROUND TOC1
ELEMENT: Hybrid POTT	HYBRID POTT TX1 HYBRID POTT TX2 HYBRID POTT TX3 HYBRID POTT TX4 HYBRID POTT TRIP A HYBRID POTT TRIP B HYBRID POTT TRIP C HYBRID POTT TRIP 3P HYBRID POTT OP	Hybrid permissive over-reaching transfer trip asserts transmit bit no. 1 Hybrid permissive over-reaching transfer trip asserts transmit bit no. 2 Hybrid permissive over-reaching transfer trip asserts transmit bit no. 3 Hybrid permissive over-reaching transfer trip asserts transmit bit no. 4 Hybrid permissive over-reaching transfer trip has operated to trip phase A Hybrid permissive over-reaching transfer trip has operated to trip phase B Hybrid permissive over-reaching transfer trip has operated to trip phase C Hybrid permissive over-reaching transfer trip has tripped all 3 phases Hybrid permissive over-reaching transfer trip has operated
ELEMENT: Line Pickup	LINE PICKUP OP LINE PICKUP PKP LINE PICKUP DPO LINE PICKUP UV PKP LINE PICKUP LEO PKP	Line Pickup has operated Line Pickup has picked up Line Pickup has dropped out Line Pickup Undervoltage has picked up Line Pickup Line End Open has picked up
ELEMENT: Load Encroachment	LOAD ENCRMNT PKP LOAD ENCRMNT OP LOAD ENCRMNT DPO	Load Encroachment has picked up Load Encroachment has operated Load Encroachment has dropped out
ELEMENT: Negative Sequence Directional OC	NEG SEQ DIR OC1 FWD NEG SEQ DIR OC1 REV NEG SEQ DIR OC2 FWD NEG SEQ DIR OC2 REV	Negative Sequence Directional OC1 Forward has operated Negative Sequence Directional OC1 Reverse has operated Negative Sequence Directional OC2 Forward has operated Negative Sequence Directional OC2 Reverse has operated

Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 3 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Negative Sequence IOC	NEG SEQ IOC1 PKP NEG SEQ IOC1 OP NEG SEQ IOC1 DPO	Negative Sequence Instantaneous Overcurrent 1 has picked up Negative Sequence Instantaneous Overcurrent 1 has operated Negative Sequence Instantaneous Overcurrent 1 has dropped out
	NEG SEQ IOC2	Same set of operands as shown for NEG SEQ IOC1
ELEMENT: Negative Sequence OV	NEG SEQ OV PKP NEG SEQ OV DPO NEG SEQ OV OP	Negative Sequence Overvoltage element has picked up Negative Sequence Overvoltage element has dropped out Negative Sequence Overvoltage element has operated
ELEMENT: Negative Sequence TOC	NEG SEQ TOC1 PKP NEG SEQ TOC1 OP NEG SEQ TOC1 DPO	Negative Sequence Time Overcurrent 1 has picked up Negative Sequence Time Overcurrent 1 has operated Negative Sequence Time Overcurrent 1 has dropped out
	NEG SEQ TOC2	Same set of operands as shown for NEG SEQ TOC1
ELEMENT: Neutral IOC	NEUTRAL IOC1 PKP NEUTRAL IOC1 OP NEUTRAL IOC1 DPO	Neutral Instantaneous Overcurrent 1 has picked up Neutral Instantaneous Overcurrent 1 has operated Neutral Instantaneous Overcurrent 1 has dropped out
	NEUTRAL IOC2	Same set of operands as shown for NEUTRAL IOC1
ELEMENT: Neutral OV	NEUTRAL OV1 PKP NEUTRAL OV1 DPO NEUTRAL OV1 OP	Neutral Overvoltage element has picked up Neutral Overvoltage element has dropped out Neutral Overvoltage element has operated
ELEMENT: Neutral TOC	NEUTRAL TOC1 PKP NEUTRAL TOC1 OP NEUTRAL TOC1 DPO	Neutral Time Overcurrent 1 has picked up Neutral Time Overcurrent 1 has operated Neutral Time Overcurrent 1 has dropped out
	NEUTRAL TOC2	Same set of operands as shown for NEUTRAL TOC1
ELEMENT: Neutral Directional	NTRL DIR OC1 FWD NTRL DIR OC1 REV	Neutral Directional OC1 Forward has operated Neutral Directional OC1 Reverse has operated
	NTRL DIR OC2	Same set of operands as shown for NTRL DIR OC1
ELEMENT: Open Pole Detector	OPEN POLE OP ΦA OPEN POLE OP ΦB OPEN POLE OP ΦC OPEN POLE BKR ΦA OP OPEN POLE BKR ΦB OP OPEN POLE BKR ΦC OP OPEN POLE BLK N OPEN POLE BLK AB OPEN POLE BLK BC OPEN POLE BLK CA OPEN POLE OP	Open pole condition is detected in phase A Open pole condition is detected in phase B Open pole condition is detected in phase C Based on the breaker(s) auxiliary contacts, an open pole condition is detected on phase A Based on the breaker(s) auxiliary contacts, an open pole condition is detected on phase B Based on the breaker(s) auxiliary contacts, an open pole condition is detected on phase C Blocking signal for neutral, ground, and negative-sequence overcurrent element is established Blocking signal for the AB phase distance elements is established Blocking signal for the BC phase distance elements is established Blocking signal for the CA phase distance elements is established Open pole detector is operated
ELEMENT: Phase Directional	PH DIR1 BLK A PH DIR1 BLK B PH DIR1 BLK C PH DIR1 BLK	Phase A Directional 1 Block Phase B Directional 1 Block Phase C Directional 1 Block Phase Directional 1 Block
	PH DIR2	Same set of operands as shown for PH DIR1
ELEMENT: Phase Distance	PH DIST Zx PKP PH DIST Zx OP PH DIST Zx OP AB PH DIST Zx OP BC PH DIST Zx OP CA PH DIST Zx PKP AB PH DIST Zx PKP BC PH DIST Zx PKP CA PH DIST Zx SUPN IAB PH DIST Zx SUPN IBC PH DIST Zx SUPN ICA PH DIST Zx DPO AB PH DIST Zx DPO BC PH DIST Zx DPO CA	Phase Distance Zone x has picked up Phase Distance Zone x has operated Phase Distance Zone x phase AB has operated Phase Distance Zone x phase BC has operated Phase Distance Zone x phase CA has operated Phase Distance Zone x phase AB has picked up Phase Distance Zone x phase BC has picked up Phase Distance Zone x phase CA has picked up Phase Distance Zone x phase AB IOC is supervising Phase Distance Zone x phase BC IOC is supervising Phase Distance Zone x phase CA IOC is supervising Phase Distance Zone x phase AB has dropped out Phase Distance Zone x phase BC has dropped out Phase Distance Zone x phase CA has dropped out
	PH DIST Z2 to Z4	Same set of operands as shown for PH DIST Z1

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Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 4 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: Phase IOC	PHASE IOC1 PKP PHASE IOC1 OP PHASE IOC1 DPO PHASE IOC1 PKP A PHASE IOC1 PKP B PHASE IOC1 PKP C PHASE IOC1 OP A PHASE IOC1 OP B PHASE IOC1 OP C PHASE IOC1 DPO A PHASE IOC1 DPO B PHASE IOC1 DPO C	At least one phase of PHASE IOC1 has picked up At least one phase of PHASE IOC1 has operated At least one phase of PHASE IOC1 has dropped out Phase A of PHASE IOC1 has picked up Phase B of PHASE IOC1 has picked up Phase C of PHASE IOC1 has picked up Phase A of PHASE IOC1 has operated Phase B of PHASE IOC1 has operated Phase C of PHASE IOC1 has operated Phase A of PHASE IOC1 has dropped out Phase B of PHASE IOC1 has dropped out Phase C of PHASE IOC1 has dropped out
	PHASE IOC2	Same set of operands as shown for PHASE IOC1
ELEMENT: Phase OV	PHASE OV1 PKP PHASE OV1 OP PHASE OV1 DPO PHASE OV1 PKP A PHASE OV1 PKP B PHASE OV1 PKP C PHASE OV1 OP A PHASE OV1 OP B PHASE OV1 OP C PHASE OV1 DPO A PHASE OV1 DPO B PHASE OV1 DPO C	At least one phase of OV1 has picked up At least one phase of OV1 has operated At least one phase of OV1 has dropped out Phase A of OV1 has picked up Phase B of OV1 has picked up Phase C of OV1 has picked up Phase A of OV1 has operated Phase B of OV1 has operated Phase C of OV1 has operated Phase A of OV1 has dropped out Phase B of OV1 has dropped out Phase C of OV1 has dropped out
ELEMENT (Phase Select)	PHASE SELECT AG PHASE SELECT BG PHASE SELECT CG PHASE SELECT SLG PHASE SELECT AB PHASE SELECT BC PHASE SELECT CA PHASE SELECT ABG PHASE SELECT BCG PHASE SELECT CAG PHASE SELECT 3P PHASE SELECT MULTI-P PHASE SELECT VOID	Phase A to Ground fault is detected. Phase B to Ground fault is detected. Phase C to Ground fault is detected. Single Line to Ground fault is detected. Phase A to B fault is detected. Phase B to C fault is detected. Phase C to A fault is detected. Phase A to B to Ground fault is detected. Phase B to C to Ground fault is detected. Phase C to A to Ground fault is detected. Three-phase symmetrical fault is detected. Multi-phase fault is detected Fault type cannot be detected
ELEMENT: Phase TOC	PHASE TOC1 PKP PHASE TOC1 OP PHASE TOC1 DPO PHASE TOC1 PKP A PHASE TOC1 PKP B PHASE TOC1 PKP C PHASE TOC1 OP A PHASE TOC1 OP B PHASE TOC1 OP C PHASE TOC1 DPO A PHASE TOC1 DPO B PHASE TOC1 DPO C	At least one phase of PHASE TOC1 has picked up At least one phase of PHASE TOC1 has operated At least one phase of PHASE TOC1 has dropped out Phase A of PHASE TOC1 has picked up Phase B of PHASE TOC1 has picked up Phase C of PHASE TOC1 has picked up Phase A of PHASE TOC1 has operated Phase B of PHASE TOC1 has operated Phase C of PHASE TOC1 has operated Phase A of PHASE TOC1 has dropped out Phase B of PHASE TOC1 has dropped out Phase C of PHASE TOC1 has dropped out
	PHASE TOC2	Same set of operands as shown for PHASE TOC1
ELEMENT: Phase UV	PHASE UV1 PKP PHASE UV1 OP PHASE UV1 DPO PHASE UV1 PKP A PHASE UV1 PKP B PHASE UV1 PKP C PHASE UV1 OP A PHASE UV1 OP B PHASE UV1 OP C PHASE UV1 DPO A PHASE UV1 DPO B PHASE UV1 DPO C	At least one phase of UV1 has picked up At least one phase of UV1 has operated At least one phase of UV1 has dropped out Phase A of UV1 has picked up Phase B of UV1 has picked up Phase C of UV1 has picked up Phase A of UV1 has operated Phase B of UV1 has operated Phase C of UV1 has operated Phase A of UV1 has dropped out Phase B of UV1 has dropped out Phase C of UV1 has dropped out
	PHASE UV2	Same set of operands as shown for PHASE UV1

Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 5 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
ELEMENT: POTT	POTT OP POTT TX1 POTT TX2 POTT TX3 POTT TX4 POTT TRIP A POTT TRIP B POTT TRIP C POTT TRIP 3P	Permissive over-reaching transfer trip has operated Permissive over-reaching transfer trip asserts transit bit number 1 Permissive over-reaching transfer trip asserts transit bit number 2 Permissive over-reaching transfer trip asserts transit bit number 3 Permissive over-reaching transfer trip asserts transit bit number 4 Permissive over-reaching transfer trip has operated to trip Phase A Permissive over-reaching transfer trip has operated to trip Phase B Permissive over-reaching transfer trip has operated to trip Phase C Permissive over-reaching transfer trip has operated to trip all three phases
ELEMENT: Power Swing Detect	POWER SWING OUTER POWER SWING MIDDLE POWER SWING INNER POWER SWING BLOCK POWER SWING TMRX PKP POWER SWING TRIP	Positive Sequence impedance in outer characteristic Positive Sequence impedance in middle characteristic Positive Sequence impedance in inner characteristic Power Swing Blocking element operated Power Swing Timer X picked up Out-of-step Tripping operated
ELEMENT: PUTT	PUTT OP PUTT TX1 PUTT TX2 PUTT TX3 PUTT TX4 PUTT TRIP A PUTT TRIP B PUTT TRIP C PUTT TRIP 3P	Permissive under-reaching transfer trip has operated Permissive under-reaching transfer trip asserts transit bit number 1 Permissive under-reaching transfer trip asserts transit bit number 2 Permissive under-reaching transfer trip asserts transit bit number 3 Permissive under-reaching transfer trip asserts transit bit number 4 Permissive under-reaching transfer trip has operated to trip Phase A Permissive under-reaching transfer trip has operated to trip Phase B Permissive under-reaching transfer trip has operated to trip Phase C Permissive under-reaching transfer trip has operated to trip all three phases
ELEMENT: Setting Group	SETTING GROUP ACT 1 ↓ SETTING GROUP ACT 8	Setting group 1 is active ↓ Setting group 8 is active
ELEMENT: Synchrocheck	SYNC 1 DEAD S OP SYNC 1 DEAD S DPO SYNC 1 SYNC OP SYNC 1 SYNC DPO SYNC 1 CLS OP SYNC 1 CLS DPO	Synchrocheck 1 dead source has operated Synchrocheck 1 dead source has dropped out Synchrocheck 1 in synchronization has operated Synchrocheck 1 in synchronization has dropped out Synchrocheck 1 close has operated Synchrocheck 1 close has dropped out
	SYNC 2	Same set of operands as shown for SYNC 1
ELEMENT (Trip Output)	TRIP 3-POLE TRIP 1-POLE TRIP PHASE A TRIP PHASE B TRIP PHASE C TRIP AR INIT 3-POLE TRIP FORCE 3-POLE	Trip all three breaker poles A single-pole trip-and-reclose operation is initiated Trip breaker pole A, initiate phase A breaker fail and reclose Trip breaker pole B, initiate phase B breaker fail and reclose Trip breaker pole C, initiate phase C breaker fail and reclose Initiate a three-pole reclose Three-pole trip must be initiated
ELEMENT: VTFF	SRCx VT FUSE F OP SRCx VT FUSE F DPO	Source x VT Fuse Failure detector has operated Source x VT Fuse Failure detector has dropped out
FIXED OPERANDS	Off	Logic = 0. Does nothing and may be used as a delimiter in an equation list; used as 'Disable' by other features.
	On	Logic = 1. Can be used as a test setting.
INPUTS/OUTPUTS: Contact Inputs	Cont Ip 1 On Cont Ip 2 On ↓ Cont Ip 1 Off Cont Ip 2 Off ↓	(will not appear unless ordered) (will not appear unless ordered) ↓ (will not appear unless ordered) (will not appear unless ordered) ↓
INPUTS/OUTPUTS: Contact Outputs, Current (from detector on Form-A output only)	Cont Op 1 IOn Cont Op 2 IOn ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
	Cont Op 1 IOff Cont Op 2 IOff ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
INPUTS/OUTPUTS: Contact Outputs, Voltage (from detector on Form-A output only)	Cont Op 1 VOn Cont Op 2 VOn ↓	(will not appear unless ordered) (will not appear unless ordered) ↓
	Cont Op 1 VOff Cont Op 2 VOff ↓	(will not appear unless ordered) (will not appear unless ordered) ↓

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Table 5–11: D60 FLEXLOGIC™ OPERANDS (Sheet 6 of 6)

OPERAND TYPE	OPERAND SYNTAX	OPERAND DESCRIPTION
INPUTS/OUTPUTS: Direct Input	Direct I/P 1-1 On ↓ Direct I/P 1-8 On	(appears only when L90 Comm card is used) ↓ (appears only when L90 Comm card is used)
	Direct I/P 2-1 On ↓ Direct I/P 2-8 On	(appears only when L90 Comm card is used) ↓ (appears only when L90 Comm card is used)
INPUTS/OUTPUTS: Remote Inputs	REMOTE INPUT 1 On ↓ REMOTE INPUT 32 On	Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual Inputs	Virt Ip 1 On ↓ Virt Ip 32 On	Flag is set, logic=1 ↓ Flag is set, logic=1
INPUTS/OUTPUTS: Virtual Outputs	Virt Op 1 On ↓ Virt Op 64 On	Flag is set, logic=1 ↓ Flag is set, logic=1
REMOTE DEVICES	REMOTE DEVICE 1 On ↓ REMOTE DEVICE 16 On	Flag is set, logic=1 ↓ Flag is set, logic=1
	REMOTE DEVICE 1 Off ↓ REMOTE DEVICE 16 Off	Flag is set, logic=1 ↓ Flag is set, logic=1
RESETTING	RESET OP RESET OP (COMMS) RESET OP (OPERAND) RESET OP (PUSHBUTTON)	Reset command is operated (set by all 3 operands below) Communications source of the reset command Operand source of the reset command Reset key (pushbutton) source of the reset command
SELF-DIAGNOSTICS	ANY MAJOR ERROR ANY MINOR ERROR ANY SELF-TEST LOW ON MEMORY WATCHDOG ERROR PROGRAM ERROR EEPROM DATA ERROR PRI ETHERNET FAIL SEC ETHERNET FAIL BATTERY FAIL SYSTEM EXCEPTION UNIT NOT PROGRAMMED EQUIPMENT MISMATCH FLEXLGC ERROR TOKEN PROTOTYPE FIRMWARE UNIT NOT CALIBRATED NO DSP INTERRUPTS DSP ERROR IRIG-B FAILURE REMOTE DEVICE OFFLINE	Any of the major self-test errors generated (major error) Any of the minor self-test errors generated (minor error) Any self-test errors generated (generic, any error) See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter. See description in the COMMANDS chapter.

Some operands can be re-named by the user. These are the names of the breakers in the breaker control feature, the ID (identification) of contact inputs, the ID of virtual inputs, and the ID of virtual outputs. If the user changes the default name/ID of any of these operands, the assigned name will appear in the relay list of operands. The default names are shown in the FLEXLOGIC™ OPERANDS table above.

The characteristics of the logic gates are tabulated below, and the operators available in FlexLogic™ are listed in the FLEXLOGIC™ OPERATORS table.

Table 5–12: FLEXLOGIC™ GATE CHARACTERISTICS

GATES	NUMBER OF INPUTS	OUTPUT IS ‘1’ (= ON) IF...
NOT	1	input is ‘0’
OR	2 to 16	any input is ‘1’
AND	2 to 16	all inputs are ‘1’
NOR	2 to 16	all inputs are ‘0’
NAND	2 to 16	any input is ‘0’
XOR	2	only one input is ‘1’

Table 5–13: FLEXLOGIC™ OPERATORS

OPERATOR TYPE	OPERATOR SYNTAX	DESCRIPTION	NOTES
Editor	INSERT	Insert a parameter in an equation list.	
	DELETE	Delete a parameter from an equation list.	
End	END	The first END encountered signifies the last entry in the list of FlexLogic™ parameters that is processed.	
One Shot	POSITIVE ONE SHOT	One shot that responds to a positive going edge.	A 'one shot' 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 is a maximum of 32 'one shots'.
	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.	
Logic Gate	NOT	Logical Not	Operates on the previous parameter.
	OR(2) ↓ OR(16)	2 input OR gate ↓ 16 input OR gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	AND(2) ↓ AND(16)	2 input AND gate ↓ 16 input AND gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	NOR(2) ↓ NOR(16)	2 input NOR gate ↓ 16 input NOR gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	NAND(2) ↓ NAND(16)	2 input NAND gate ↓ 16 input NAND gate	Operates on the 2 previous parameters. ↓ Operates on the 16 previous parameters.
	XOR(2)	2 input Exclusive OR gate	Operates on the 2 previous parameters.
	LATCH (S,R)	Latch (Set, Reset) - reset-dominant	The parameter preceding LATCH(S,R) is the Reset input. The parameter preceding the Reset input is the Set input.
Timer	TIMER 1 ↓ TIMER 32	Timer as configured with FlexLogic™ Timer 1 settings. ↓ Timer as configured with FlexLogic™ Timer 32 settings.	The timer is started by the preceding parameter. The output of the timer is TIMER #.
Assign Virtual Output	= Virt Op 1 ↓ = Virt Op 64	Assigns previous FlexLogic™ parameter to Virtual Output 1. ↓ Assigns previous FlexLogic™ parameter to Virtual Output 64.	The virtual output is set by the preceding parameter

5.4.2 FLEXLOGIC™ RULES

When forming a FlexLogic™ equation, the sequence in the linear array of parameters must follow these general rules:

1. Operands must precede the operator which uses the operands as inputs.
2. 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 an operator to a Virtual Output terminates the equation.
4. A timer operator (e.g. "TIMER 1") or virtual output assignment (e.g. " = Virt Op 1") may only be used once. If this rule is broken, a syntax error will be declared.

5.4.3 FLEXLOGIC™ EVALUATION

Each equation is evaluated in the order in which the parameters have been entered.

CAUTION

FLEXLOGIC™ PROVIDES LATCHES WHICH BY DEFINITION HAVE A MEMORY ACTION, REMAINING IN THE SET STATE AFTER THE SET INPUT HAS BEEN ASSERTED. HOWEVER, THEY ARE VOLATILE; I.E. THEY RESET ON THE RE-APPLICATION OF CONTROL POWER.

WHEN MAKING CHANGES TO PROGRAMMING, ALL FLEXLOGIC™ EQUATIONS ARE RE-COMPILED WHEN ANY NEW SETTING IS ENTERED, SO ALL LATCHES ARE AUTOMATICALLY RESET. IF IT IS REQUIRED TO RE-INITIALIZE FLEXLOGIC™ DURING TESTING, FOR EXAMPLE, IT IS SUGGESTED TO POWER THE UNIT DOWN AND THEN BACK UP.

5.4.4 FLEXLOGIC™ PROCEDURE EXAMPLE

This section provides an example of implementing logic for a typical application. The sequence of the steps is quite important as it should minimize the work necessary to develop the relay settings. Note that the example presented in the figure below is intended to demonstrate the procedure, not to solve a specific application situation.

In the example below, it is assumed that logic has already been programmed to produce Virtual Outputs 1 and 2, and is only a part of the full set of equations used. When using FlexLogic™, it is important to make a note of each Virtual Output used – a Virtual Output designation (1 to 64) can only be properly assigned once.

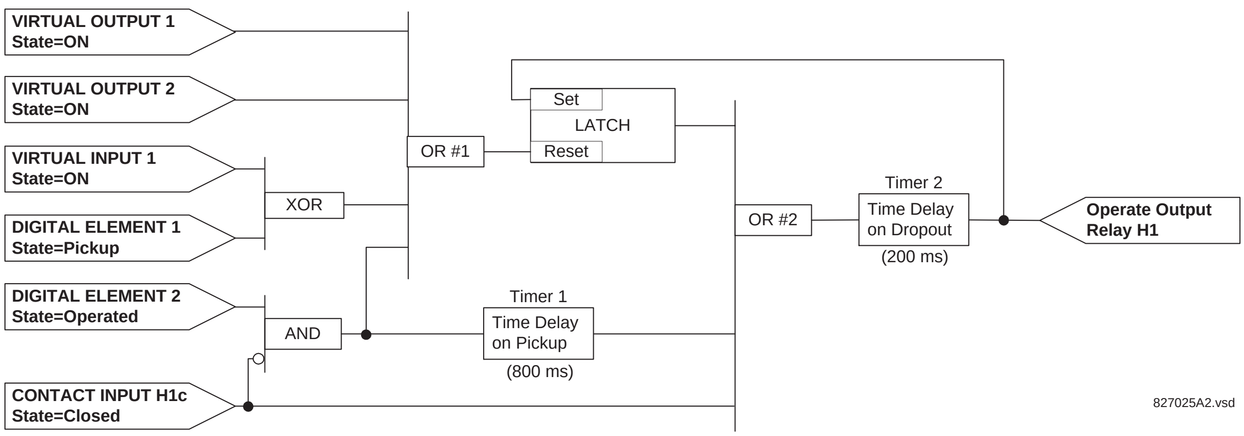

Figure 5–6: EXAMPLE LOGIC SCHEME

1. Inspect the example logic diagram to determine if the required logic can be implemented with the FlexLogic™ operators. If this is not possible, the logic must be altered until this condition is satisfied. Once this is done, count the inputs to each gate to verify that the number of inputs does not exceed the FlexLogic™ limits, which is unlikely but possible. If the number of inputs is too high, subdivide the inputs into multiple gates to produce an equivalent. For example, if 25 inputs to an AND gate are required, connect inputs 1 through 16 to one AND(16), 17 through 25 to another AND(9), and the outputs from these two gates to a third AND(2).

   Inspect each operator between the initial operands and final virtual outputs to determine if the output from the operator is used as an input to more than one following operator. If so, the operator output must be assigned as a Virtual Output.

   For the example shown above, the output of the AND gate is used as an input to both OR#1 and Timer 1, and must therefore be made a Virtual Output and assigned the next available number (i.e. Virtual Output 3). The final output must also be assigned to a Virtual Output as Virtual Output 4, which will be programmed in the contact output section to operate relay H1 (i.e. Output Contact H1).

Therefore, the required logic can be implemented with two FlexLogic™ equations with outputs of Virtual Output 3 and Virtual Output 4 as shown below.

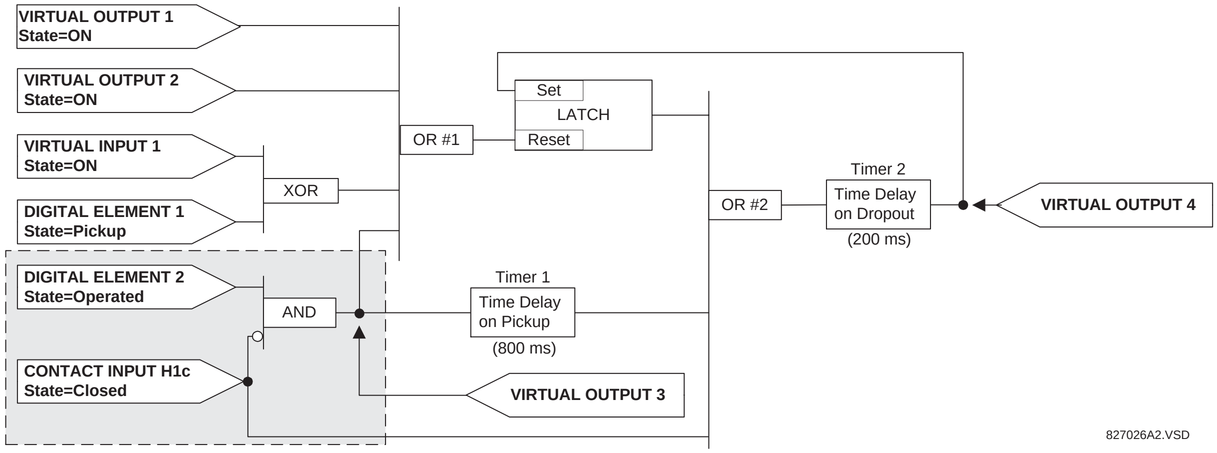

Figure 5–7: LOGIC EXAMPLE WITH VIRTUAL OUTPUTS

2. Prepare a logic diagram for the equation to produce Virtual Output 3, as this output will be used as an operand in the Virtual Output 4 equation (create the equation for every output that will be used as an operand first, so that when these operands are required they will already have been evaluated and assigned to a specific Virtual Output). The logic for Virtual Output 3 is shown below with the final output assigned.

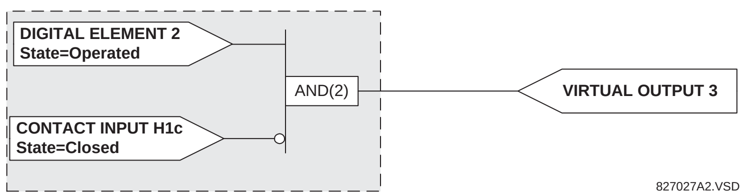

Figure 5–8: LOGIC FOR VIRTUAL OUTPUT 3

3. Prepare a logic diagram for Virtual Output 4, replacing the logic ahead of Virtual Output 3 with a symbol identified as Virtual Output 3, as shown below.

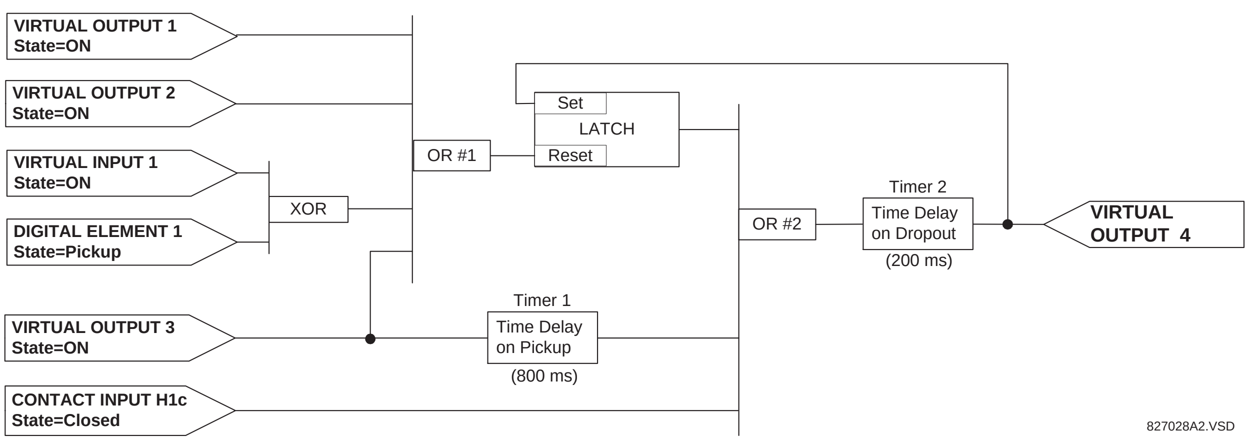

Figure 5–9: LOGIC FOR VIRTUAL OUTPUT 4

4. Program the FlexLogic™ equation for Virtual Output 3 by translating the logic into available FlexLogic™ parameters. The equation is formed one parameter at a time until the required logic is complete. It is generally easier to start at the output end of the equation and work back towards the input, as shown in the following steps. It is also recommended to list operator inputs from bottom to top. For demonstration, the final output will be arbitrarily identified as parameter 99, and each preceding parameter decremented by one in turn. Until accustomed to using FlexLogic™, it is suggested that a worksheet with a series of cells marked with the arbitrary parameter numbers be prepared, as shown below.

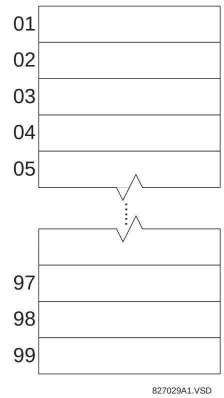

Figure 5–10: FLEXLOGIC™ WORKSHEET

5. Following the procedure outlined, start with parameter 99, as follows:

99: The final output of the equation is Virtual Output 3, which is created by the operator "= Virt Op n". This parameter is therefore "= Virt Op 3."

98: The gate preceding the output is an AND, which in this case requires two inputs. The operator for this gate is a 2-input AND so the parameter is “AND(2)”. Note that FlexLogic™ rules require that the number of inputs to most types of operators must be specified to identify the operands for the gate. As the 2-input AND will operate on the two operands preceding it, these inputs must be specified, starting with the lower.

97: This lower input to the AND gate must be passed through an inverter (the NOT operator) so the next parameter is “NOT”. The NOT operator acts upon the operand immediately preceding it, so specify the inverter input next.

96: The input to the NOT gate is to be contact input H1c. The ON state of a contact input can be programmed to be set when the contact is either open or closed. Assume for this example the state is to be ON for a closed contact. The operand is therefore "Cont Ip H1c On".

95: The last step in the procedure is to specify the upper input to the AND gate, the operated state of digital element 2. This operand is "DIG ELEM 2 OP".

Writing the parameters in numerical order can now form the equation for VIRTUAL OUTPUT 3:

```
[95] DIG ELEM 2 OP
[96] Cont Ip H1c On
[97] NOT
[98] AND(2)
[99] = Virt Op 3
```

It is now possible to check that this selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to figure: LOGIC FOR VIRTUAL OUTPUT 3 as a check.

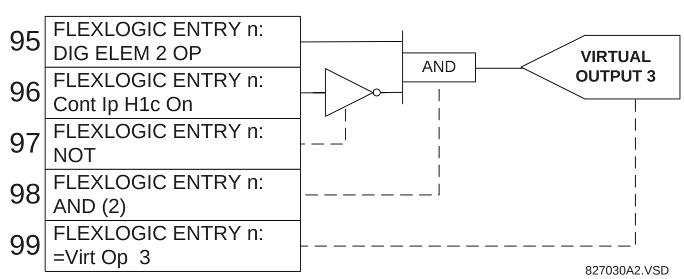

Figure 5–11: FLEXLOGIC™ EQUATION & LOGIC FOR VIRTUAL OUTPUT 3

6. Repeating the process described for VIRTUAL OUTPUT 3, select the FlexLogic™ parameters for Virtual Output 4.

99: The final output of the equation is VIRTUAL OUTPUT 4 which is parameter “= Virt Op 4".

98: The operator preceding the output is Timer 2, which is operand “TIMER 2". Note that the settings required for the timer are established in the timer programming section.

97: The operator preceding Timer 2 is OR #2, a 3-input OR, which is parameter “OR(3)”.

96: The lowest input to OR #2 is operand “Cont Ip H1c On”.

95: The center input to OR #2 is operand “TIMER 1".

94: The input to Timer 1 is operand “Virt Op 3 On".

93: The upper input to OR #2 is operand “LATCH (S,R)”.

92: There are two inputs to a latch, and the input immediately preceding the latch reset is OR #1, a 4-input OR, which is parameter “OR(4)”.

91: The lowest input to OR #1 is operand “Virt Op 3 On".

90: The input just above the lowest input to OR #1 is operand “XOR(2)”.

89: The lower input to the XOR is operand “DIG ELEM 1 PKP”.

88: The upper input to the XOR is operand “Virt Ip 1 On".

87: The input just below the upper input to OR #1 is operand “Virt Op 2 On".

86: The upper input to OR #1 is operand “Virt Op 1 On".

85: The last parameter is used to set the latch, and is operand “Virt Op 4 On".

The equation for VIRTUAL OUTPUT 4 is:

```
[85] Virt Op 4 On
[86] Virt Op 1 On
[87] Virt Op 2 On
[88] Virt Ip 1 On
[89] DIG ELEM 1 PKP
[90] XOR(2)
[91] Virt Op 3 On
[92] OR(4)
[93] LATCH (S,R)
[94] Virt Op 3 On
[95] TIMER 1
[96] Cont Ip H1c On
[97] OR(3)
[98] TIMER 2
[99] = Virt Op 4
```

It is now possible to check that the selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to figure: LOGIC FOR VIRTUAL OUTPUT 4, as a check.

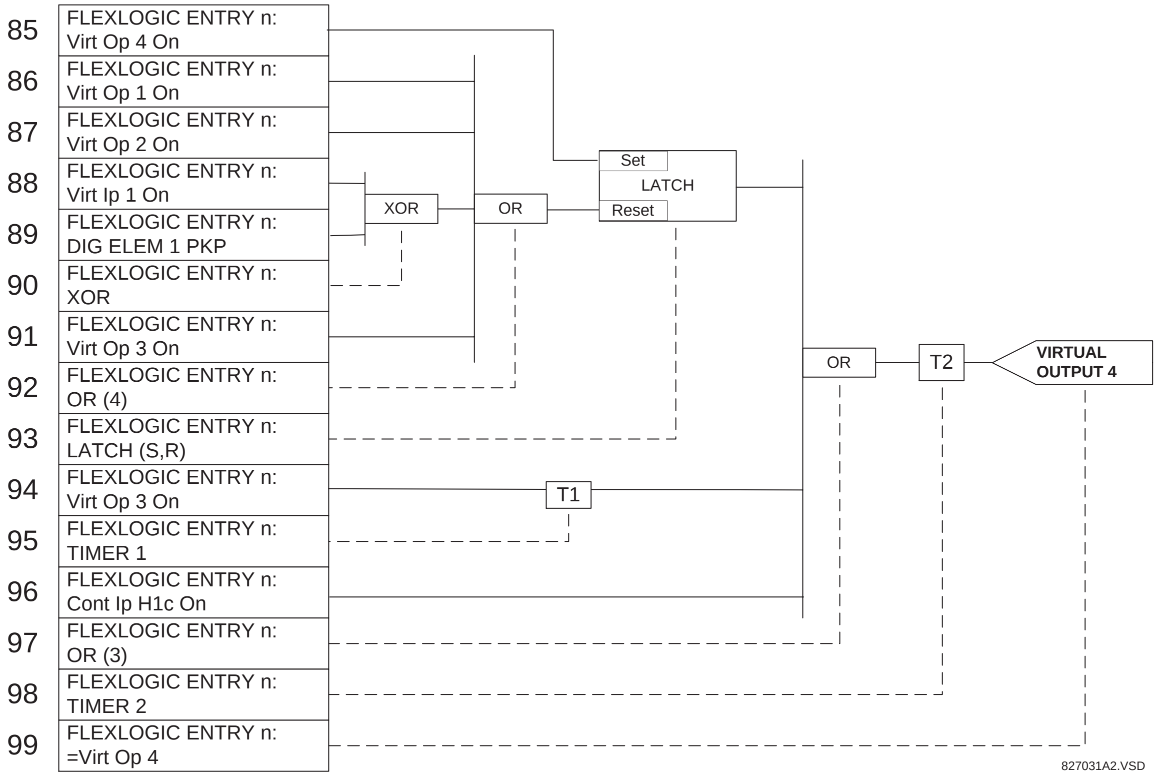

Figure 5–12: FLEXLOGIC™ EQUATION & LOGIC FOR VIRTUAL OUTPUT 4

7. Now write the complete FlexLogic™ expression required to implement the required logic, making an effort to assemble the equation in an order where Virtual Outputs that will be used as inputs to operators are created before needed. In cases where a lot of processing is required to perform considerable logic, this may be difficult to achieve, but in most cases will not cause problems because all of the logic is calculated at least 4 times per power frequency cycle. The possibility of a problem caused by sequential processing emphasizes the necessity to test the performance of Flex-Logic™ before it is placed in service.

   In the following equation, Virtual Output 3 is used as an input to both Latch 1 and Timer 1 as arranged in the order shown below:

```
DIG ELEM 2 OP
Cont Ip H1c On
NOT
AND(2)
= Virt Op 3
Virt Op 4 On
Virt Op 1 On
Virt Op 2 On
Virt Ip 1 On
DIG ELEM 1 PKP
XOR(2)
Virt Op 3 On
OR(4)
LATCH (S,R)
Virt Op 3 On
TIMER 1
Cont Ip H1c On
OR(3)
```


5

```
TIMER 2
= Virt Op 4
END
```

In the expression above, the Virtual Output 4 input to the 4-input OR is listed before it is created. This is typical of a form of feedback, in this case, used to create a seal-in effect with the latch, and is correct.

8. The logic should always be tested after it is loaded into the relay, in the same fashion as has been used in the past. Testing can be simplified by placing an "END" operator within the overall set of FlexLogic™ equations. The equations will then only be evaluated up to the first "END" operator.

   The "On" and "Off" operands can be placed in an equation to establish a known set of conditions for test purposes, and the "INSERT" and "DELETE" commands can be used to modify equations.

5.4.5 FLEXLOGIC™ EQUATION EDITOR

PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨ FLEXLOGIC EQUATION EDITOR

■ FLEXLOGIC ■ EQUATION EDITOR	◁▷	FLEXLOGIC ENTRY 1: END	Range: FlexLogic™ parameters
		↓	
MESSAGE	△	FLEXLOGIC ENTRY 512: END	Range: FlexLogic™ parameters

There are 512 FlexLogic™ entries available, numbered from 1 to 512, with default 'END' entry settings. If a "Disabled" Element is selected as a FlexLogic™ entry, the associated state flag will never be set to '1'. The '+/–' key may be used when editing FlexLogic™ equations from the keypad to quickly scan through the major parameter types.

5.4.6 FLEXLOGIC™ TIMERS

PATH: SETTINGS ⇨⇩ FLEXLOGIC ⇨⇩ FLEXLOGIC TIMERS ⇨ FLEXLOGIC TIMER 1(32)

■ FLEXLOGIC ■ TIMER 1	◁▷	TIMER 1 TYPE: millisecond	Range: millisecond, second, minute
MESSAGE	△▽	TIMER 1 PICKUP DELAY: 0	Range: 0 to 60000 in steps of 1
MESSAGE	△	TIMER 1 DROPOUT DELAY: 0	Range: 0 to 60000 in steps of 1

There are 32 identical FlexLogic™ timers available, numbered from 1 to 32. These timers can be used as operators for FlexLogic™ equations.

TIMER 1 TYPE:

This setting is used to select the time measuring unit.

TIMER 1 PICKUP DELAY:

This setting is used to set the time delay to pickup. If a pickup delay is not required, set this function to "0".

TIMER 1 DROPOUT DELAY:

This setting is used to set the time delay to dropout. If a dropout delay is not required, set this function to "0".

5.4.7 FLEXELEMENTS™

PATH: SETTING ⇨⇩ FLEXLOGIC ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)

■ FLEXELEMENT 1 ■	◁▷	FLEXELEMENT 1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	△▽	FLEXELEMENT 1 NAME: FxE1	Range: up to 6 alphanumeric characters
MESSAGE	△▽	FLEXELEMENT 1 +IN Off	Range: Off, any analog actual value parameter
MESSAGE	△▽	FLEXELEMENT 1 -IN Off	Range: Off, any analog actual value parameter
MESSAGE	△▽	FLEXELEMENT 1 INPUT MODE: Signed	Range: Signed, Absolute
MESSAGE	△▽	FLEXELEMENT 1 COMP MODE: Level	Range: Level, Delta
MESSAGE	△▽	FLEXELEMENT 1 DIRECTION: Over	Range: Over, Under
MESSAGE	△▽	FLEXELEMENT 1 PICKUP: 1.000 pu	Range: –90.000 to 90.000 pu in steps of 0.001
MESSAGE	△▽	FLEXELEMENT 1 HYSTERESIS: 3.0%	Range: 0.1 to 50.0% in steps of 0.1
MESSAGE	△▽	FLEXELEMENT 1 dt UNIT: milliseconds	Range: milliseconds, seconds, minutes
MESSAGE	△▽	FLEXELEMENT 1 dt: 20	Range: 20 to 86400 in steps of 1
MESSAGE	△▽	FLEXELEMENT 1 PKP DELAY: 0.000 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	△▽	FLEXELEMENT 1 RST DELAY: 0.000 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	△▽	FLEXELEMENT 1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	△▽	FLEXELEMENT 1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	△	FLEXELEMENT 1 EVENTS: Disabled	Range: Disabled, Enabled

A FlexElement™ is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference of any two analog actual values of the same type. The effective operating signal could be treated as a signed number or its absolute value could be used as per user's choice.

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 threshold as per user's choice.

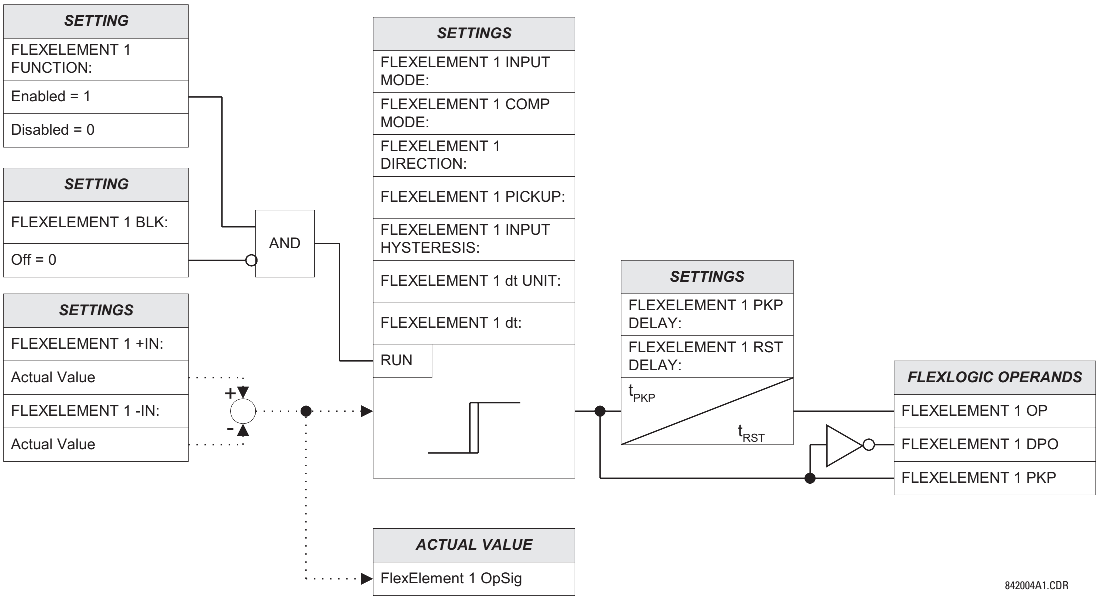

Figure 5–13: FLEXELEMENT™ SCHEME LOGIC

5

The **FLEXELEMENT 1 +IN** setting specifies the first (non-inverted) input to the FlexElement™. 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 will not assert its output operands.

This **FLEXELEMENT 1 –IN** setting specifies the second (inverted) input to the FlexElement™. 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 will not assert its output operands. This input should be used 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 will 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.

The element responds directly to the differential signal if the **FLEXELEMENT 1 INPUT MODE** setting is set to "Signed". The element responds to the absolute value of the differential signal if this setting is set to "Absolute". Sample applications for the "Absolute" setting 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 of decreases.

The element responds directly to its operating signal – as defined by the **FLEXELEMENT 1 +IN**, **FLEXELEMENT 1 –IN** and **FLEXELEMENT 1 INPUT MODE** settings – if the **FLEXELEMENT 1 COMP MODE** setting is set to "Threshold". The element responds to the rate of change of its operating signal if the **FLEXELEMENT 1 COMP MODE** setting is set to "Delta". In this case the **FLEXELEMENT 1 dt UNIT** and **FLEXELEMENT 1 dt** settings specify how the rate of change is derived.

The **FLEXELEMENT 1 DIRECTION** setting enables the relay to respond to either high or low values of the operating signal. The following figure explains the application of the **FLEXELEMENT 1 DIRECTION**, **FLEXELEMENT 1 PICKUP** and **FLEXELEMENT 1 HYSTERESIS** settings.

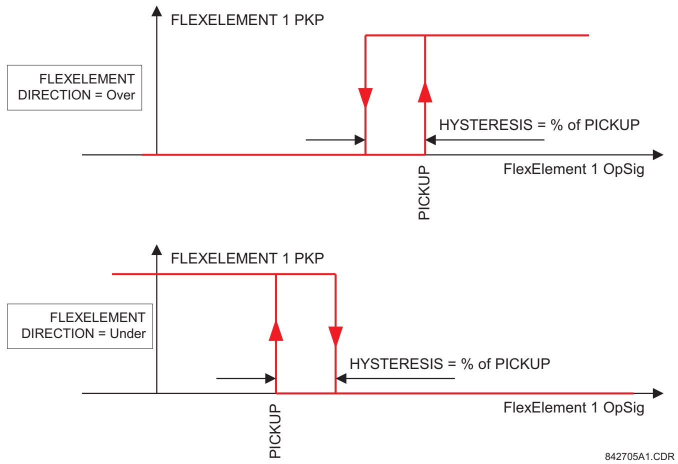

Figure 5–14: FLEXELEMENT™ DIRECTION, PICKUP, AND HYSTERESIS

In conjunction with the **FLEXELEMENT 1 INPUT MODE** setting the element could be programmed to provide two extra characteristics as shown in the figure below.

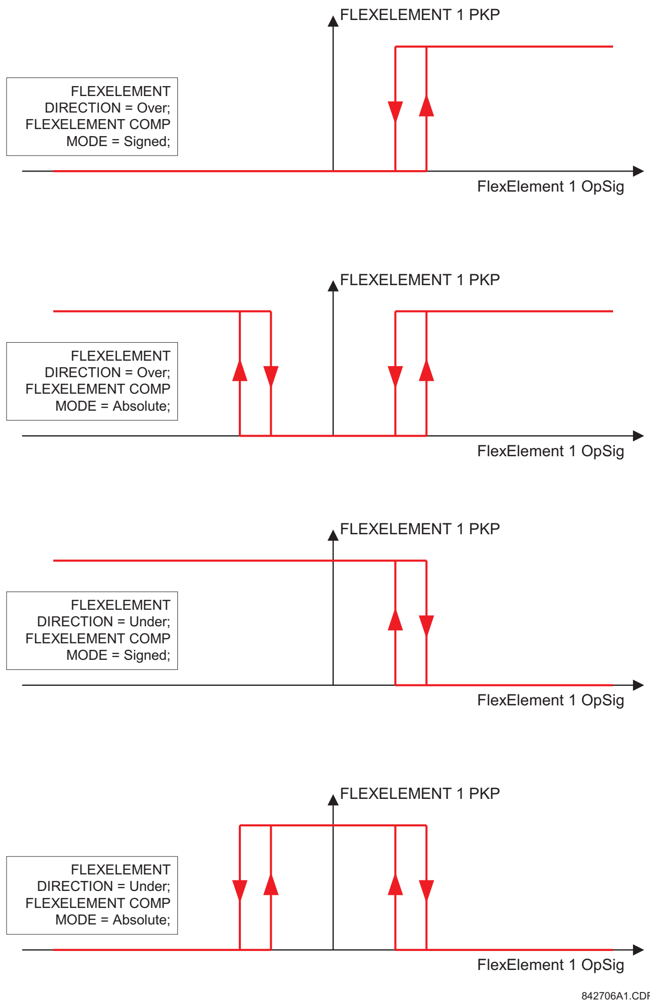

Figure 5–15: FLEXELEMENT™ INPUT MODE SETTING

5

The **FLEXELEMENT 1 PICKUP** setting specifies the operating threshold for the effective operating signal of the element. If set to "Over", the element picks up when the operating signal exceeds the **FLEXELEMENT 1 PICKUP** value. If set to "Under", the element picks up when the operating signal falls below the **FLEXELEMENT 1 PICKUP** value.

The **FLEXELEMENT 1 HYSTERESIS** setting controls the element dropout. It should be noticed that 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. The **FLEXELEMENT 1 PICKUP** setting is entered in pu values using the following definitions of the base units:

Table 5–14: FLEXELEMENT™ BASE UNITS

BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)	BASE = 2000 $kA^2 \times$ cycle
dcmA	BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs.
FREQUENCY	f_{BASE} = 1 Hz
PHASE ANGLE	φ_{BASE} = 360 degrees (see the UR angle referencing convention)
POWER FACTOR	PF_{BASE} = 1.00
RTDs	BASE = 100°C
SOURCE CURRENT	I_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SOURCE POWER	P_{BASE} = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SYNCHROCHECK (Max Delta Volts)	V_{BASE} = maximum primary RMS value of all the sources related to the +IN and –IN inputs

The **FLEXELEMENT 1 HYSTERESIS** setting defines the pickup–dropout relation of the element by specifying the width of the hysteresis loop as a percentage of the pickup value as shown in the FLEXELEMENT DIRECTION, PICKUP, AND HYSTERESIS diagram.

The **FLEXELEMENT 1 DT UNIT** setting specifies the time unit for the setting **FLEXELEMENT 1 dt**. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to "Delta". The **FLEXELEMENT 1 DT** setting specifies duration of the time interval for the rate of change mode of operation. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to "Delta".

This **FLEXELEMENT 1 PKP DELAY** setting specifies the pickup delay of the element. The **FLEXELEMENT 1 RST DELAY** setting specifies the reset delay of the element.

5.5.1 OVERVIEW

Each protection element can be assigned up to 8 different sets of settings according to SETTING GROUP designations 1 to 8. 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 (e.g. altered power system configuration, season of the year). The active setting group can be preset or selected via the SETTING GROUPS menu (see the CONTROL ELEMENTS section). See also the INTRODUCTION TO ELEMENTS section at the front of this chapter.

5.5.2 SETTING GROUP

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8)

■ SETTING GROUP 1 ■		■ LINE PICKUP ■	See page 5-52.
	MESSAGE	■ DISTANCE ■	See page 5-54.
	MESSAGE	■ POWER SWING ■ DETECT	See page 5-68.
	MESSAGE	■ LOAD ENCROACHMENT ■	See page 5-68.
	MESSAGE	■ PHASE CURRENT ■	See page 5-82.
	MESSAGE	■ NEUTRAL CURRENT ■	See page 5-88.
	MESSAGE	■ GROUND CURRENT ■	See page 5-95.
	MESSAGE	■ NEGATIVE SEQUENCE ■ CURRENT	See page 5-97.
	MESSAGE	■ BREAKER FAILURE ■	See page 5-103.
	MESSAGE	■ VOLTAGE ELEMENTS ■	See page 5-112.

Each of the 8 SETTING GROUP menus is identical. SETTING GROUP 1 (the default active group) automatically becomes active if no other group is active (see the CONTROL ELEMENTS section for additional details).

5.5.3 LINE PICKUP

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ LINE PICKUP

■ LINE PICKUP ■		
	LINE PICKUP FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	LINE PICKUP SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	PHASE IOC LINE PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
MESSAGE	POS SEQ UV PICKUP: 0.700 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	LINE END OPEN PICKUP DELAY: 0.150 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LINE END OPEN RESET DELAY: 0.090 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POS SEQ OV PICKUP DELAY: 0.040 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	AR CO-ORD BYPASS: Enabled	Range: Disabled, Enabled
MESSAGE	AR CO-ORD PICKUP DELAY: 0.045 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	AR CO-ORD RESET DELAY: 0.005 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LINE PICKUP BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	LINE PICKUP TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	LINE PICKUP EVENTS: Disabled	Range: Disabled, Enabled

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 which could be due to maintenance grounds that have not been removed. Faults other than close-in faults can be identified satisfactorily by the distance elements which initially will be self or faulted phase polarized and then become memory polarized when a satisfactory memory signal is available.

Co-ordination features are included to ensure satisfactory operation when high speed 'automatic reclosure (AR)' is employed. The **AR CO-ORD DELAY** setting allows the overcurrent setting to be below the expected load current seen after reclose. Co-ordination is achieved by the POS SEQ OV element picking up and blocking the trip path, before the **AR CO-ORD DELAY** times out. The **AR CO-ORD BYPASS** setting is normally enabled. It is disabled if high speed AR is implemented.

The positive sequence undervoltage pickup setting is based on phase to neutral quantities. If Delta VTs are used, then this per unit pickup is based on the (**VT SECONDARY** setting) / $\sqrt{3}$.

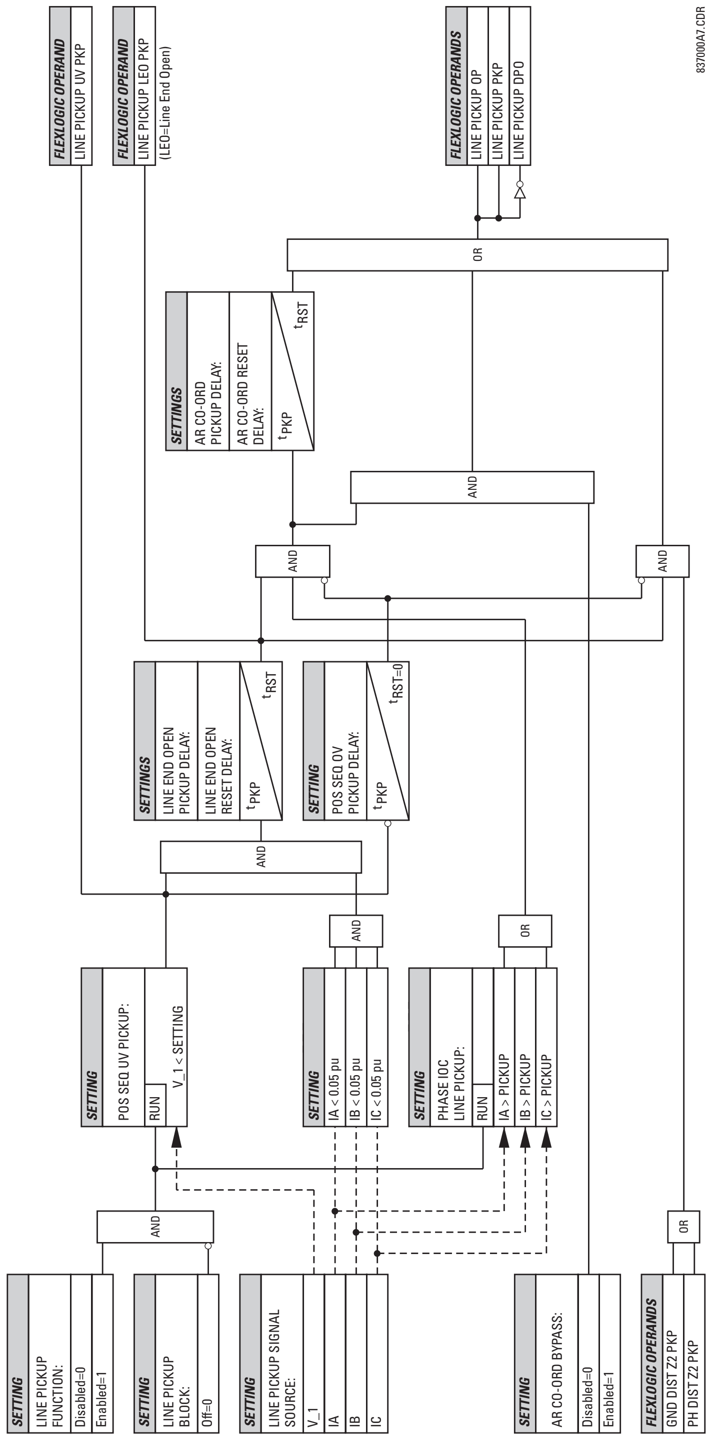

Figure 5–16: LINE PICKUP LOGIC

5.5.4 DISTANCE

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE

■ DISTANCE ■	◁▷	DISTANCE SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	⇧⇩	MEMORY DURATION: 10 cycles	Range: 5 to 25 cycles
MESSAGE	⇧⇩	■ PHASE DISTANCE Z1 ■	
MESSAGE	⇧⇩	■ PHASE DISTANCE Z2 ■	
MESSAGE	⇧⇩	■ PHASE DISTANCE Z3 ■	
MESSAGE	⇧⇩	■ PHASE DISTANCE Z4 ■	
MESSAGE	⇧⇩	■ GROUND DISTANCE Z1 ■	
MESSAGE	⇧⇩	■ GROUND DISTANCE Z2 ■	
MESSAGE	⇧⇩	■ GROUND DISTANCE Z3 ■	
MESSAGE	⇧	■ GROUND DISTANCE Z4 ■	

5

Two common settings (**DISTANCE SOURCE** and **MEMORY DURATION**) and eight menus for four zones of phase and ground distance protection are available. The **DISTANCE SOURCE** 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.

The **MEMORY DURATION** setting specifies the length of time a memorized positive-sequence voltage should be 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, 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 under the SETTINGS ⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu.

Set **MEMORY DURATION** long enough to ensure stability on close-in reverse three-phase faults. For this purpose, the maximum fault clearing time (breaker fail time) in the substation should be considered. On the other hand, the **MEMORY DURATION** cannot be too long as the power system may 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 may eventually cause maloperation of the distance functions.

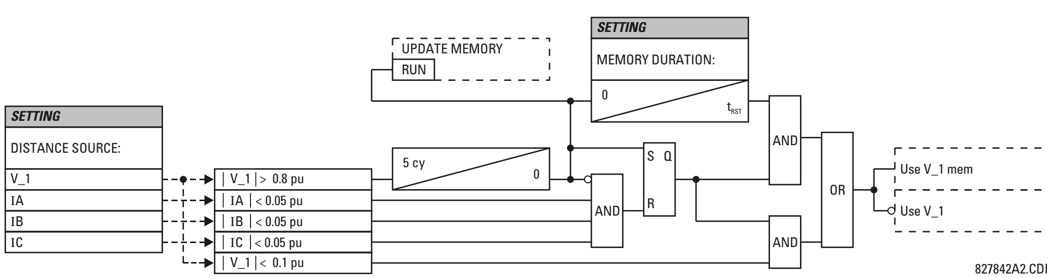

Figure 5–17: MEMORY VOLTAGE LOGIC

a) PHASE DISTANCE Z1 to Z4

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE ⇨⇩ PHASE DISTANCE Z1

■ PHASE DISTANCE Z1 ■	PHS DIST Z1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	PHS DIST Z1 DIRECTION: Forward	Range: Forward, Reverse
MESSAGE	PHS DIST Z1 SHAPE: Mho	Range: Mho, Quad
MESSAGE	PHS DIST Z1 REACH: 2.00 Ω	Range: 0.02 to 250.00 Ω in steps of 0.01
MESSAGE	PHS DIST Z1 RCA: 85°	Range: 30 to 90° in steps of 1
MESSAGE	PHS DIST Z1 COMP LIMIT: 90°	Range: 30 to 90° in steps of 1
MESSAGE	PHS DIST Z1 DIR RCA: 85°	Range: 30 to 90° in steps of 1
MESSAGE	PHS DIST Z1 DIR COMP LIMIT: 90°	Range: 30 to 90° in steps of 1
MESSAGE	PHS DIST Z1 QUAD RGT BLD: 10.00 Ω	Range: 0.02 to 500.00 Ω in steps of 0.01
MESSAGE	PHS DIST Z1 QUAD RGT BLD RCA: 85°	Range: 60 to 90° in steps of 1
MESSAGE	PHS DIST Z1 QUAD LFT BLD: 10.00 Ω	Range: 0.02 to 500.00 Ω in steps of 0.01
MESSAGE	PHS DIST Z1 QUAD LFT BLD RCA: 85°	Range: 60 to 90° in steps of 1
MESSAGE	PHS DIST Z1 SUPV: 0.200 pu	Range: 0.050 to 30.000 pu in steps of 0.001
MESSAGE	PHS DIST Z1 VOLT LEVEL: 0.000 pu	Range: 0.000 to 5.000 pu in steps of 0.001
MESSAGE	PHS DIST Z1 DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	PHS DIST Z1 BLK: Off	Range: FlexLogic™ operand
MESSAGE	PHS DIST Z1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	PHS DIST Z1 EVENTS: Disabled	Range: Disabled, Enabled

The phase MHO distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, and overcurrent supervising characteristics. The phase quad distance function is comprised of a reactance characteristic, right and left blinders, and 100% memory-polarized directional and current supervising characteristics. Additional details may be found in the THEORY OF OPERATION chapter.

Four zones of phase distance protection are provided. Each zone is configured individually through its own setting menu. All of the settings can be independently modified for each of the zones except:

- Signal Source (common for both phase and ground elements of all four zones as entered under SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE).

- Memory duration (common for both phase and ground elements of all four zones as entered under **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE**).

The COMMON DISTANCE SETTINGS described earlier must be properly chosen for correct operation of the phase distance elements.

Even though all four 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 underreaching tripping mode.

WARNING

Ensure that the PHASE VT SECONDARY VOLTAGE setting (see the SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu) is set correctly to prevent improper operation of associated memory action.

PHS DIST Z1 DIRECTION:

All four zones are reversible. The forward direction by the **PHS DIST Z1 RCA** setting, whereas the reverse direction is shifted 180° from that angle.

PHS DIST Z1 SHAPE:

This setting selects the shape of the phase distance function between the mho and quad characteristics. The selection is available on a per-zone basis. The two characteristics and their possible variations are shown in the following figures.

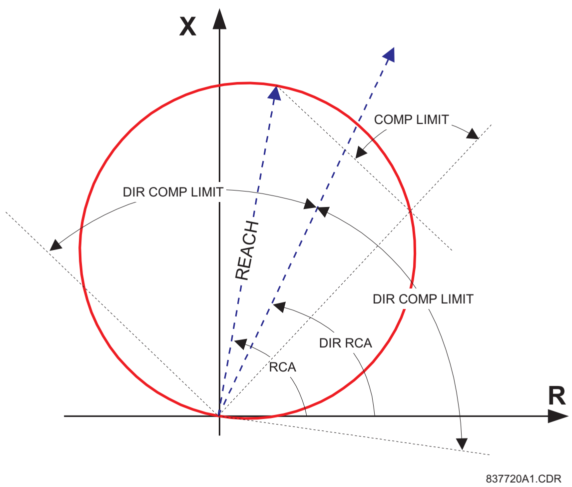

Figure 5–18: MHO DISTANCE CHARACTERISTIC

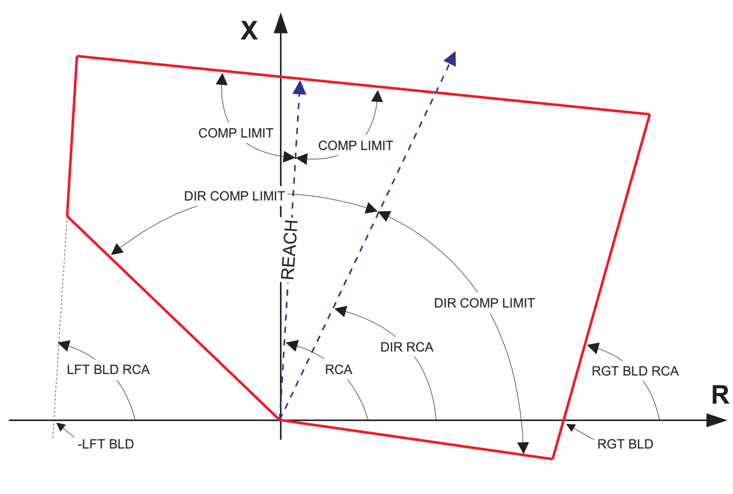

Figure 5–19: QUAD DISTANCE CHARACTERISTIC

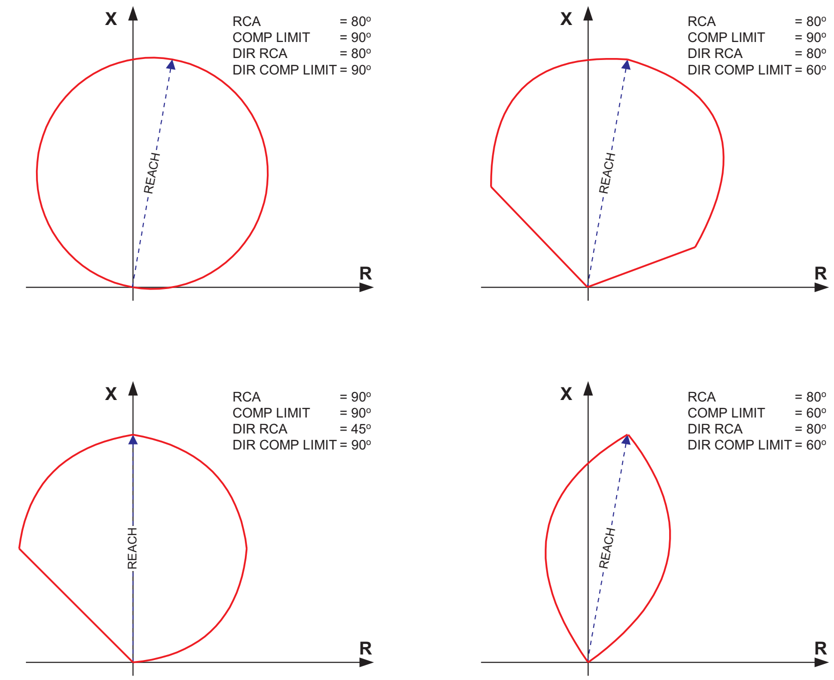

Figure 5–20: MHO DISTANCE CHARACTERISTIC SAMPLE SHAPES

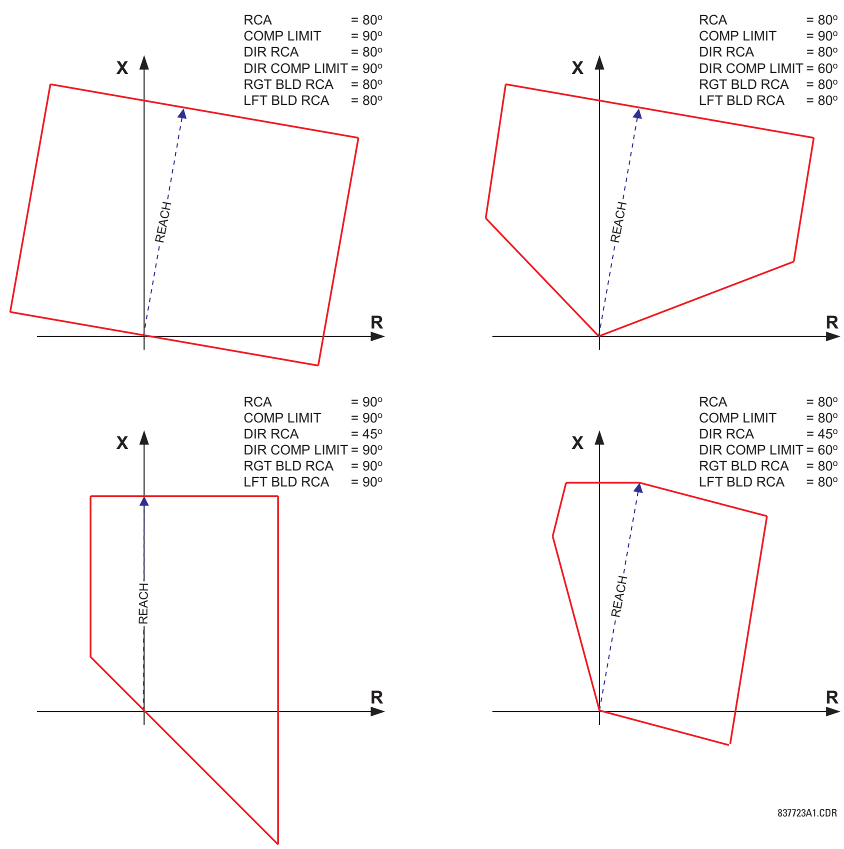

Figure 5–21: QUAD DISTANCE CHARACTERISTIC SAMPLE SHAPES

PHS DIST Z1 REACH:

This setting defines the zone reach. The reach impedance is entered in secondary ohms. The reach impedance angle is entered as the **PHS DIST Z1 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 dripping and under-reaching pilot schemes (DUTT, PUTT) other factors should be also considered as per rules of distance relaying.

PHS DIST Z1 RCA:

This setting specifies the characteristic angle (similar to the "maximum torque angle" in previous technologies) of the phase distance characteristic. The setting is an angle of reach impedance as shown in MHO DISTANCE CHARACTERISTIC and QUAD DISTANCE CHARACTERISTIC figures.

This setting is independent from **PHS DIST Z1 DIR RCA**, the characteristic angle of an extra directional supervising function.

PHS DIST Z1 COMP LIMIT:

This setting shapes 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 quad 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 loadability of the protected line. In conjunction with the quad characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

PHS DIST Z1 DIR RCA:

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This setting select 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 quad shape selection, 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 **PHS DIST Z1 RCA**.

PHS DIST Z1 DIR COMP LIMIT:

This setting selects the comparator limit angle for the directional supervising function.

PHS DIST Z1 QUAD RGT BLD:

This setting defines the right blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **PHS DIST Z1 QUAD RGT BLD RCA** setting.

This setting applies only to the quad characteristic and should be set giving consideration to the maximum load current and required resistive coverage.

PHS DIST Z1 QUAD RGT BLD RCA:

This setting defines the angular position of the right blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

PHS DIST Z1 QUAD LFT BLD:

This setting defines the left blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **PHS DIST Z1 QUAD LFT BLD RCA** setting. This setting applies only to the quad characteristic and should be set with consideration to the maximum load current.

PHS DIST Z1 QUAD LFT BLD RCA:

This setting defines the angular position of the left blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

PHS DIST Z1 SUPV:

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 (i.e., before being used, the entered value of the threshold setting is multiplied by $\sqrt{3}$).

If the minimum fault current level is sufficient, the current supervision pickup should be set above maximum full load current preventing maloperation under VT fuse fail conditions. This requirement may be difficult to meet for remote faults at the end of Zones 2 through 4. If this is the case, the current supervision pickup would be set below the full load current, but this may result in maloperation during fuse fail conditions.

Zone 1 is sealed-in with the current supervision.

PHS DIST Z1 VOLT LEVEL:

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, this setting shall be set to zero. Otherwise, the setting is entered in per unit of the phase VT bank configured under the **DISTANCE SOURCE**. See the THEORY OF OPERATION chapter for more details, and the APPLICATION OF SETTINGS chapter for information on how to calculate this setting for applications on series compensated lines.

PHS DIST Z1 DELAY:

This setting enables the user to delay operation of the distance elements and implement a stepped distance protection. The distance element timers for Zones 2 through 4 apply a short dropout delay to cope with faults located close to the zone boundary when small oscillations in the voltages and/or currents could inadvertently reset the timer. Zone 1 does not need any drop out delay because it is sealed-in by the presence of current.

PHS DIST Z1 BLK:

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.

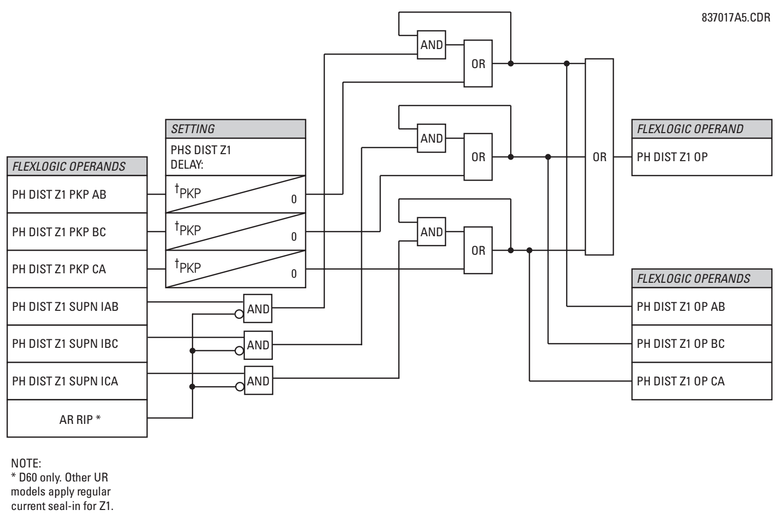

Figure 5–22: PHASE DISTANCE Z1 OP SCHEME

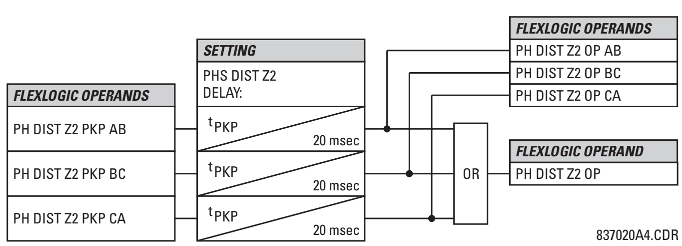

Figure 5–23: PHASE DISTANCE Z2 TO Z4 OP SCHEME

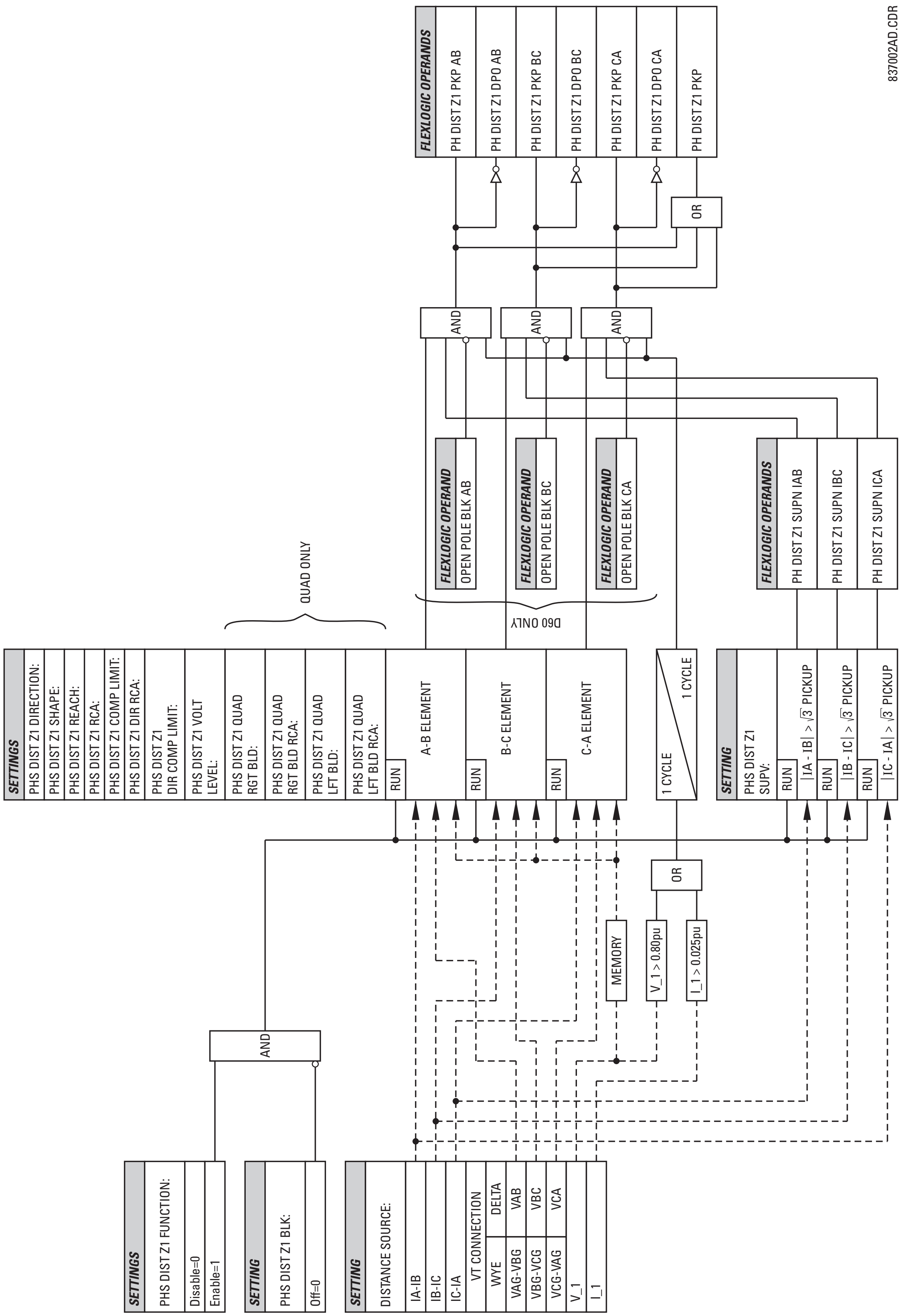

Figure 5–24: PHASE DISTANCE Z1 TO Z4 SCHEME LOGIC

b) GROUND DISTANCE Z1 to Z4

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE ⇨⇩ GROUND DISTANCE Z1

■ GROUND DISTANCE Z1 ■	◁▷	GND DIST Z1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	△▽	GND DIST Z1 DIRECTION: Forward	Range: Forward, Reverse
MESSAGE	△▽	GND DIST Z1 SHAPE: Mho	Range: Mho, Quad
MESSAGE	△▽	GND DIST Z1 Z0/Z1 MAG: 2.70	Range: 0.50 to 7.00 in steps of 0.01
MESSAGE	△▽	GND DIST Z1 Z0/Z1 ANG: 0°	Range: –90 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 ZOM/Z1 MAG: 0.00	Range: 0.00 to 7.00 in steps of 0.01
MESSAGE	△▽	GND DIST Z1 ZOM/Z1 ANG: 0°	Range: –90 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 REACH: 2.00 Ω	Range: 0.02 to 250.00 Ω in steps of 0.01
MESSAGE	△▽	GND DIST Z1 RCA: 85°	Range: 30 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 COMP LIMIT: 90°	Range: 30 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 DIR RCA: 85°	Range: 30 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 DIR COMP LIMIT: 90°	Range: 30 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 QUAD RGT BLD: 10.00 Ω	Range: 0.02 to 500.00 Ω in steps of 0.01
MESSAGE	△▽	GND DIST Z1 QUAD RGT BLD RCA: 85°	Range: 60 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 QUAD LFT BLD: 10.00 Ω	Range: 0.02 to 500.00 Ω in steps of 0.01
MESSAGE	△▽	GND DIST Z1 QUAD LFT BLD RCA: 85°	Range: 60 to 90° in steps of 1
MESSAGE	△▽	GND DIST Z1 SUPV: 0.200 pu	Range: 0.050 to 30.000 pu in steps of 0.001
MESSAGE	△▽	GND DIST Z1 VOLT LEVEL: 0.000 pu	Range: 0.000 to 5.000 pu in steps of 0.001
MESSAGE	△▽	GND DIST Z1 DELAY:0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	△▽	GND DIST Z1 BLK: Off	Range: FlexLogic™ operand
MESSAGE	△▽	GND DIST Z1 TARGET: Self-Reset	Range: Self-Rest, Latched, Disabled

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MESSAGE | GND DIST Z1 EVENTS: Disabled | Range: Disabled, Enabled

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.

The reactance supervision uses zero-sequence current as a polarizing quantity making the characteristic adaptable to the pre-fault power flow. 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 principles of distance relaying – may be inaccurate in such conditions. Ground distance Zones 2 through 4 apply additional zero-sequence directional supervision. See the THEORY OF OPERATION chapter for additional details.

Four zones of ground distance protection are provided. Each zone is configured individually through its own setting menu. All of the settings can be independently modified for each of the zones except:

- Signal Source (common for both phase and ground elements for all four zones as entered under the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE** menu).
- Memory duration (common for both phase and ground elements for all four zones as entered under the **SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ DISTANCE** menu).

The common distance settings noted at the start of the DISTANCE section must be properly chosen for correct operation of the ground distance elements.

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Although all four 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 underreaching tripping mode.

WARNING

Ensure that the PHASE VT SECONDARY VOLTAGE (see the SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK menu) is set correctly to prevent improper operation of associated memory action.

GND DIST Z1 DIRECTION:

All four zones are reversible. The forward direction is defined by the **GND DIST Z1 RCA** setting and the reverse direction is shifted by 180° from that angle.

GND DIST Z1 SHAPE:

This setting selects the shape of the ground distance characteristic between the mho and quad characteristics. The selection is available on a per-zone basis.

GND DIST Z1 Z0/Z1 MAG:

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.

GND DIST Z1 Z0/Z1 ANG:

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.

GND DIST Z1 ZOM/Z1 MAG:

The ground distance elements can be programmed to apply compensation for the zero-sequence mutual coupling between parallel lines. If the compensation is required, the ground current from the parallel line (3I_0) measured in the direction of zone being compensated must be connected to the ground input CT of the CT bank configured under the **DISTANCE SOURCE**. 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. It is imperative to set this setting to zero if the compensation is not to be performed.

GND DIST Z1 ZOM/Z1 ANG:

This setting specifies the angle difference between the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line.

GND DIST Z1 REACH:

This setting defines the reach of the zone. The angle of the reach impedance is entered as the **GND DIST Z1 RCA** setting. The reach impedance is entered in secondary ohms.

GND DIST Z1 RCA:

The characteristic angle (similar to the "maximum torque angle" in previous technologies) of the ground distance characteristic is specified by this setting. It is set as an angle of reach impedance as shown in the MHO DISTANCE CHARACTERISTIC and QUAD DISTANCE CHARACTERISTIC figures. This setting is independent from the **GND DIST Z1 DIR RCA** setting (the characteristic angle of an extra directional supervising function).

GND DIST Z1 COMP LIMIT:

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 reactance boundary of the quad function.

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 quad characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.

GND DIST Z1 DIR RCA:

The characteristic angle (or "maximum torque angle") of the directional supervising function is selected by this setting. 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 quad shape selection, this setting defines the only directional function built into the ground distance element. The directional function uses memory voltage for polarization.

GND DIST Z1 DIR COMP LIMIT:

This setting selects the comparator limit angle for the directional supervising function.

GND DIST Z1 QUAD RGT BLD:

This setting defines the right blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z1 QUAD RGT BLD RCA** setting.

This setting applies only to the quad characteristic and should be set giving consideration to the maximum load current and required resistive coverage.

GND DIST Z1 QUAD RGT BLD RCA:

This setting defines the angular position of the right blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

GND DIST Z1 QUAD LFT BLD:

This setting defines the left blinder position of the quad characteristic along the resistive axis of the impedance plane (see the QUAD DISTANCE CHARACTERISTIC figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z1 QUAD LFT BLD RCA** setting. This setting applies only to the quad characteristic and should be set with consideration to the maximum load current.

GND DIST Z1 QUAD LFT BLD RCA:

This setting defines the angular position of the left blinder of the quad characteristic (see the QUAD DISTANCE CHARACTERISTIC figure). This setting applies only to the quad characteristic.

GND DIST Z1 SUPV:

The ground distance elements are supervised by the magnitude of the neutral (3I_0) current. The current supervision pickup should be set above the maximum unbalance current under maximum load conditions preventing maloperation due to VT fuse failure.

Zone 1 is sealed in with the current supervision.

GND DIST Z1 VOLT LEVEL:

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, this setting shall be set to zero. Otherwise, the setting is entered in per unit of the VT bank configured under the **DISTANCE SOURCE**. See the THEORY OF OPERATION chapter for more details, and the APPLICATION OF SETTINGS chapter for information on how to calculate this setting for applications on series compensated lines.

GND DIST Z1 DELAY:

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 and/or currents could inadvertently reset the timer.

GND DIST Z1 BLK:

This setting enables the user to select a FlexLogic™ operand to block the given distance element. VT fuse fail detection is one of the applications for this setting.

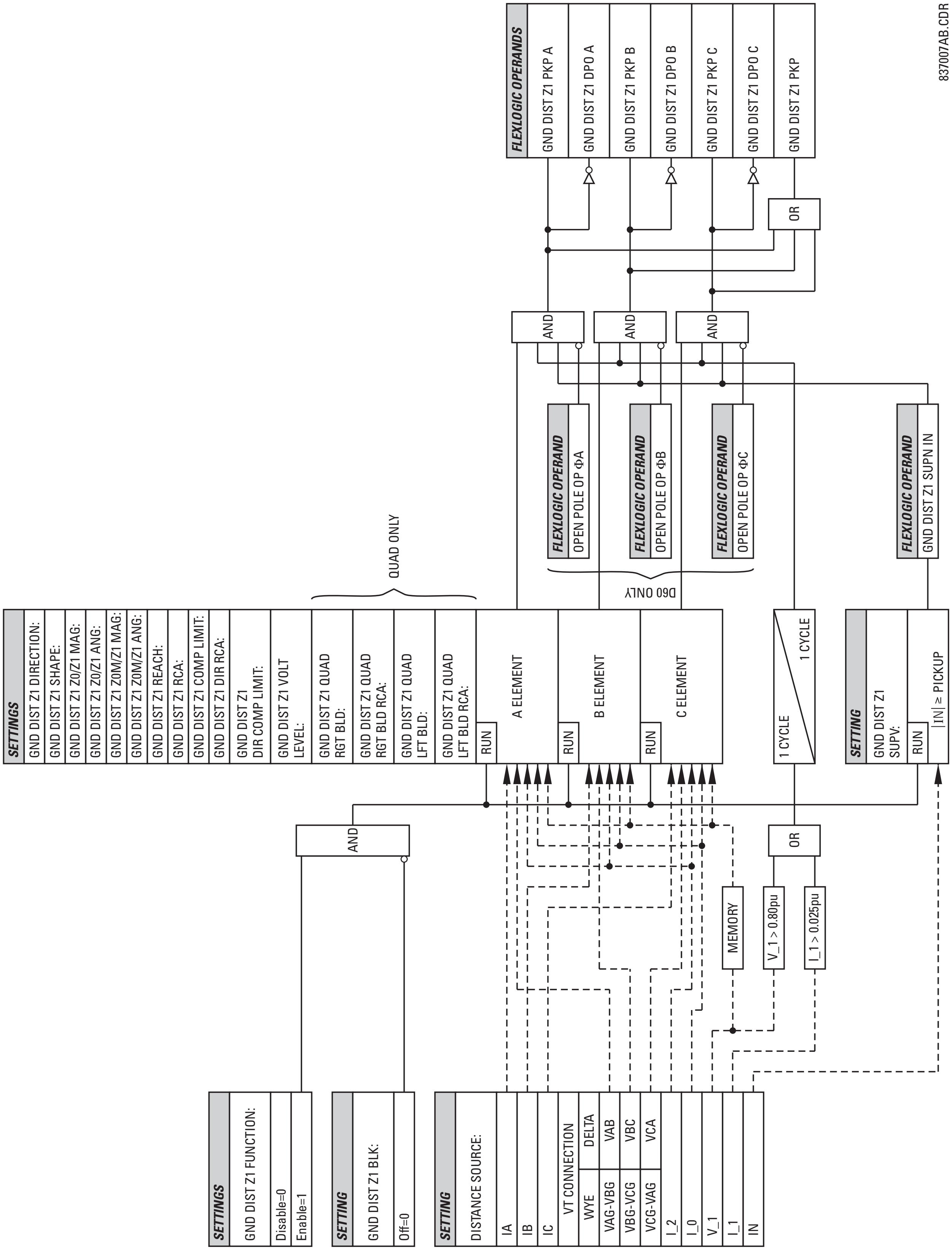

Figure 5–25: GROUND DISTANCE Z1 SCHEME LOGIC

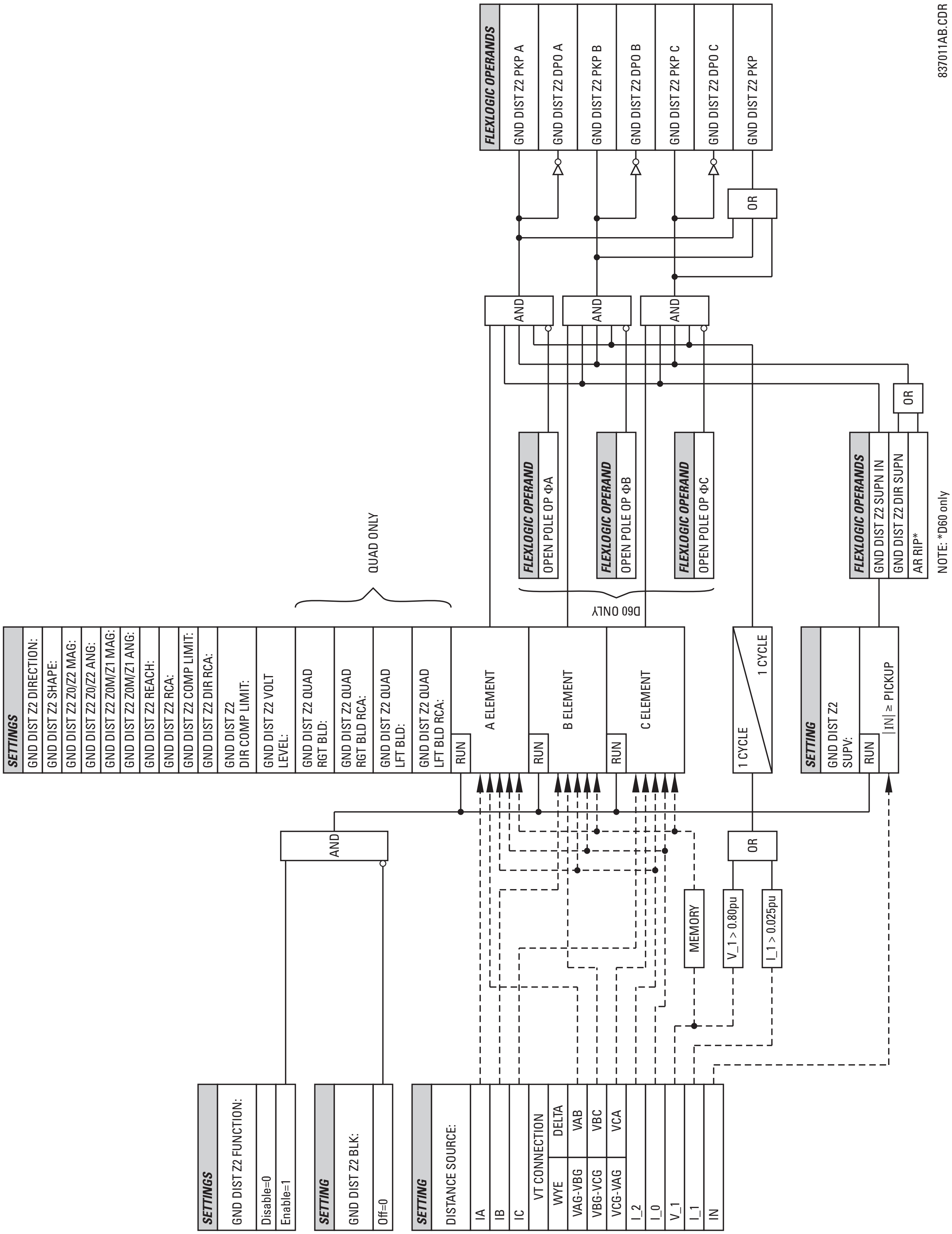

Figure 5–26: GROUND DISTANCE Z2 TO Z4 SCHEME LOGIC

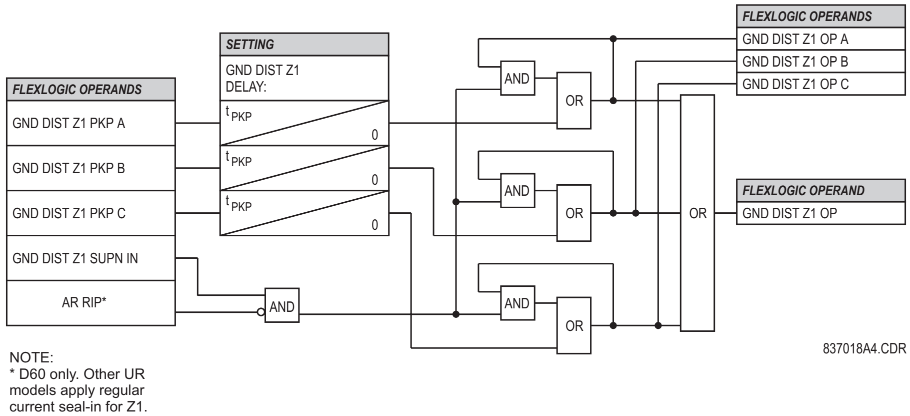

Figure 5–27: GROUND DISTANCE Z1 OP SCHEME

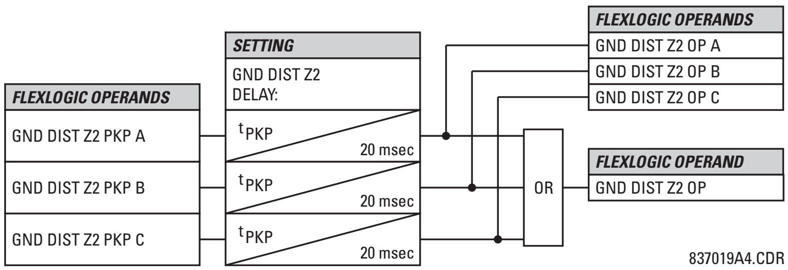

Figure 5–28: GROUND DISTANCE Z2 TO Z4 OP SCHEME

GROUND DIRECTIONAL SUPERVISION:

A dual (zero- 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 a maloperation 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 4 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 will have high polarizing levels so that a correct reverse fault decision can be reliably made. The supervision for Zones 2 and 3 is removed during single-pole reclosure.

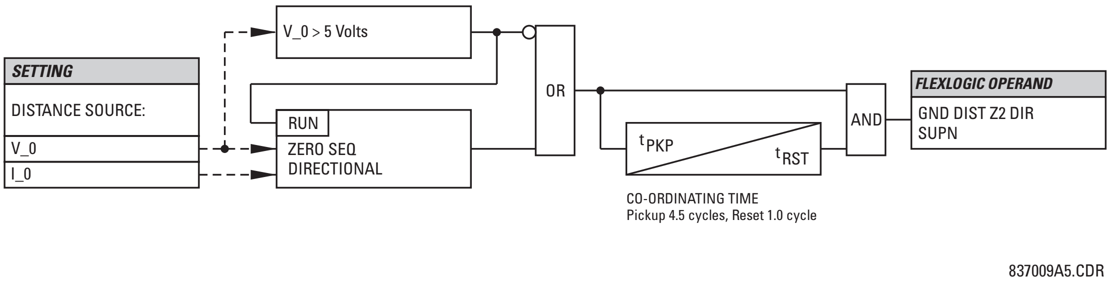

Figure 5–29: GROUND DIRECTIONAL SUPERVISION SCHEME LOGIC – Z2, Z3, Z4

5.5.5 POWER SWING DETECT

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ POWER SWING DETECT

■ POWER SWING ■ DETECT	POWER SWING FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	POWER SWING SOURCE: SRC 1	Range: SRC 1,..., SRC 6
MESSAGE	POWER SWING MODE: Two Step	Range: Two Step, Three Step
MESSAGE	POWER SWING SUPV: 0.600 pu	Range: 0.050 to 30.000 pu in steps of 0.001
MESSAGE	POWER SWING FWD REACH: 50.00 ohms	Range: 0.10 to 500.00 ohms in steps of 0.01
MESSAGE	POWER SWING FWD RCA: 75°	Range: 40 to 90° in steps of 1
MESSAGE	POWER SWING REV REACH: 50.00 ohms	Range: 0.10 to 500.00 ohms in steps of 0.01
MESSAGE	POWER SWING REV RCA: 75°	Range: 40 to 90° in steps of 1
MESSAGE	POWER SWING OUTER LIMIT ANGLE: 120°	Range: 40 to 140° in steps of 1
MESSAGE	POWER SWING MIDDLE LIMIT ANGLE: 90°	Range: 40 to 140° in steps of 1
MESSAGE	POWER SWING INNER LIMIT ANGLE: 60°	Range: 40 to 140° in steps of 1
MESSAGE	POWER SWING PICKUP DELAY 1: 0.030 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING RESET DELAY 1: 0.050 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING PICKUP DELAY 2: 0.017 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING PICKUP DELAY 3: 0.009 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING PICKUP DELAY 4: 0.017 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING SEAL-IN DELAY 1: 0.400 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	POWER SWING TRIP MODE: Delayed	Range: Early, Delayed
MESSAGE	POWER SWING BLK: Off	Range: Flexlogic™ operand
MESSAGE	POWER SWING TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
MESSAGE	POWER SWING EVENTS: Disabled	Range: Disabled, Enabled

5

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 as per user choice. Upon detecting appropriate timing relations, the blocking and/or tripping indication is given through FlexLogic™ operands. The POWER SWING OPERATING CHARACTERISTICS and POWER SWING LOGIC figures should be viewed along with the following discussion to develop an understanding of the operation of the element.

a) POWER SWING BLOCKING

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 (as indicated by setting of the POWER SWING OUTER FlexLogic™ operand) but stays outside the middle characteristic (as indicated by setting of the POWER SWING MIDDLE FlexLogic™ operand) for an interval longer than **POWER SWING PICKUP DELAY 1** 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 after **POWER SWING RESET DELAY 1** time.

Two-step operation:

If the 2-step mode is selected, the sequence is identical, but it is the outer and inner characteristics that are used to time the power swing locus.

b) OUT-OF-STEP TRIPPING

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 timer **POWER SWING PICKUP DELAY 1** 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 as **POWER SWING PICKUP DELAY 2**, 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 as **POWER SWING PICKUP DELAY 3**, 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, operand POWER SWING TRIP is set immediately and is sealed-in for the interval established by setting **POWER SWING SEAL-IN DELAY**.

If the "Delayed" trip mode is selected, the element waits until the impedance locus leaves the inner characteristic, then times out the **POWER SWING PICKUP DELAY 2** delay, and sets Latch 4 - the element is now ready to trip. The trip operand will be set later, when the impedance locus leaves the outer characteristic.

Two-step operation:

The 2-step mode of operation is similar to the 3-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 timer POWER SWING PICKUP DELAY 2 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.

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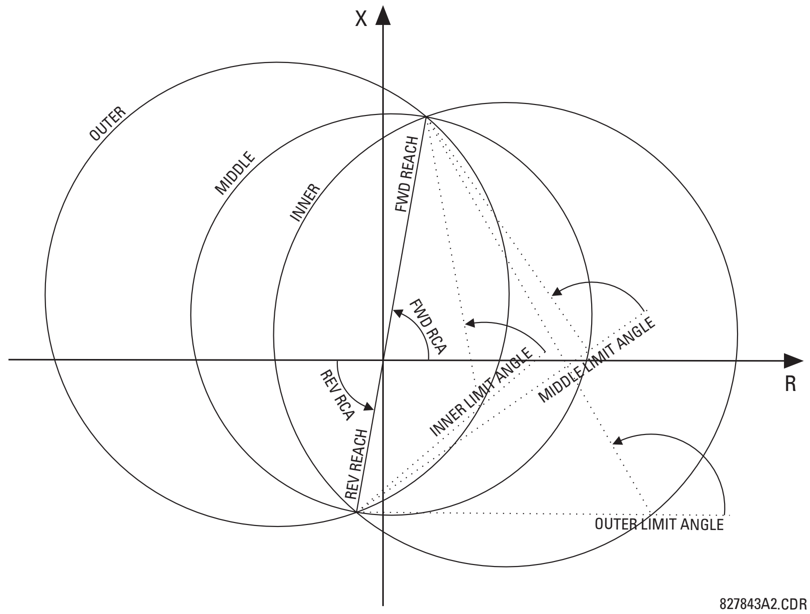

Figure 5–30: POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS

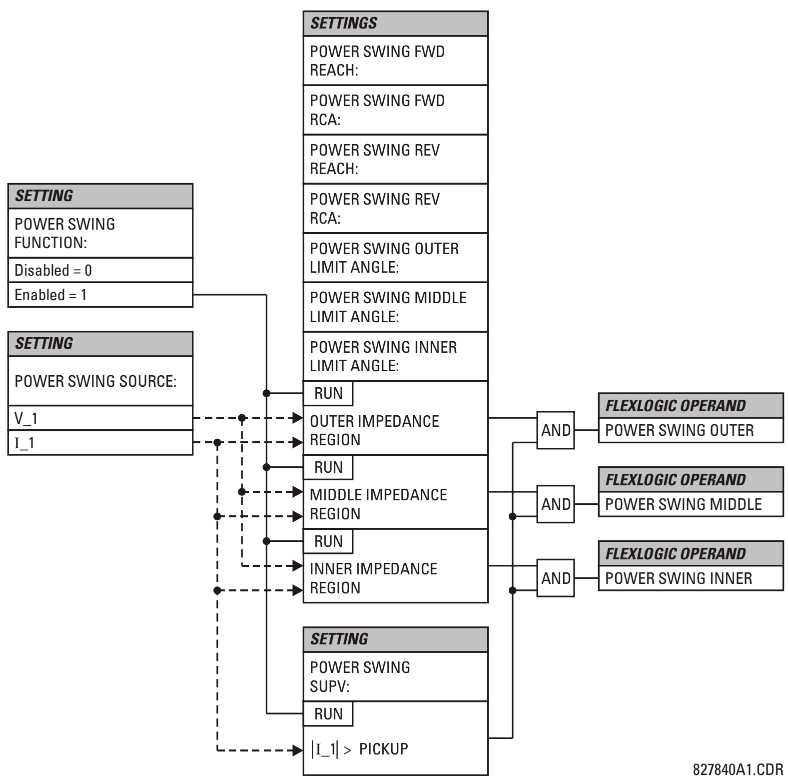

Figure 5–31: POWER SWING DETECT LOGIC (1 of 2)

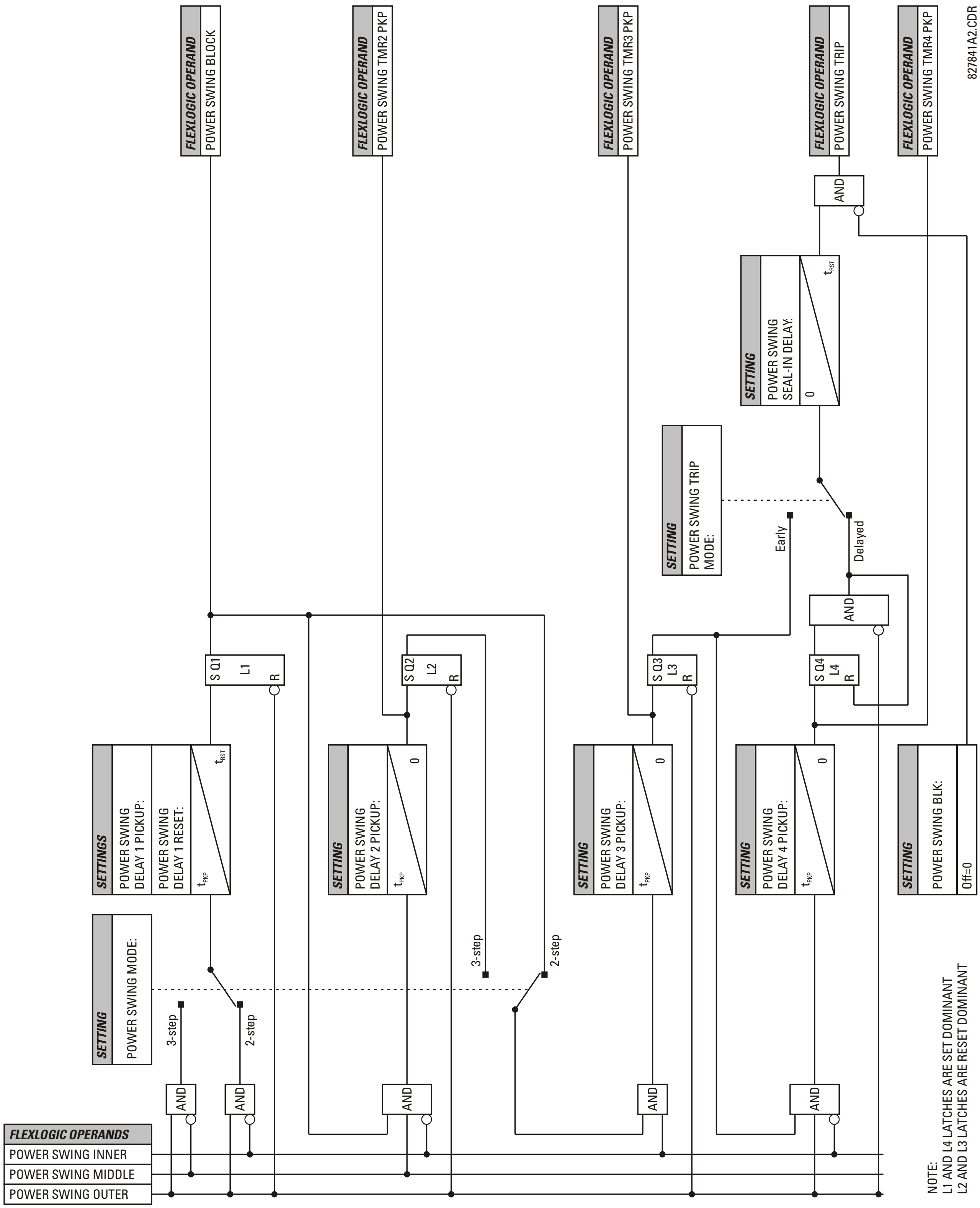

Figure 5–32: POWER SWING DETECT LOGIC (2 of 2)

c) SETTINGS

POWER SWING FUNCTION:

This setting enables/disables the entire POWER SWING DETECT protection element. The setting applies to both power swing blocking and out-of-step tripping functions.

POWER SWING SOURCE:

The source setting identifies the Signal Source for both blocking and tripping functions.

POWER SWING MODE:

This setting selects between the 2-step and 3-step operating modes and applies to both power swing blocking and out-of-step tripping functions.

The 3-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 should be determined by analysis of the fastest power swings expected in correlation with settings of the power swing timers.

The 2-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.

POWER SWING SUPV:

A common overcurrent pickup level supervises all three power swing characteristics. The supervision responds to the positive sequence current.

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POWER SWING FWD REACH:

This setting specifies the forward reach of all three characteristics. For a simple system consisting of a line and two equivalent sources, this reach should be higher than the sum of the line and remote source positive-sequence impedances. Detailed transient stability studies may be needed for complex systems in order to determine this setting.

POWER SWING FWD RCA:

This setting specifies the angle of the forward reach impedance. The angle is measured as shown in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram.

POWER SWING REV REACH:

This setting specifies the reverse reach of all three power detect characteristics. For a simple system consisting of a line and two equivalent sources, this reach should be higher than the positive-sequence impedance of the local source. Detailed transient stability studies may be needed for complex systems in order to determine this setting.

POWER SWING REV RCA:

This setting specifies the angle of the reverse reach impedance. The angle is measured as shown in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram.

POWER SWING OUTER LIMIT ANGLE:

This setting defines the outer power swing detect characteristic. The convention depicted in the POWER SWING DETECT ELEMENT OPERATING CHARACTERISTICS diagram should be observed: values greater than 90° result in an "apple" shaped characteristic, values lower than 90° result in a lens shaped characteristic. This angle must be selected in consideration of to the maximum expected load. If the "maximum load angle" is known, the outer limit angle should be coordinated with some 20° security margin. Detailed studies may be needed for complex systems in order to determine this setting.

POWER SWING MIDDLE LIMIT ANGLE:

This setting defines the middle power swing detect characteristic. This setting is relevant only if the 3-step mode is selected. A typical value would be close to the average of the outer and inner limit angles.

POWER SWING INNER LIMIT ANGLE:

This setting defines 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 may 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.

The inner characteristic is also used by the power swing blocking function in the 2-step mode. Therefore, this angle must be set large enough so that the characteristics of the distance elements are safely enclosed by the inner characteristic.

POWER SWING PICKUP DELAY 1:

All the coordinating timers are related to each other and should be set to detect the fastest expected power swing and produce out-of-step tripping in a secure manner. The timers should be set in consideration 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 (2-step operating mode), or between the outer and middle characteristics (3-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.

POWER SWING RESET DELAY 1:

This setting defines the dropout delay for the power swing blocking signal. Detection of a condition requiring a Block output sets Latch 1 after **PICKUP DELAY 1** time. When the impedance locus leaves the outer characteristic, timer **POWER SWING RESET DELAY 1** is started. When the timer times-out the latch is reset.

This setting should be selected to give extra security for the power swing blocking action.

POWER SWING PICKUP DELAY 2:

This setting controls the out-of-step tripping function in the 3-step mode only. This timer defines 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.

POWER SWING PICKUP DELAY 3:

This setting controls the out-of-step tripping function only. This timer 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.

POWER SWING PICKUP DELAY 4:

This setting controls the out-of-step tripping function in the Delayed trip mode only. This timer defines the interval the impedance locus must spend outside the inner characteristic but within the outer characteristic before the element gets armed for the Delayed trip. The delayed trip will take place when the impedance leaves the outer characteristic.

This time delay is provided for extra security and should be set considering the fastest expected power swing.

POWER SWING SEAL-IN DELAY:

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.

POWER SWING TRIP MODE:

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 will stress 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 will relax the operating conditions for the breakers as the currents at that moment are low.

The selection should be made considering the capability of the breakers in the system.

POWER SWING BLK:

This setting specifies 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.

5.5.6 LOAD ENCROACHMENT

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ LOAD ENCROACHMENT

■ LOAD ENCROACHMENT ■	LOAD ENCROACHMENT FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	LOAD ENCROACHMENT SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	LOAD ENCROACHMENT MIN VOLT: 0.250 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	LOAD ENCROACHMENT REACH: 1.00 Ω	Range: 0.02 to 250.00 ohms in steps of 0.01
MESSAGE	LOAD ENCROACHMENT ANGLE: 30°	Range: 5 to 50° in steps of 1
MESSAGE	LOAD ENCROACHMENT PKP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LOAD ENCROACHMENT RST DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	LOAD ENCRMNT BLK: Off	Range: Flexlogic™ operand
MESSAGE	LOAD ENCROACHMENT TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	LOAD ENCROACHMENT EVENTS: Disabled	Range: Disabled, Enabled

The Load Encroachment element responds to the positive-sequence impedance and applies a characteristic shown in the figure below.

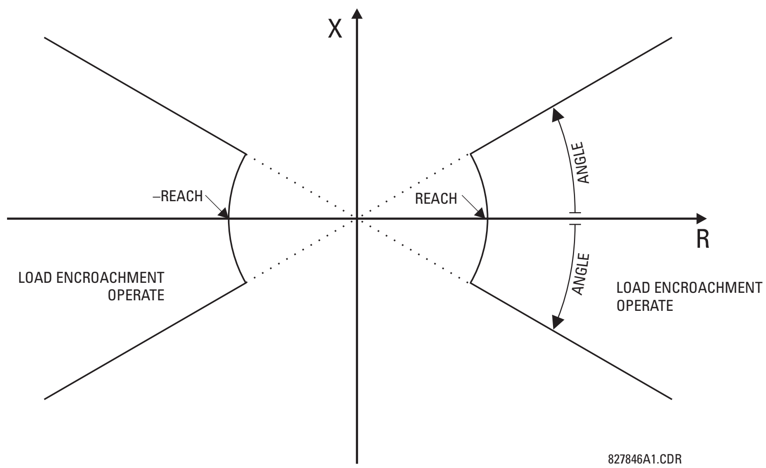

Figure 5–33: LOAD ENCROACHMENT CHARACTERISTIC

The element operates if the positive-sequence voltage is above a settable 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 QUAD distance element.

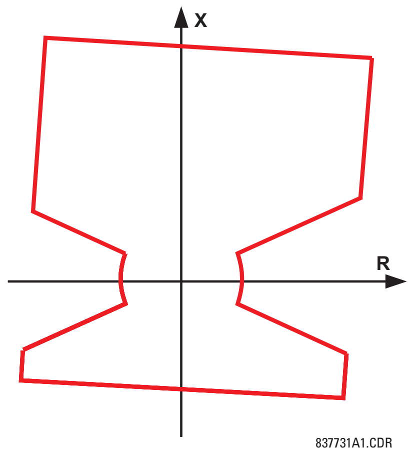

Figure 5–34: LOAD ENCROACHMENT APPLIED TO DISTANCE ELEMENT

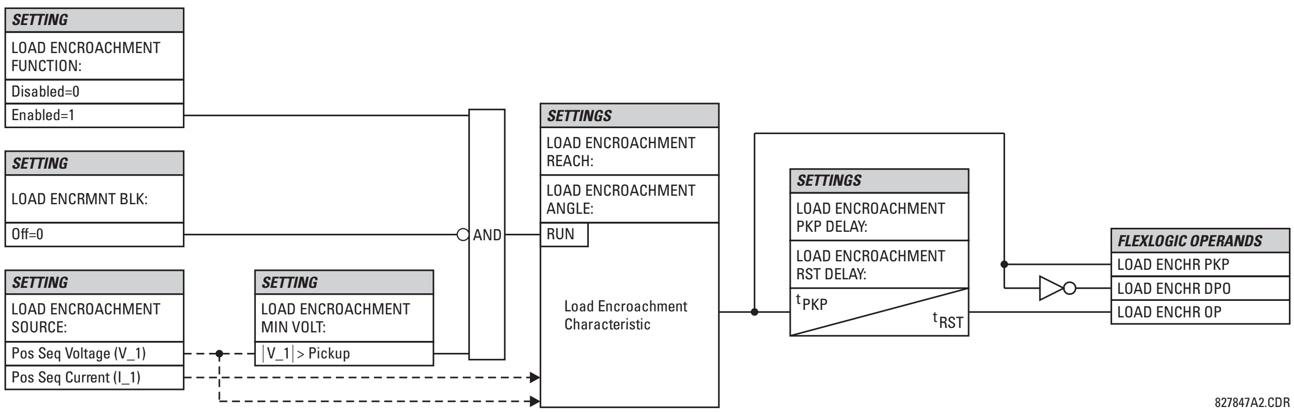

Figure 5–35: LOAD ENCROACHMENT SCHEME LOGIC

LOAD ENCROACHMENT MIN VOLT:

This setting specifies the minimum positive-sequence voltage required for operation of the element. If the voltage is below this threshold a blocking signal will not be asserted by the element. When selecting this setting one must remember that the UR measures the phase-to-ground sequence voltages regardless of the VT connection.

The nominal VT secondary voltage as specified under **PATH: SYSTEM SETUP ⇨⇩ AC INPUTS ⇨ VOLTAGE BANK X1 ⇨⇩ PHASE VT SECONDARY** is the p.u. base for this setting.

LOAD ENCROACHMENT REACH:

This setting specifies the resistive reach of the element as shown in the LOAD ENCROACHMENT CHARACTERISTIC diagram. This setting applies to the positive sequence impedance and should be entered in secondary ohms and should be calculated as the positive-sequence resistance seen by the relay under maximum load conditions and unity power factor.

LOAD ENCROACHMENT ANGLE:

This setting specifies the size of the blocking region as shown on the LOAD ENCROACHMENT CHARACTERISTIC and applies to the positive sequence impedance.

5.5.7 CURRENT ELEMENTS

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨

■ PHASE CURRENT ■		■ PHASE TOC1 ■
	MESSAGE	■ PHASE TOC2 ■
	MESSAGE	■ PHASE IOC1 ■
	MESSAGE	■ PHASE IOC2 ■
	MESSAGE	■ PHASE ■ DIRECTIONAL 1
	MESSAGE	■ PHASE ■ DIRECTIONAL 2
■ NEUTRAL CURRENT ■		■ NEUTRAL TOC1 ■
	MESSAGE	■ NEUTRAL TOC2 ■
	MESSAGE	■ NEUTRAL IOC1 ■
	MESSAGE	■ NEUTRAL IOC2 ■
	MESSAGE	■ NEUTRAL ■ DIRECTIONAL OC1
	MESSAGE	■ NEUTRAL ■ DIRECTIONAL OC2
■ GROUND CURRENT ■		■ GROUND TOC1 ■
	MESSAGE	■ GROUND TOC2 ■
	MESSAGE	■ GROUND IOC1 ■
	MESSAGE	■ GROUND IOC2 ■
■ NEGATIVE SEQUENCE ■ CURRENT		■ NEG SEQ TOC1 ■
	MESSAGE	■ NEG SEQ TOC2 ■
	MESSAGE	■ NEG SEQ IOC1 ■
	MESSAGE	■ NEG SEQ IOC2 ■
	MESSAGE	■ NEG SEQ DIR OC1 ■

5

MESSAGE ■ NEG SEQ DIR OC2
■

The relay current elements menu consists of time overcurrent (TOC) , instantaneous overcurrent (IOC), and directional current elements. These elements can be used for tripping, alarming, or other functions.

5.5.8 INVERSE TOC CURVE CHARACTERISTICS

The inverse time overcurrent curves used by the TOC (time overcurrent) Current 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, the FlexCurve™ may be used to customize the inverse time curve characteristics. The Definite Time curve is also an option that may be appropriate if only simple protection is required.

Table 5–15: OVERCURRENT CURVE TYPES

IEEE	IEC	GE TYPE IAC	OTHER
IEEE Extremely Inv.	IEC Curve A (BS142)	IAC Extremely Inv.	I^2t
IEEE Very Inverse	IEC Curve B (BS142)	IAC Very Inverse	FlexCurve A
IEEE Moderately Inv.	IEC Curve C (BS142)	IAC Inverse	FlexCurve B
	IEC Short Inverse	IAC Short Inverse	Definite Time

A time dial multiplier setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape (**CURVE**) setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier (**TD 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 will operate. 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 resetting operation are available: “Instantaneous” and “Timed”. The Instantaneous selection 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 selection can be used where the relay must coordinate with electromechanical relays. With this setting, the energy capacity variable is decremented according to the equation provided.

NOTE

Graphs of standard time-current curves on 11” × 17” log-log graph paper are available upon request from the GE Power Management literature department. The original files are also available in PDF format on the UR Software Installation CD and the GE Power Management Web Page.

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. The IEEE curves are derived from the formulae:

$$T = TDM \times \left[\frac{A}{\left(\frac{I}{I_{pickup}}\right)^p - 1} + B \right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}}\right)^2 - 1} \right]$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
A, B, p = Constants
T_{RESET} = reset time in sec. (assuming energy capacity is 100% and RESET: Timed)
t_r = characteristic constant

Table 5–16: 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

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Table 5–17: 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
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 relay 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 formulae for these curves are:

$$T = TDM \times \left[\frac{K}{\left(\frac{I}{I_{pickup}}\right)^{E} - 1}\right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}}\right)^{2} - 1}\right]$$

where: T = Operate Time (sec.) TDM = Multiplier Setting I = Input Current
I_{pickup} = Pickup Current Setting K, E = Constants t_r = Characteristic Constant
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–18: IEC (BS) INVERSE TIME CURVE CONSTANTS

IEC (BS) 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 5–19: IEC 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
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 TIME										
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:

$$T = \text{TDM} \times \left[A + \frac{B}{\left(\frac{I}{I_{pickup}} - C\right)} + \frac{D}{\left(\frac{I}{I_{pickup}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{pickup}} - C\right)^3} \right] \qquad T_{RESET} = TDM \times \left[\frac{t_r}{\left(\frac{I}{I_{pickup}}\right)^2 - 1} \right]$$

where: T = Operate Time (sec.) TDM = Multiplier Setting I = Input Current
I_{pickup} = Pickup Current Setting A to E = Constants t_r = Characteristic Constant
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–20: 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 5–21: IAC CURVE TRIP TIMES

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 curves for the I^2t are derived from the formulae:

$$T = \text{TDM} \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^2} \right] \qquad T_{RESET} = \text{TDM} \times \left[\frac{100}{\left(\frac{I}{I_{pickup}} \right)^{-2}} \right]$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

Table 5–22: I^2t CURVE TRIP TIMES

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

FLEXCURVE™:

The custom FlexCurve™ is described in detail in the FLEXCURVE™ section of this chapter. The curve shapes for the FlexCurves™ are derived from the formulae:

$$T = \text{TDM} \times \left[\text{FlexcurveTime@}\left(\frac{I}{I_{pickup}} \right) \right] \qquad \text{When } \left(\frac{I}{I_{pickup}} \right) \geq 1.00$$

$$T_{RESET} = \text{TDM} \times \left[\text{FlexcurveTime@}\left(\frac{I}{I_{pickup}} \right) \right] \qquad \text{When } \left(\frac{I}{I_{pickup}} \right) \leq 0.98$$

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in seconds (assuming energy capacity is 100% and RESET: 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.

T = TDM in seconds, when $I > I_{pickup}$

T_{RESET} = –TDM in seconds

where: T = Operate Time (sec.)
TDM = Multiplier Setting
I = Input Current
I_{pickup} = Pickup Current Setting
T_{RESET} = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

5

5.5.9 PHASE CURRENT

a) PHASE TOC1 / TOC2 (PHASE TIME OVERCURRENT: ANSI 51P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE TOC1

■ PHASE TOC1 ■		PHASE TOC1 FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	PHASE TOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
	MESSAGE	PHASE TOC1 INPUT: Phasor	Range: Phasor, RMS
	MESSAGE	PHASE TOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
	MESSAGE	PHASE TOC1 CURVE: IEEE Mod Inv	Range: See OVERCURRENT CURVE TYPES table
	MESSAGE	PHASE TOC1 TD MULTIPLIER: 1.00	Range: 0.00 to 600.00 in steps of 0.01
	MESSAGE	PHASE TOC1 RESET: Instantaneous	Range: Instantaneous, Timed
	MESSAGE	PHASE TOC1 VOLTAGE RESTRAINT: Disabled	Range: Disabled, Enabled
	MESSAGE	PHASE TOC1 BLOCK A: Off	Range: FlexLogic™ operand
	MESSAGE	PHASE TOC1 BLOCK B: Off	Range: FlexLogic™ operand
	MESSAGE	PHASE TOC1 BLOCK C: Off	Range: FlexLogic™ operand
	MESSAGE	PHASE TOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
	MESSAGE	PHASE TOC1 EVENTS: Disabled	Range: Disabled, Enabled

The phase 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 phase current input quantities may 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” (refer to the INVERSE TOC CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator will be cleared 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-phase voltages of the voltage restraint characteristic curve (see the figure below); the pickup level is calculated as ‘Mvr’ times the PICKUP setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

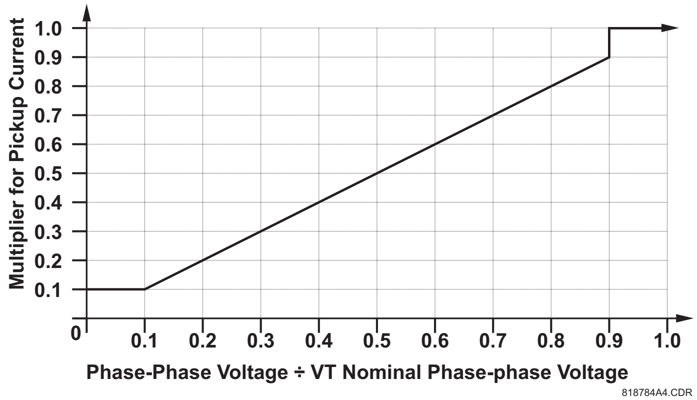

Figure 5–36: VOLTAGE RESTRAINT CHARACTERISTIC FOR PHASE TOC

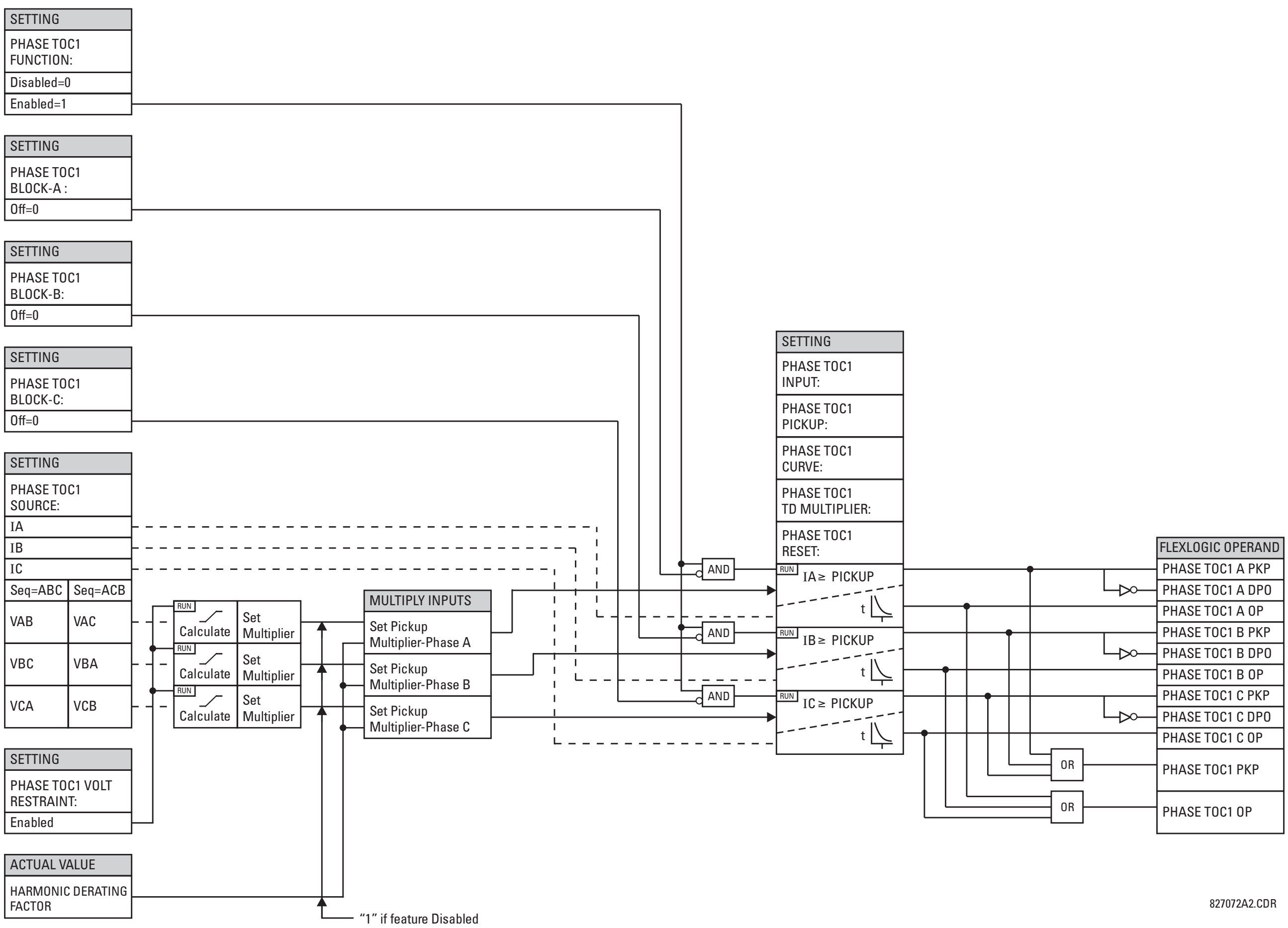

Figure 5–37: PHASE TOC1 SCHEME LOGIC

b) PHASE IOC1 / IOC2 (PHASE INSTANTANEOUS OVERCURRENT: ANSI 50P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE IOC 1

■ PHASE IOC1 ■	PHASE IOC1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	PHASE IOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	PHASE IOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
MESSAGE	PHASE IOC1 PICKUP DELAY: 0.00 s	Range: 0.00 to 600.00 in steps of 0.01
MESSAGE	PHASE IOC1 RESET DELAY: 0.00 s	Range: 0.00 to 600.00 in steps of 0.01
MESSAGE	PHASE IOC1 BLOCK A: Off	Range: FlexLogic™ operand
MESSAGE	PHASE IOC1 BLOCK B: Off	Range: FlexLogic™ operand
MESSAGE	PHASE IOC1 BLOCK C: Off	Range: FlexLogic™ operand
MESSAGE	PHASE IOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	PHASE IOC1 EVENTS: Disabled	Range: Disabled, Enabled

The phase instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a Definite Time element. The input current is the fundamental phasor magnitude.

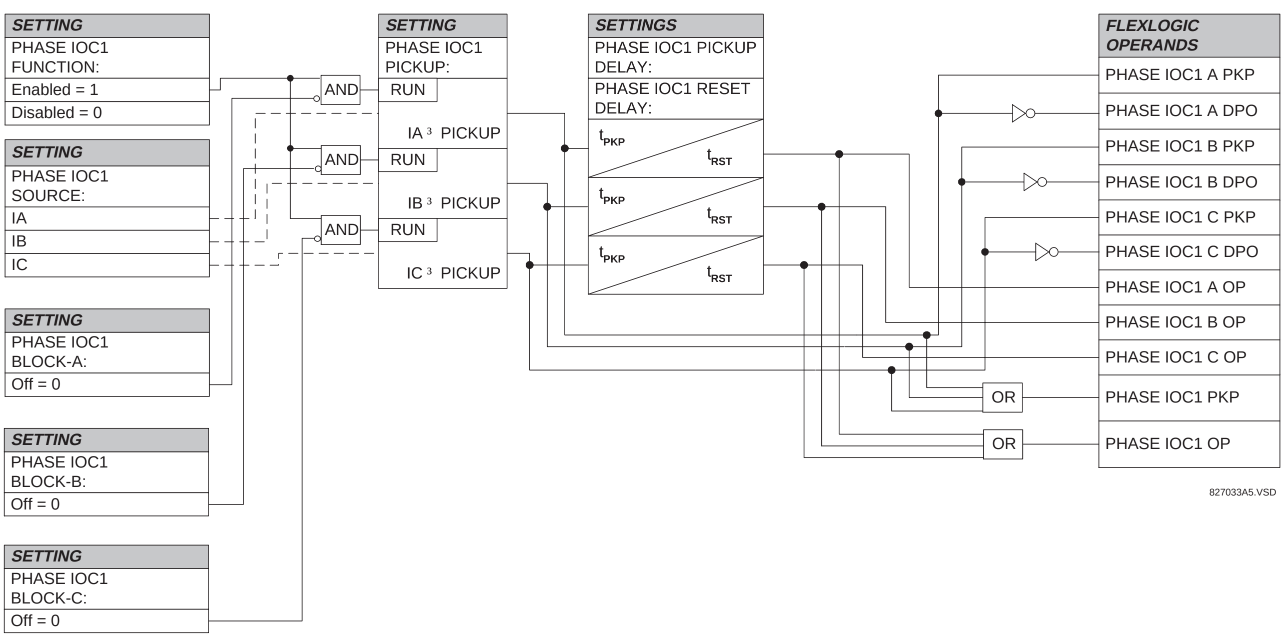

Figure 5–38: PHASE IOC1 SCHEME LOGIC

c) PHASE DIRECTIONAL 1(2) (PHASE DIRECTIONAL OVERCURRENT: ANSI 67P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ PHASE CURRENT ⇨ PHASE DIRECTIONAL 1

■ PHASE ■ DIRECTIONAL 1	◀▶	PHASE DIR 1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	▲▼	PHASE DIR 1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	▲▼	PHASE DIR 1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	▲▼	PHASE DIR 1 ECA: 30	*Range: 0 to 359° in steps of 1*
MESSAGE	▲▼	PHASE DIR POL V1 THRESHOLD:0.050 pu	*Range: 0.000 to 3.000 pu in steps of 0.001*
MESSAGE	▲▼	PHASE DIR 1 BLOCK WHEN V MEM EXP: No	*Range: No, Yes*
MESSAGE	▲▼	PHASE DIR 1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	▲	PHASE DIR 1 EVENTS: Disabled	*Range: Disabled, Enabled*

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.

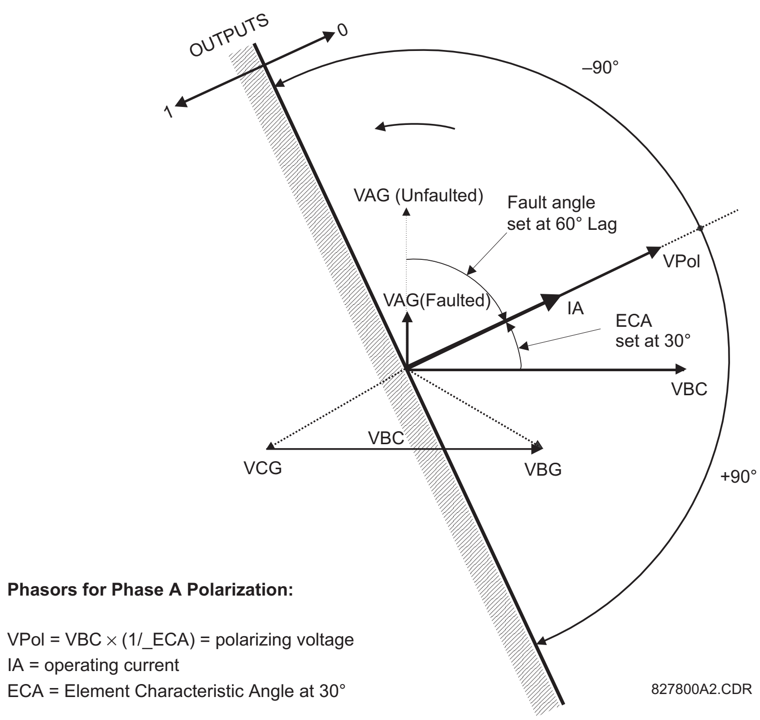

Figure 5–39: PHASE A DIRECTIONAL POLARIZATION

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 ECA settings.

5

To increase security for three phase faults very close to the location of the VTs used to measure the polarizing voltage, a ‘voltage memory’ feature is incorporated. This feature remembers the measurement of 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 following table shows the operating and polarizing signals used for phase directional control:

PHASE	OPERATING SIGNAL	POLARIZING SIGNAL VPOL	
		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)

MODE OF OPERATION:

- When the Phase Directional function is "Disabled", or the operating current is below 5% × CT Nominal, the element output is "0".
- When the Phase Directional function is "Enabled", the operating current is above 5% × CT Nominal and the polarizing voltage is above the set threshold, the element output depends on the phase angle between the operating and polarizing signals as follows:

  – 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 **BLOCK WHEN V MEM EXP** is set to "Yes", the directional element will block 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 when voltage memory expires.

In all cases, directional blocking will be permitted to resume when the polarizing voltage becomes greater than the "polarizing voltage threshold".

SETTINGS:

PHASE DIR 1 SIGNAL SOURCE:

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).

PHASE DIR 1 ECA:

This setting is used to select the Element Characteristic Angle, i.e. the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of UR elements, a block is applied to an element by asserting logic 1 at the blocking input. This element should be programmed via the ECA setting so that the output is **logic 1 for current in the non-tripping direction**.

PHASE DIR 1 POL V THRESHOLD:

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. The default value is 0.05 pu.

PHASE DIR 1 BLOCK WHEN V MEM EXP:

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.

NOTE

The Phase Directional element would respond to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 msec – to establish a blocking signal. Some protection elements such as instantaneous overcurrent may respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 msec must be added to all the instantaneous protection elements under the supervision of the Phase Directional element. If current reversal is of a concern, a longer delay – in the order of 20 msec – may be needed.

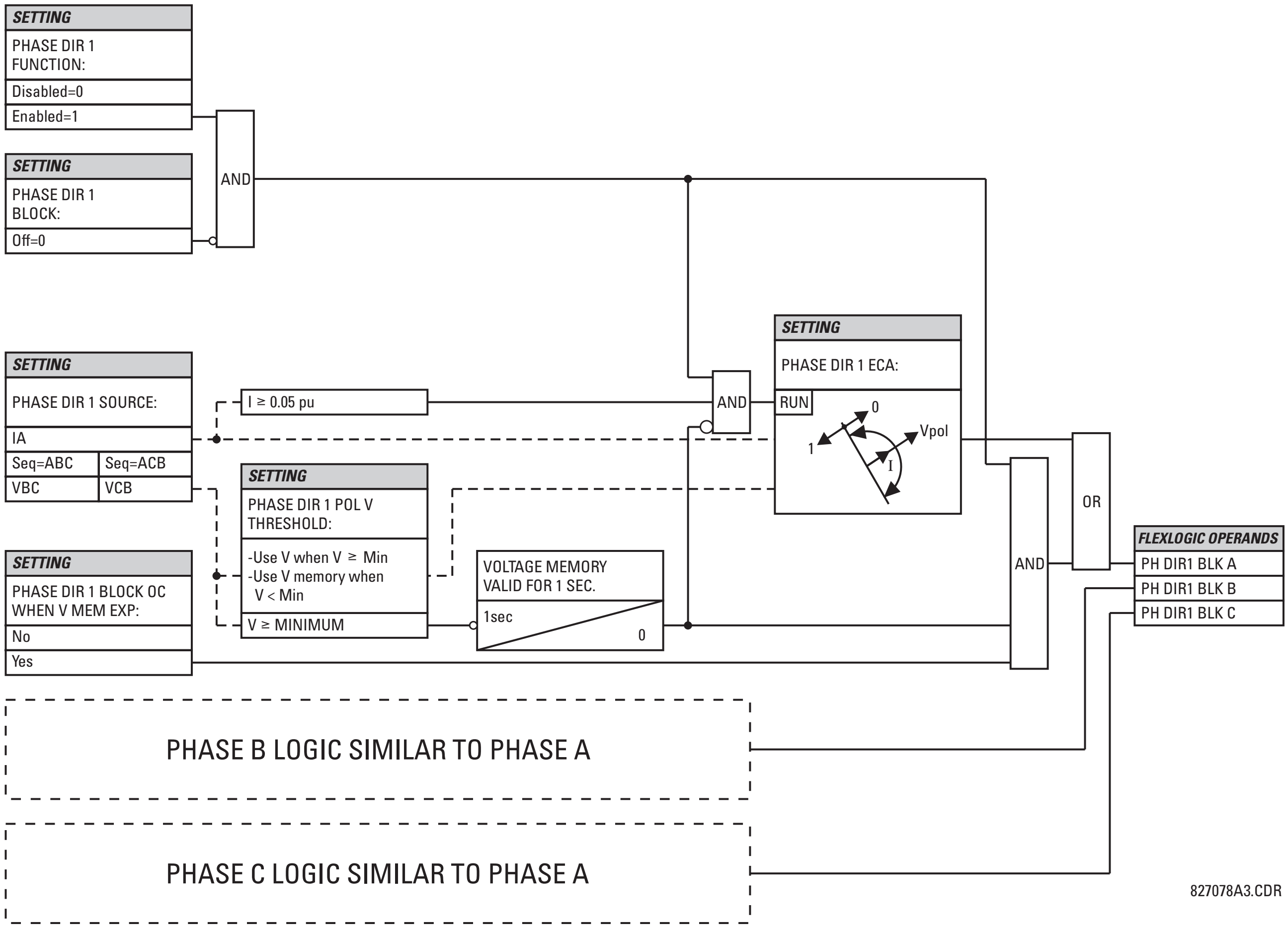

Figure 5–40: PHASE DIRECTIONAL SCHEME LOGIC

5

5.5.10 NEUTRAL CURRENT

a) NEUTRAL TOC1 / TOC2 (NEUTRAL TIME OVERCURRENT: ANSI 51N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEUTRAL CURRENT ⇨ NEUTRAL TOC1

■ NEUTRAL TOC1 ■	NEUTRAL TOC1 FUNCTION: Disabled	Range: *Disabled, Enabled*
MESSAGE	NEUTRAL TOC1 SIGNAL SOURCE: SRC 1	Range: *SRC 1, SRC 2,..., SRC 6*
MESSAGE	NEUTRAL TOC1 INPUT: Phasor	Range: *Phasor, RMS*
MESSAGE	NEUTRAL TOC1 PICKUP: 1.000 pu	Range: *0.000 to 30.000 pu in steps of 0.001*
MESSAGE	NEUTRAL TOC1 CURVE: IEEE Mod Inv	Range: *See OVERCURRENT CURE TYPES table*
MESSAGE	NEUTRAL TOC1 TD MULTIPLIER: 1.00	Range: *0.00 to 600.00 in steps of 0.01*
MESSAGE	NEUTRAL TOC1 RESET: Instantaneous	Range: *Instantaneous, Timed*
MESSAGE	NEUTRAL TOC1 BLOCK: Off	Range: *FlexLogic™ operand*
MESSAGE	NEUTRAL TOC1 TARGET: Self-reset	Range: *Self-reset, Latched, Disabled*
MESSAGE	NEUTRAL TOC1 EVENTS: Disabled	Range: *Disabled, Enabled*

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 3Io from the phase currents and may 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” (refer to the INVERSE TOC CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator will be cleared immediately.

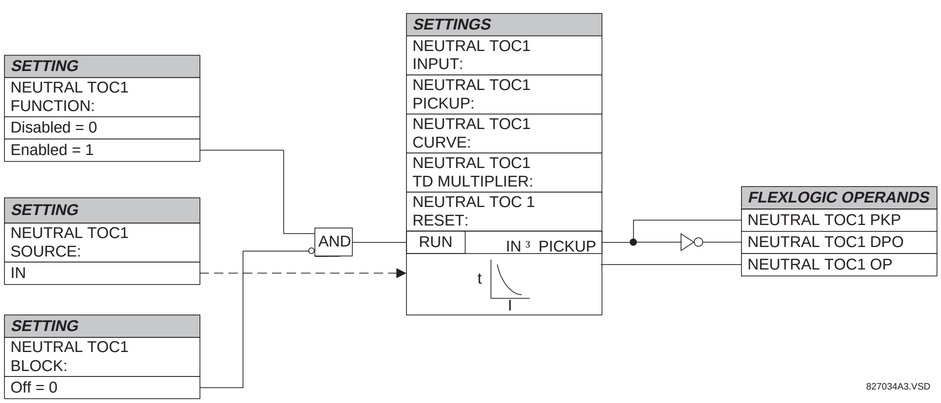

Figure 5–41: NEUTRAL TOC1 SCHEME LOGIC

NOTE

Once picked up, the NEUTRAL TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless NEUTRL TOCx RESET is set to "Instantaneous".

b) NEUTRAL IOC1 / IOC2 (NEUTRAL INSTANTANEOUS OVERCURRENT: ANSI 50N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL IOC1

■ NEUTRAL IOC1 ■		NEUTRAL IOC1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE		NEUTRAL IOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE		NEUTRAL IOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
MESSAGE		NEUTRAL IOC1 PICKUP DELAY: 0.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE		NEUTRAL IOC1 RESET DELAY: 0.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE		NEUTRAL IOC1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE		NEUTRAL IOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE		NEUTRAL IOC1 EVENTS: Disabled	Range: Disabled, Enabled

The Neutral Instantaneous Overcurrent element may 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:

$$I_{op} = 3 \times (|I\_0| - K \cdot |I\_1|) \quad , \text{ where } K = 1/16.$$

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 (single-phase injection: $I_{op} = 0.9375 \cdot I_{injected}$; three-phase pure zero-sequence injection: $I_{op} = 3 \times I_{injected}$).

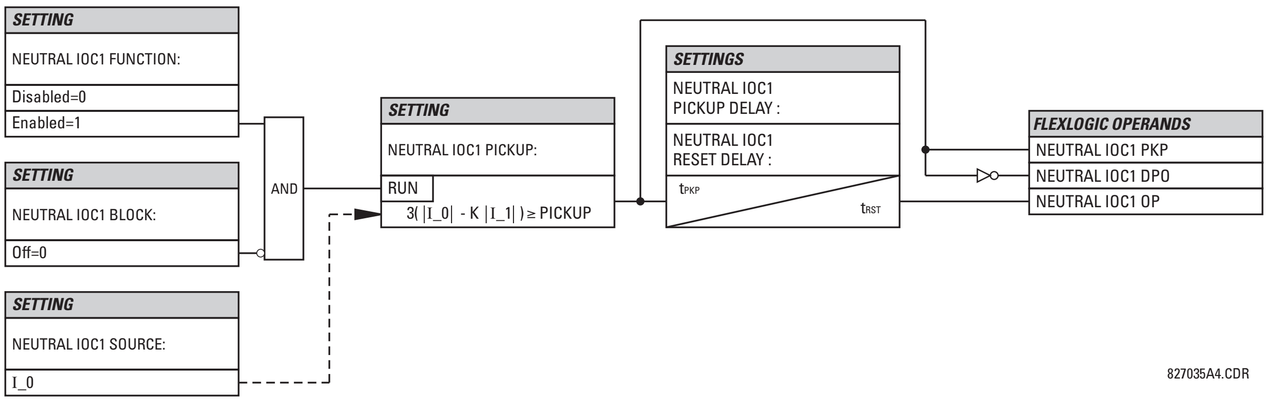

Figure 5–42: NEUTRAL IOC1 SCHEME LOGIC

c) NEUTRAL DIRECTIONAL OC1 / OC2 (NEUTRAL DIRECTIONAL OVERCURRENT: ANSI 67N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨ NEUTRAL CURRENT ⇨⇩ NEUTRAL DIRECTIONAL OC1

■ NEUTRAL ■ DIRECTIONAL OC1	NEUTRAL DIR OC1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	NEUTRAL DIR OC1 SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	NEUTRAL DIR OC1 POLARIZING: Voltage	Range: Voltage, Current, Dual
MESSAGE	NEUTRAL DIR OC1 POL VOLT: Calculated V0	Range: Calculated V0, Measured VX
MESSAGE	NEUTRAL DIR OC1 OP CURR: Calculated 3I0	Range: Calculated 3I0, Measured IG
MESSAGE	NEUTRAL DIR OC1 OFFSET: 0.00 Ω	Range: 0.00 to 250.00 Ω in steps of 0.01
MESSAGE	NEUTRAL DIR OC1 FWD ECA: 75° Lag	Range: –90 to 90° in steps of 1
MESSAGE	NEUTRAL DIR OC1 FWD LIMIT ANGLE: 90°	Range: 40 to 90° in steps of 1
MESSAGE	NEUTRAL DIR OC1 FWD PICKUP: 0.050 pu	Range: 0.002 to 30.000 pu in steps of 0.001
MESSAGE	NEUTRAL DIR OC1 REV LIMIT ANGLE: 90°	Range: 40 to 90° in steps of 1
MESSAGE	NEUTRAL DIR OC1 REV PICKUP: 0.050 pu	Range: 0.002 to 30.000 pu in steps of 0.001
MESSAGE	NEUTRAL DIR OC1 BLK: Off	Range: FlexLogic™ operand
MESSAGE	NEUTRAL DIR OC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	NEUTRAL DIR OC1 EVENTS: Disabled	Range: Disabled, Enabled

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 the either the neutral current calculated from the phase currents or the ground current. There are two separate pickup settings for the forward- and reverse-looking functions, respectively. If set to use the calculated 3I_0, the element applies a "positive-sequence restraint" 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.

$$I_{op} = 3 \times (|I\_0| - K \times |I\_1|)$$, where K is 1/16.

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 (single-phase injection: $I_{op} = 0.9375 \times I_{injected}$; three-phase pure zero-sequence injection: $I_{op} = 3 \times I_{injected}$).

The **directional unit** uses the zero-sequence current (I_0) or ground current (IG) for fault direction discrimination and may be programmed to use either zero-sequence voltage ("Calculated V0" or "Measured VX"), ground current (IG), or both for polarizing. The following tables define the Neutral Directional Overcurrent element.

Table 5–23: QUANTITIES FOR "CALCULATED 3I0" CONFIGURATION

DIRECTIONAL UNIT				OVERCURRENT UNIT
POLARIZING MODE	DIRECTION	COMPARED PHASORS		
Voltage	Forward	–V_0 + Z_offset × I_0	I_0 × 1∠ECA	$I_{op} = 3 \times (\|I\_0\| – K \times \|I\_1\|)$
	Reverse	–V_0 + Z_offset × I_0	–I_0 × 1∠ECA	
Current	Forward	IG	I_0	
	Reverse	IG	–I_0	
Dual	Forward	–V_0 + Z_offset × I_0	I_0 × 1∠ECA	
		or		
		IG	I_0	
	Reverse	–V_0 + Z_offset × I_0	–I_0 × 1∠ECA	
		or		
		IG	–I_0	

Table 5–24: QUANTITIES FOR "MEASURED IG" CONFIGURATION

DIRECTIONAL UNIT				OVERCURRENT UNIT
POLARIZING MODE	DIRECTION	COMPARED PHASORS		
Voltage	Forward	–V_0 + Z_offset × IG/3	IG × 1∠ECA	$I_{op} = \|IG\|$
	Reverse	–V_0 + Z_offset × IG/3	–IG × 1∠ECA	

where: $V\_0 = \frac{1}{3}(VAG + VBG + VCG) = \text{zero sequence voltage}$

$$I\_0 = \frac{1}{3}IN = \frac{1}{3}(IA + IB + IC) = \text{zero sequence current}$$

ECA = element characteristic angle
IG = ground current

When **NEUTRAL DIR OC1 POL VOLT** is set to "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.

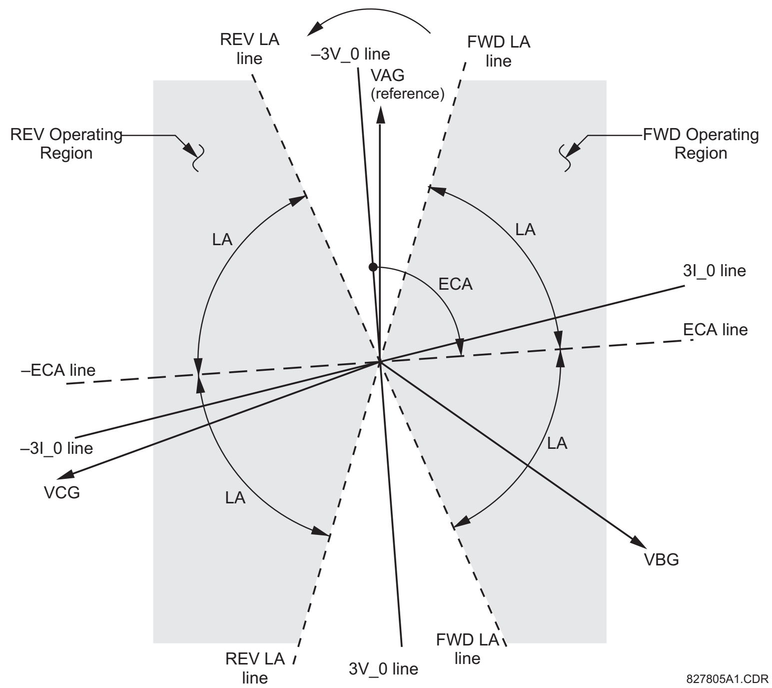

Figure 5–43: NEUTRAL DIRECTIONAL VOLTAGE-POLARIZED CHARACTERISTICS

The above figure shows the voltage-polarized phase angle comparator characteristics for a phase-A to ground fault, with:

ECA = 90° (Element Characteristic Angle = centerline of operating characteristic)
FWD LA = 80° (Forward Limit Angle = the ± angular limit with the ECA for operation)
REV LA = 80° (Reverse Limit Angle = the ± angular limit with the ECA for operation)

The 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 will be delayed by 1.5 of a power system cycle. The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals will result 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, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination.

The above bias should be taken into account when using the Neutral Directional Overcurrent element to ’directionalize’ other protection elements.

NEUTRAL DIR OC1 POLARIZING:

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 Vx, both from the **NEUTRAL DIR OC1 SOURCE**.

  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 **SYSTEM SETUP** ⇨ **AC INPUTS** ⇨⇩ **VOLTAGE BANK** ⇨⇩ **AUXILIARY VT CONNECTION** is set to "Vn" and the auxiliary voltage is connected to a zero-sequence voltage source (such as open delta connected secondary of VTs).

  The zero-sequence voltage (V_0) or auxiliary voltage (Vx), accordingly, must be higher than 1 V secondary to be validated for use as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given.

- If "Current" polarizing is selected, the element uses the ground current angle connected externally and configured under **NEUTRAL OC1 SOURCE** for polarization. The ground current transformer must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be higher than 0.05 pu to be validated for use 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, it should be ensured that a reversal of the ground current does not occur for a high-side fault. The low-side system impedance should be assumed minimal when checking for this condition. A similar situation arises for a WYE/DELTA/WYE transformer, where current in one transformer winding neutral may reverse when faults on both sides of the transformer are considered.

- If "Dual" polarizing is selected, the element performs both directional comparisons as described above. 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.

NEUTRAL DIR OC1 POL VOLT:

Selects the polarizing voltage used by the directional unit when "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").

NEUTRAL DIR OC1 OP CURR:

This setting indicates whether the 3I_0 current calculated from the phase currents, or the ground current shall be used by this protection. This setting acts as a switch between the neutral and ground modes of operation (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 **NEUTRAL DIR OC1 SOURCE**. Naturally, it is not possible to use the ground current as an operating and polarizing signal simultaneously. Therefore, "Voltage" is the only applicable selection for the polarizing mode under the "Measured IG" selection of this setting.

NEUTRAL DIR OC1 OFFSET:

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. See the APPLICATION OF SETTINGS chapter for information on how to calculate this setting.

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 shall not be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. See the THEORY OF OPERATION chapter for more details. The offset impedance shall be entered in secondary ohms.

NEUTRAL DIR OC1 FWD ECA:

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°.

NEUTRAL DIR OC1 FWD LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

NEUTRAL DIR OC1 FWD PICKUP:

This setting defines the pickup level for the overcurrent unit of the element in the forward direction. When selecting this setting it must be kept in mind that the design uses a "positive-sequence restraint" technique for the "Calculated 3I0" mode of operation.

NEUTRAL DIR OC1 REV LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

NEUTRAL DIR OC1 REV PICKUP:

This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. When selecting this setting it must be kept in mind that the design uses a "positive-sequence restraint" technique for the "Calculated 3I0" mode of operation.

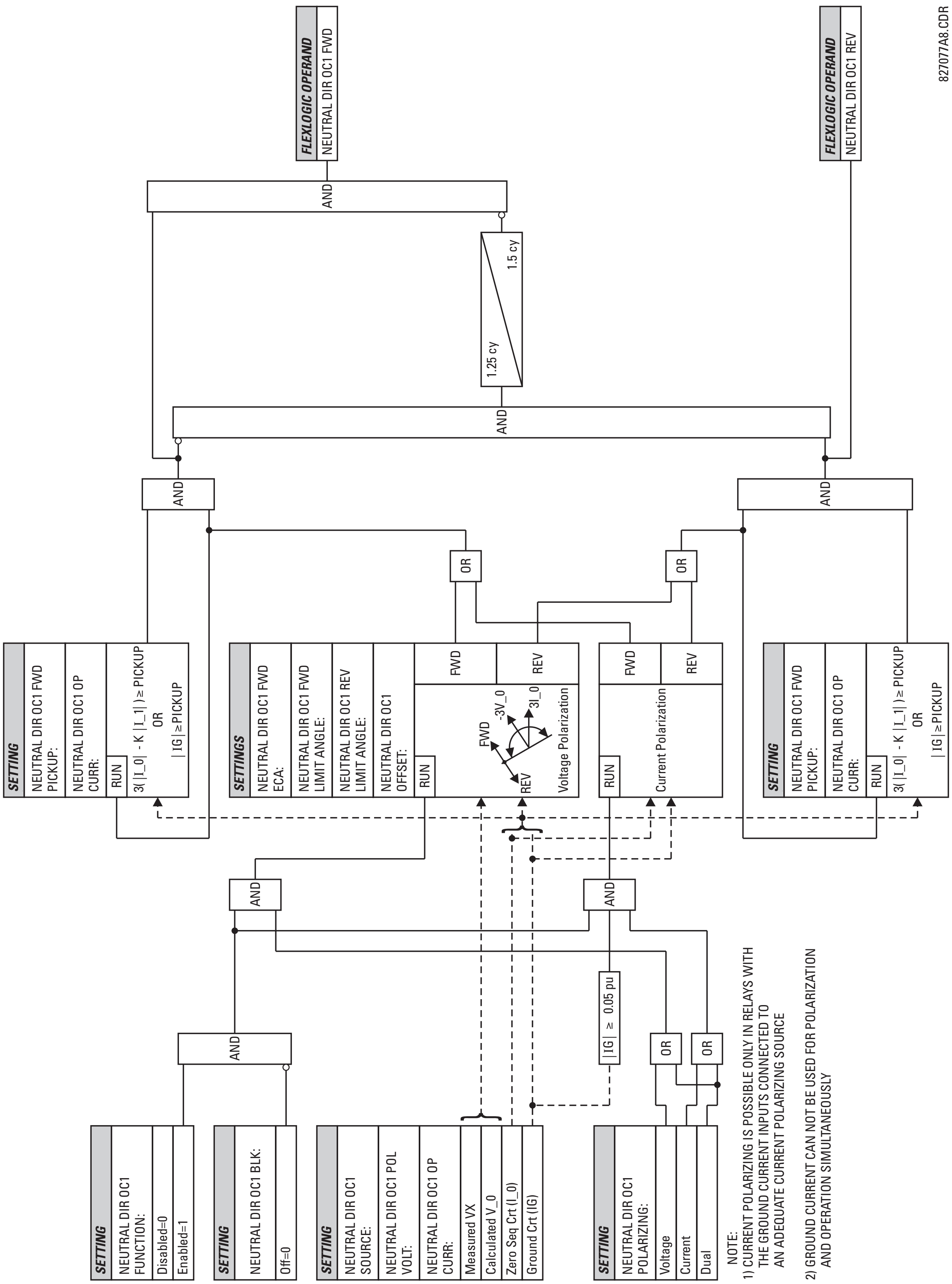

Figure 5–44: NEUTRAL DIRECTIONAL OC1 SCHEME LOGIC

5.5.11 GROUND CURRENT

a) GROUND TOC1 / TOC2 (GROUND TIME OVERCURRENT: ANSI 51G)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ GROUND CURRENT ⇨ GROUND TOC1

Menu	Setting	Range
■ GROUND TOC1 ■	GROUND TOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	GROUND TOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	GROUND TOC1 INPUT: Phasor	*Range: Phasor, RMS*
MESSAGE	GROUND TOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	GROUND TOC1 CURVE: IEEE Mod Inv	*Range: see OVERCURRENT CURVE TYPES table*
MESSAGE	GROUND TOC1 TD MULTIPLIER: 1.00	*Range: 0.00 to 600.00 in steps of 0.01*
MESSAGE	GROUND TOC1 RESET: Instantaneous	*Range: Instantaneous, Timed*
MESSAGE	GROUND TOC1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	GROUND TOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	GROUND TOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

This element can provide a desired 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" (refer to the INVERSE TIME OVERCURRENT CURVE CHARACTERISTICS section for details). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator will be cleared immediately.

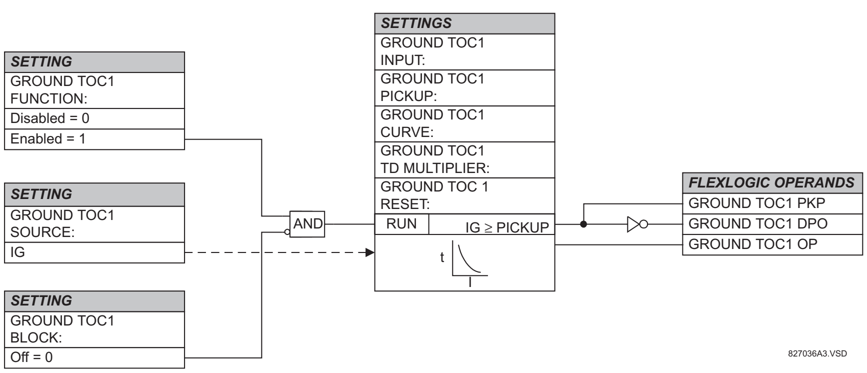

Figure 5–45: GROUND TOC1 SCHEME LOGIC

NOTE: These elements measure the current that is connected to the ground channel of a CT/VT module. This channel may 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.

NOTE: **Once picked up, the GROUND TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless GROUND TOCx RESET is set to "Instantaneous".**

b) GROUND IOC1 / IOC2 (GROUND INSTANTANEOUS OVERCURRENT: ANSI 50G)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ GROUND CURRENT ⇨⇩ GROUND IOC1

■ GROUND IOC1 ■	GROUND IOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	GROUND IOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	GROUND IOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	GROUND IOC1 PICKUP DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	GROUND IOC1 RESET DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	GROUND IOC1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	GROUND IOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	GROUND IOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

5

The ground instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a Definite Time element. The ground current input value is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

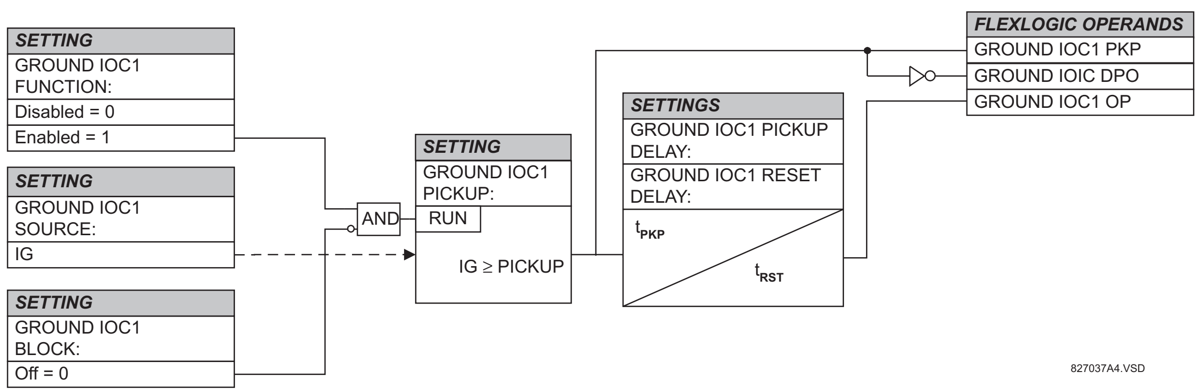

Figure 5–46: GROUND IOC1 SCHEME LOGIC

NOTE: These elements measure the current that is connected to the ground channel of a CT/VT module. This channel may 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.

5.5.12 NEGATIVE SEQUENCE CURRENT

a) NEGATIVE SEQUENCE TOC1 / TOC2 (NEGATIVE SEQUENCE TIME OVERCURRENT: ANSI 51_2)

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨⇩ SETTING GROUP 1(8) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨ NEG SEQ TOC1

Menu		Setting	Range
■ NEG SEQ TOC1 ■		NEG SEQ TOC1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE		NEG SEQ TOC1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE		NEG SEQ TOC1 PICKUP: 1.000 pu	Range: 0.000 to 30.000 pu in steps of 0.001
MESSAGE		NEG SEQ TOC1 CURVE: IEEE Mod Inv	Range: see OVERCURRENT CURVE TYPES table
MESSAGE		NEG SEQ TOC1 TD MULTIPLIER: 1.00	Range: 0.00 to 600.00 in steps of 0.01
MESSAGE		NEG SEQ TOC1 RESET: Instantaneous	Range: Instantaneous, Timed
MESSAGE		NEG SEQ TOC1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE		NEG SEQ TOC1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE		NEG SEQ TOC1 EVENTS: Disabled	Range: Disabled, Enabled

The negative sequence time overcurrent element may 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" (refer to the INVERSE TIME OVERCURRENT CURVE CHARACTERISTICS section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to "Instantaneous" and the element is blocked, the time accumulator will be cleared immediately.

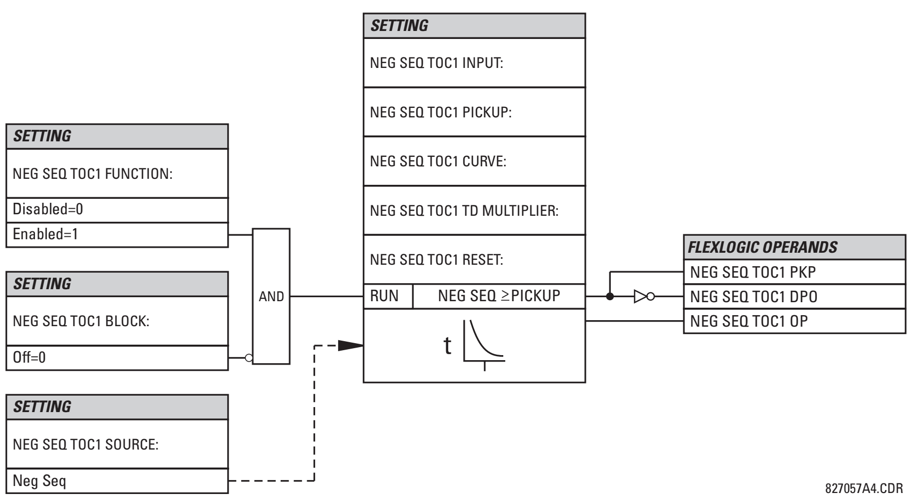

Figure 5–47: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC

NOTE

Once picked up, the NEG SEQ TOCx PKP output operand remains picked up until the thermal memory of the element resets completely. The PKP operand will not reset immediately after the operating current drops below the pickup threshold unless NEG SEQ TOCx RESET is set to "Instantaneous".

b) NEGATIVE SEQUENCE IOC1 / IOC2 (NEGATIVE SEQUENCE INSTANTANEOUS O/C: ANSI 50_2)

PATH: SETTINGS ⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨⇩ NEG SEQ OC1

■ NEG SEQ IOC1 ■	NEG SEQ IOC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	NEG SEQ IOC1 SIGNAL SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	NEG SEQ IOC1 PICKUP: 1.000 pu	*Range: 0.000 to 30.000 pu in steps of 0.001*
MESSAGE	NEG SEQ IOC1 PICKUP DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	NEG SEQ IOC1 RESET DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
MESSAGE	NEG SEQ IOC1 BLOCK: Off	*Range: FlexLogic™ operand*
MESSAGE	NEG SEQ IOC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	NEG SEQ IOC1 EVENTS: Disabled	*Range: Disabled, Enabled*

5

The Negative Sequence Instantaneous Overcurrent element may 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:

$$I_{op} = |I\_2| - K \cdot |I\_1| \quad , \text{ where } K = 1/8.$$

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 the way the test currents are injected into the relay (single phase injection: $I_{op} = 0.2917 \cdot I_{injected}$; three phase injection, opposite rotation: $I_{op} = I_{injected}$).

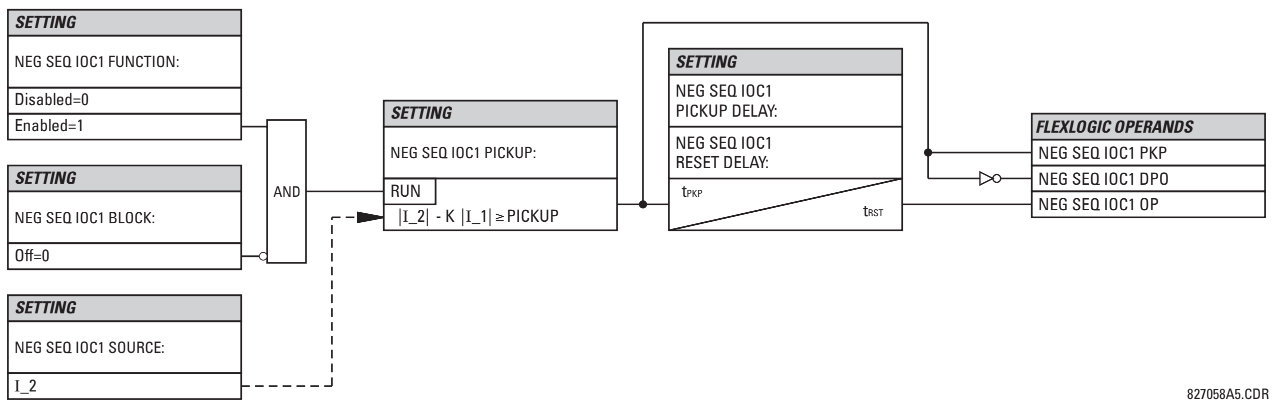

Figure 5–48: NEGATIVE SEQUENCE IOC1 SCHEME LOGIC

c) NEGATIVE SEQUENCE DIRECTIONAL OC1 / OC2 (NEGATIVE SEQUENCE DIRECTIONAL O/C: ANSI 67_2)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ NEGATIVE SEQUENCE CURRENT ⇨⇩ NEG SEQ DIR OC1

■ NEG SEQ DIR OC1 ■	◁▷	NEG SEQ DIR OC1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	△▽	NEG SEQ DIR OC1 SOURCE: SRC 1	*Range: SRC 1, SRC 2,..., SRC 6*
MESSAGE	△▽	NEG SEQ DIR OC1 OFFSET: 0.00 Ω	*Range: 0.00 to 250.00 Ω in steps of 0.01*
MESSAGE	△▽	NEG SEQ DIR OC1 TYPE: Neg Sequence	*Range: Neg Sequence, Zero Sequence*
MESSAGE	△▽	NEG SEQ DIR OC1 FWD ECA: 75° Lag	*Range: 0 to 90° Lag in steps of 1*
MESSAGE	△▽	NEG SEQ DIR OC1 FWD LIMIT ANGLE: 90°	*Range: 40 to 90° in steps of 1*
MESSAGE	△▽	NEG SEQ DIR OC1 FWD PICKUP: 0.05 pu	*Range: 0.05 to 30.00 pu in steps of 0.01*
MESSAGE	△▽	NEG SEQ DIR OC1 REV LIMIT ANGLE: 90°	*Range: 40 to 90° in steps of 1*
MESSAGE	△▽	NEG SEQ DIR OC1 REV PICKUP: 0.05 pu	*Range: 0.05 to 30.00 pu in steps of 0.01*
MESSAGE	△▽	NEG SEQ DIR OC1 BLK: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	NEG SEQ DIR OC1 TARGET: Self-reset	*Range: Self-reset, Latched, Disabled*
MESSAGE	△	NEG SEQ DIR OC1 EVENTS: Disabled	*Range: Disabled, Enabled*

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 zero-sequence current as per user selection. The zero-sequence current should not be mistaken with the neutral current (factor 3 difference).

A “positive-sequence restraint” is applied for better performance: a small portion (12.5% for negative-sequence and 6.25% for zero-sequence) of the positive–sequence current magnitude is subtracted from the negative- or zero-sequence current magnitude, respectively, when forming the element operating quantity.

$I_{op} = |I\_2| - K \times |I\_1|$, where K is 1/8, **or** $I_{op} = |I\_0| - K \times |I\_1|$, where K is 1/16.

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative- 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 pick-up accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay:

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- single-phase injection:
  $I_{op} = 0.2917 \times I_{injected}$ (negative-sequence mode);
  $I_{op} = 0.3125 \times I_{injected}$ (zero-sequence mode);
- three-phase pure zero- or negative-sequence injection, respectively: $I_{op} = I_{injected}$.
- The directional unit uses the negative-sequence current and voltage for fault direction discrimination.

The following table defines the Negative Sequence Directional Overcurrent element.

OVERCURRENT UNIT		DIRECTIONAL UNIT		
MODE	**OPERATING CURRENT**	**DIRECTION**	**COMPARED PHASORS**	
Negative-Sequence	I_{op} = |I_2| – K × |I_1|	Forward	–V_2 + Z_offset × I_2	I_2 × 1∠ECA
		Reverse	–V_2 + Z_offset × I_2	–(I_2 × 1∠ECA)
Zero-Sequence	I_{op} = |I_0| – K × |I_1|	Forward	–V_2 + Z_offset × I_2	I_2 × 1∠ECA
		Reverse	–V_2 + Z_offset × I_2	–(I_2 × 1∠ECA)

The negative-sequence voltage must be higher than 1 V secondary in order to be validated for use as a polarizing signal. If the polarizing signal is not validated neither forward nor reverse indication is given.

The following figure explains the usage of the voltage polarized directional unit of the element.

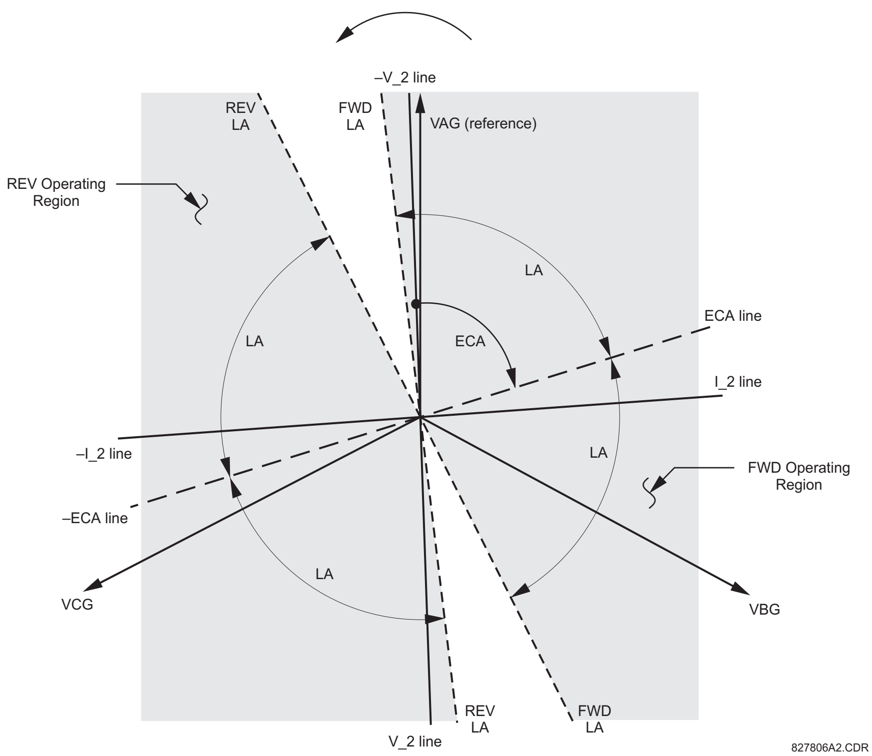

Figure 5–49: NEG SEQ DIRECTIONAL CHARACTERISTICS

The above figure shows the phase angle comparator characteristics for a phase-A to ground fault, with settings of:

ECA = 75° (Element Characteristic Angle = centerline of operating characteristic)
FWD LA = 80° (Forward Limit Angle = ± the angular limit with the ECA for operation)
REV LA = 80° (Reverse Limit Angle = ± the angular limit with the ECA for operation)

The 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 will be delayed by 1.5 of a power system cycle.

The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals will result 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, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination.

The above bias should be taken into account when using the Negative Sequence Directional Overcurrent element to "directionalize" other protection elements.

NEG SEQ DIR OC1 OFFSET:

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. See the APPLICATION OF SETTINGS chapter for information on how to calculate this setting.

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 sequence impedance of the protected circuit. Practically, it shall be several times smaller. See the THEORY OF OPERATION chapter for more details. The offset impedance shall be entered in secondary ohms.

NEG SEQ DIR OC1 TYPE:

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.\

NEG SEQ DIR OC1 FWD ECA:

This setting select 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°.

NEG SEQ DIR OC1 FWD LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.

NEG SEQ DIR OC1 FWD PICKUP:

This setting defines the pickup level for the overcurrent unit of the element in the forward direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current.

When selecting this setting it must be kept in mind that the design uses a "positive-sequence restraint" technique.

NEG SEQ DIR OC1 REV LIMIT ANGLE:

This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.

NEG SEQ DIR OC1 REV PICKUP:

This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current.

When selecting this setting it must be kept in mind that the design uses a "positive-sequence restraint" technique.

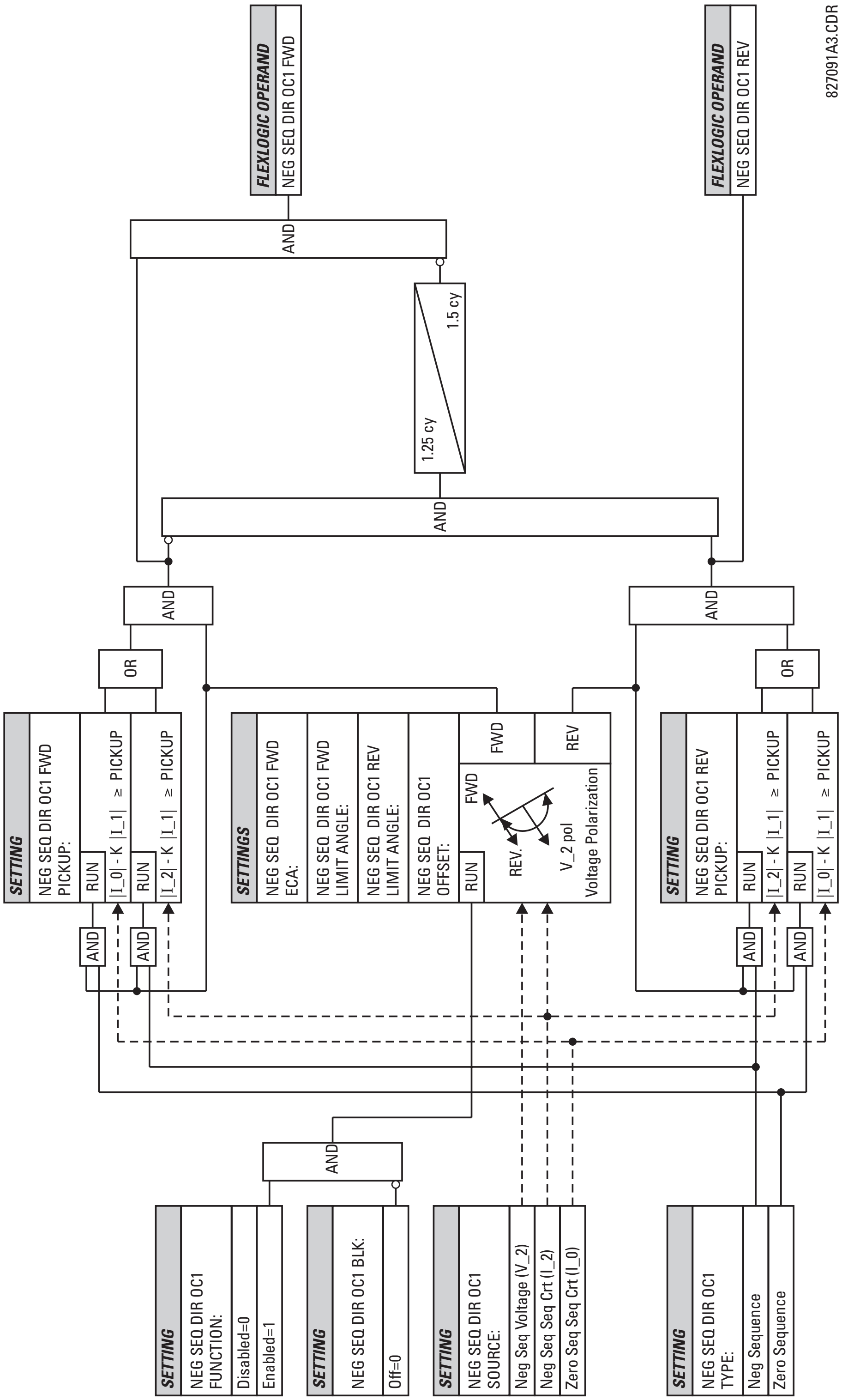

Figure 5–50: NEG SEQ DIRECTIONAL OC1 SCHEME LOGIC

5.5.13 BREAKER FAILURE

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ BREAKER FAILURE ⇨ BREAKER FAILURE 1

■ BREAKER FAILURE 1 ■	BF1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	BF1 MODE: 3-Pole	Range: 3-Pole, 1-Pole
MESSAGE	BF1 SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	BF1 USE AMP SUPV: Yes	Range: Yes, No
MESSAGE	BF1 USE SEAL-IN: Yes	Range: Yes, No
MESSAGE	BF1 3-POLE INITIATE: Off	Range: FlexLogic™ operand
MESSAGE	BF1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	BF1 PH AMP SUPV PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
MESSAGE	BF1 N AMP SUPV PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
MESSAGE	BF1 USE TIMER 1: Yes	Range: Yes, No
MESSAGE	BF1 TIMER 1 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BF1 USE TIMER 2: Yes	Range: Yes, No
MESSAGE	BF1 TIMER 2 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BF1 USE TIMER 3: Yes	Range: Yes, No
MESSAGE	BF1 TIMER 3 PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BF1 BKR POS1 ϕA/3P: Off	Range: FlexLogic™ operand
MESSAGE	BF1 BKR POS2 ϕA/3P: Off	Range: FlexLogic™ operand
MESSAGE	BF1 BREAKER TEST ON: Off	Range: FlexLogic™ operand
MESSAGE	BF1 PH AMP HISET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
MESSAGE	BF1 N AMP HISET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
MESSAGE	BF1 PH AMP LOSET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001

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MESSAGE	BF1 N AMP LOSET PICKUP: 1.050 pu	Range: 0.001 to 30.000 pu in steps of 0.001
MESSAGE	BF1 LOSET TIME DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BF1 TRIP DROPOUT DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BF1 TARGET Self-Reset	Range: Self-reset, Latched, Disabled
MESSAGE	BF1 EVENTS Disabled	Range: Disabled, Enabled
MESSAGE	BF1 PH A INITIATE: Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 PH B INITIATE: Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 PH C INITIATE: Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 BKR POS1 ϕB Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 BKR POS1 ϕC Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 BKR POS2 ϕB Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.
MESSAGE	BF1 BKR POS2 ϕC Off	Range: FlexLogic™ operand Valid only for 1-Pole breaker failure schemes.

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There are 2 identical Breaker Failure menus available, numbered 1 and 2.

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 should trip all breakers, both local and remote, that can supply current to the faulted zone. Usually operation of a breaker failure element will cause 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 (identified by the name "3BF") and one for three pole plus single-pole operation (identified by the name "1BF"). 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.

INITIATION STAGE:

A FlexLogic™ operand representing the protection trip signal initially sent to the breaker must be selected to initiate the scheme, except for the D60 relay were 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 should 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 desired, 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 may be the case for transformer faults. For those situations where it is required to maintain breaker fail coverage for fault levels below the **BF1 PH AMP SUPV PICKUP** or the **BF1 N AMP SUPV PICKUP** setting, a current supervised initiate should *not* be used. This feature should be utilized for those situations where coordinating margins may 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, Hiset and Loset, so that the supervision level can be changed from a current which flows before a breaker inserts an opening resistor into the faulted circuit to a lower level after resistor insertion. The Hiset detector is enabled after timeout of Timer 1 or 2, along with a timer that will enable the Loset detector after its delay interval. The delay interval between Hiset and Loset is the expected breaker opening time. Both current detectors provide a fast operating time for currents at small multiples of the pickup value. The O/C detectors are required to operate after the breaker failure delay interval to eliminate the need for very fast resetting O/C 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.

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9. OUTPUT:

The outputs from the schemes are:

- FlexLogic™ operands that report on the operation of portions of the scheme
- 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.
- Target message indicating a failed breaker has been declared
- Illumination of the faceplate TRIP LED (and the PHASE A, B or C LED, if applicable)

MAIN PATH SEQUENCE:

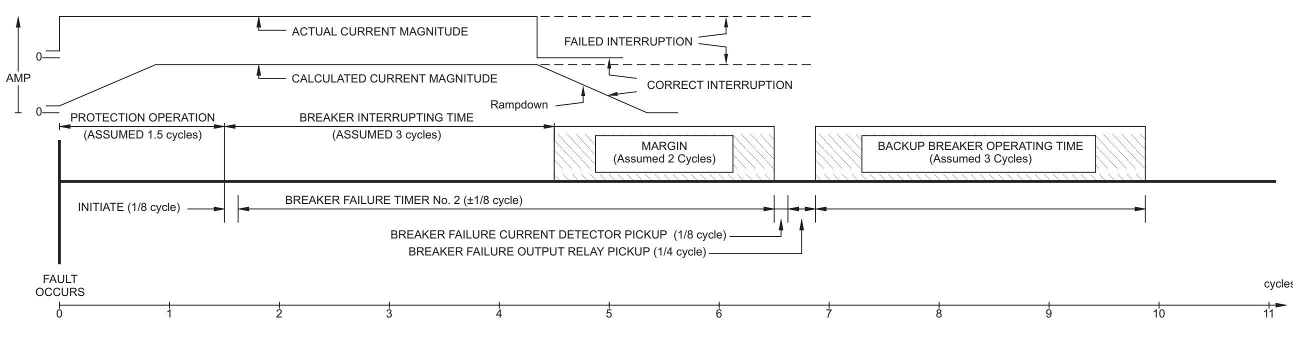

Figure 5–51: BREAKER FAILURE MAIN PATH SEQUENCE

BF1 MODE:

This setting is used to select the breaker failure operating mode: single or three pole.

BF1 USE AMP SUPV:

If set to Yes, the element will only be initiated if current flowing through the breaker is above the supervision pickup level.

BF1 USE SEAL-IN:

If set to Yes, the element will only be sealed-in if current flowing through the breaker is above the supervision pickup level.

BF1 3-POLE INITIATE:

This setting is used to select the FlexLogic™ operand that will initiate 3-pole tripping of the breaker.

BF1 PH AMP SUPV PICKUP:

This setting is used to set the phase current initiation and seal-in supervision level. Generally this setting should 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) - Hiset and Loset current supervision will guarantee correct operation.

BF1 N AMP SUPV PICKUP (valid only for 3-pole breaker failure schemes):

This setting is used to set the neutral current initiate and seal-in supervision level. Generally this setting should 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.

BF1 USE TIMER 1:

If set to Yes, the Early Path is operational.

BF1 TIMER 1 PICKUP DELAY:

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.

BF1 USE TIMER 2:

If set to Yes, the Main Path is operational.

BF1 TIMER 2 PICKUP DELAY:

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 UR relays, which use a Fourier transform, the calculated current magnitude will ramp-down to zero one power frequency cycle after the current is interrupted, and this lag should 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.

Note that 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.

BF1 USE TIMER 3:

If set to Yes, the Slow Path is operational.

BF1 TIMER 3 PICKUP DELAY:

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.

BF1 BKR POS1 ϕA/3P:

This setting selects the FlexLogic™ operand that represents the protected breaker early-type auxiliary switch contact (52/a). When using 1-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 may even be adjusted to have the shortest possible operating time.

BF1 BKR POS2 ϕA/3P:

This setting selects the FlexLogic™ operand that represents the breaker normal-type auxiliary switch contact (52/a). When using 1-Pole breaker failure scheme, this operand represents the protected breaker auxiliary switch contact on pole A. This may be a multiplied contact.

BF1 BREAKER TEST ON:

This setting is used to select the FlexLogic™ operand that represents the breaker In-Service/Out-of-Service switch set to the Out-of-Service position.

BF1 PH AMP HISET PICKUP:

This setting is used to set the phase current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, before a breaker opening resistor is inserted.

BF1 N AMP HISET PICKUP (valid only for 3-pole breaker failure schemes):

This setting sets the neutral current output supervision level. Generally this setting should 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.

BF1 PH AMP LOSET PICKUP:

This setting sets the phase current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current).

BF1 N AMP LOSET PICKUP (valid only for 3-pole breaker failure schemes):

This setting sets the neutral current output supervision level. Generally this setting should detect the lowest expected fault current on the protected breaker, after a breaker opening resistor is inserted (approximately 90% of the resistor current).

BF1 LOSET TIME DELAY:

This setting is used to set the pickup delay for current detection after opening resistor insertion.

BF1 TRIP DROPOUT DELAY:

This setting is used to set the period of 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.

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BF1 PH A INITIATE / BF1 PH B INITIATE / BF 1 PH C INITIATE: (only valid for 1-pole breaker failure schemes)

These settings select the FlexLogic™ operand to initiate phase A, B, or C single-pole tripping of the breaker and the phase A, B, or C portion of the scheme, accordingly.

BF1 BKR POS1 ϕB / BF1 BKR POS 1 ϕC (valid only for 1-pole breaker failure schemes):

These settings select the FlexLogic™ operand to represents the protected breaker early-type auxiliary switch contact on poles B or C, accordingly. This contact is normally a non-multiplied Form-A contact. The contact may even be adjusted to have the shortest possible operating time.

BF1 BKR POS2 ϕB (valid only for 1-pole breaker failure schemes):

Selects the FlexLogic™ operand that represents the protected breaker normal-type auxiliary switch contact on pole B (52/a). This may be a multiplied contact.

BF1 BKR POS2 ϕC (valid only for 1-pole breaker failure schemes):

This setting selects the FlexLogic™ operand that represents the protected breaker normal-type auxiliary switch contact on pole C (52/a). This may 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.

Upon operation of the breaker failure element for a single pole trip command, a 3-pole trip command should be given via output operand "BF1 TRIP OP".

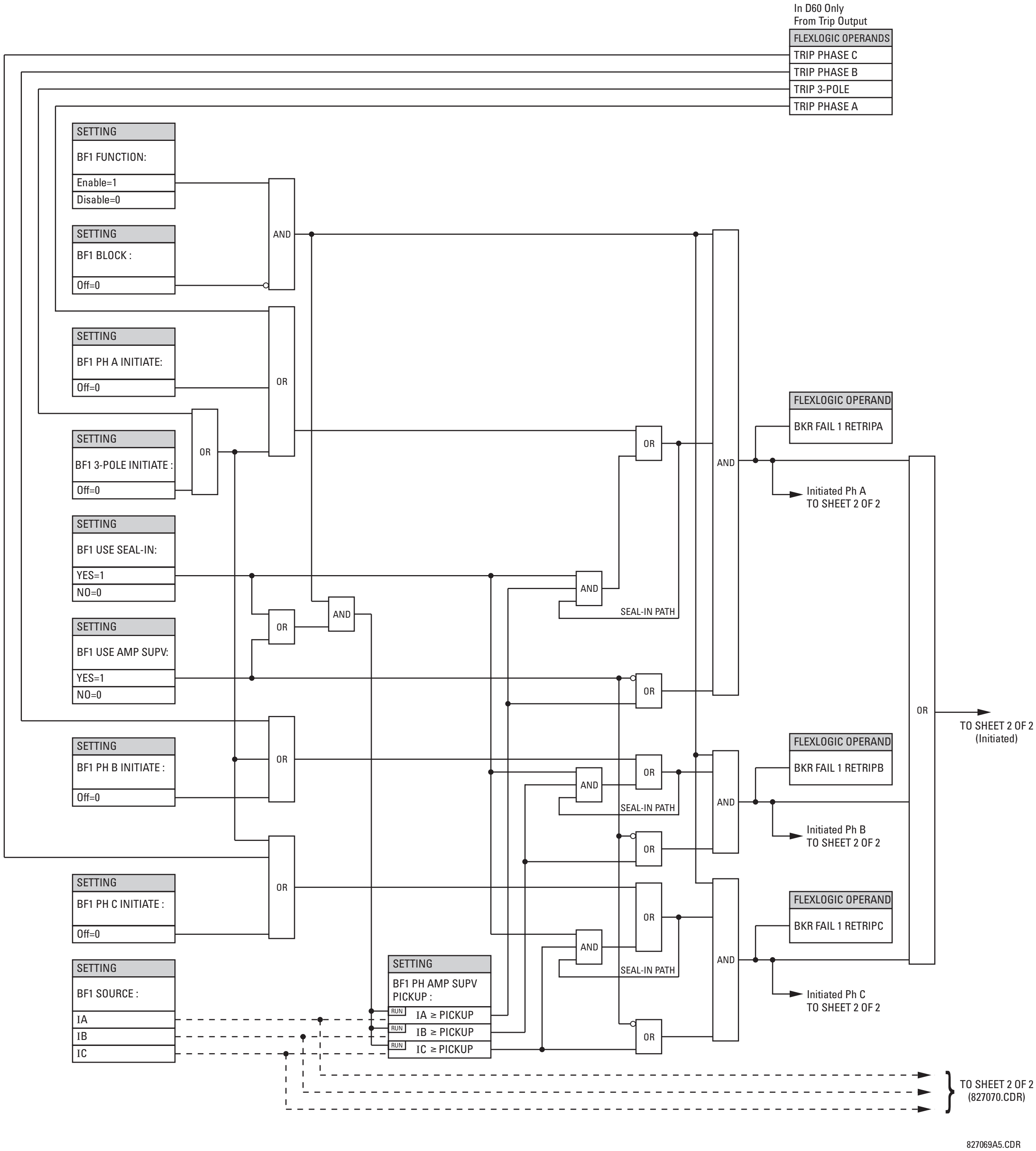

Figure 5–52: BREAKER FAILURE 1-POLE [INITIATE] (Sheet 1 of 2)

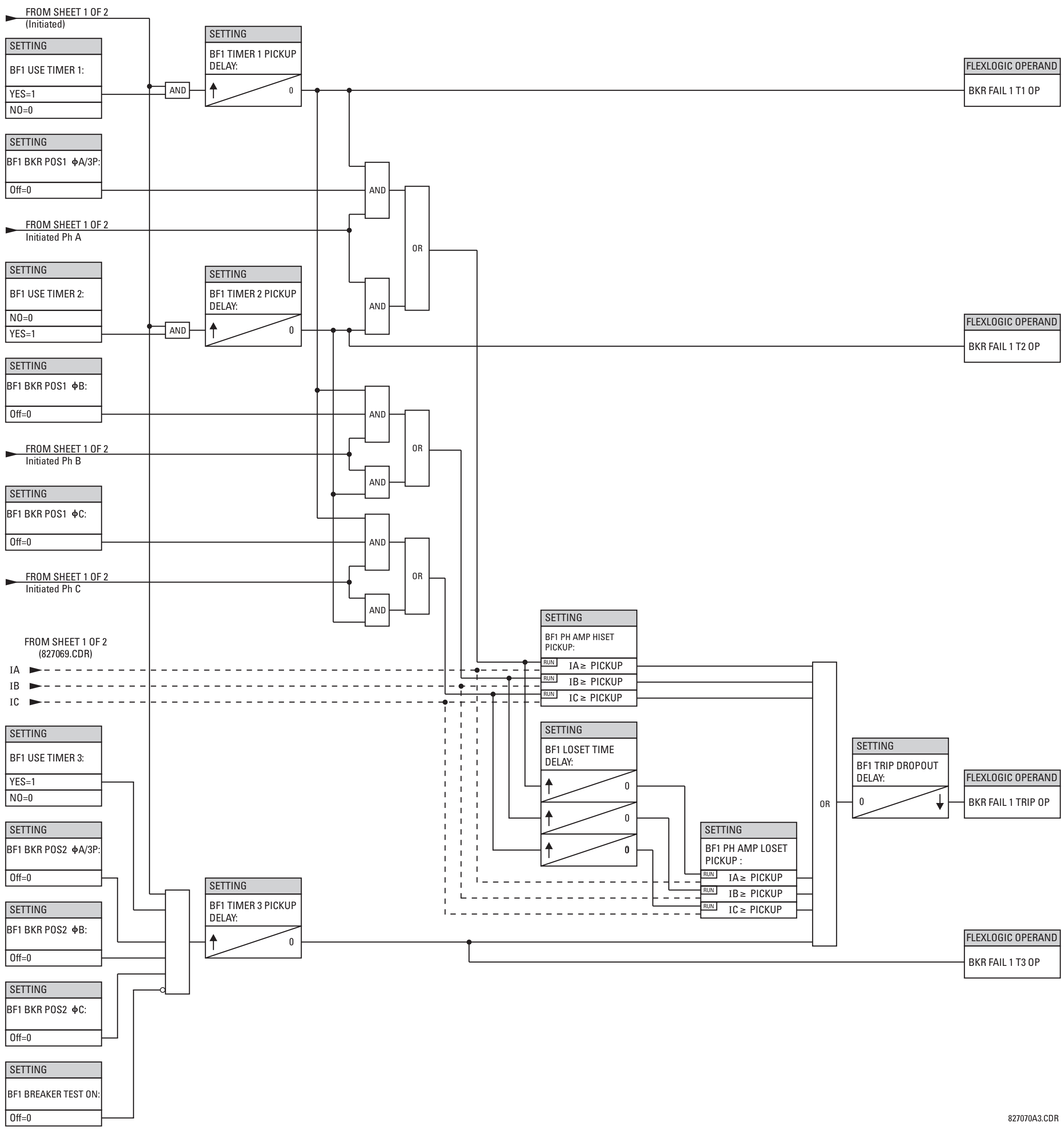

Figure 5–53: BREAKER FAILURE 1-POLE (TIMERS) [Sheet 2 of 2]

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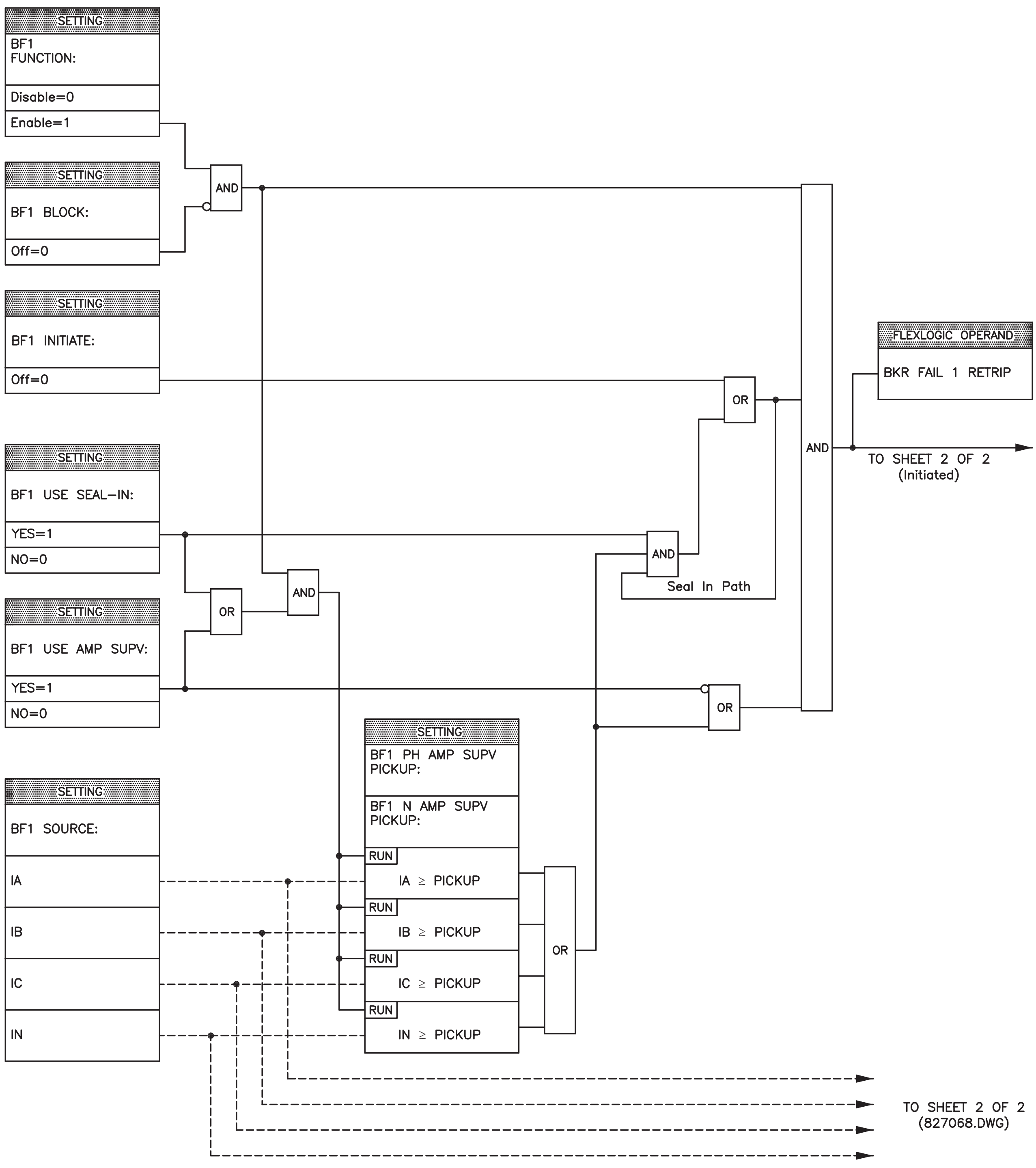

Figure 5–54: BREAKER FAILURE 3-POLE [INITIATE] (Sheet 1 of 2)

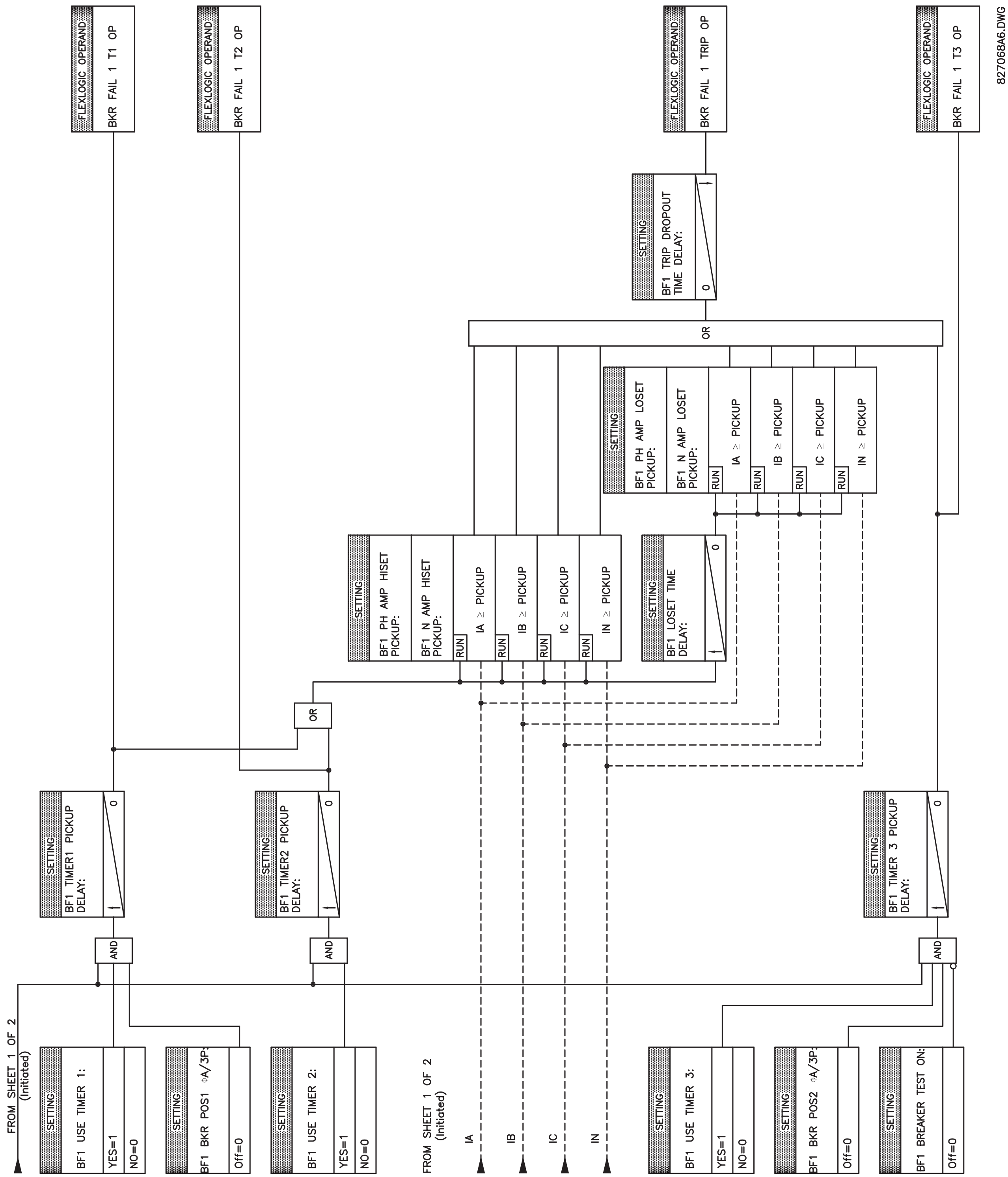

Figure 5–55: BREAKER FAILURE 3-POLE [TIMERS] (Sheet 2 of 2)

5.5.14 VOLTAGE ELEMENTS

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS

```
■ VOLTAGE ELEMENTS          ■ PHASE
■                           ■ UNDERVOLTAGE1

              MESSAGE       ■ PHASE
                            ■ UNDERVOLTAGE2

              MESSAGE       ■ PHASE
                            ■ OVERVOLTAGE1

              MESSAGE       ■ NEUTRAL OV1
                            ■

              MESSAGE       ■ NEG SEQ OV
                            ■

              MESSAGE       ■ AUXILIARY UV1
                            ■

              MESSAGE       ■ AUXILIARY OV1
                            ■
```

These protection elements can be used for a variety of applications such as:

Undervoltage Protection: For voltage sensitive loads, such as induction motors, a drop in voltage increases the drawn current which may cause dangerous overheating in the motor. The undervoltage protection feature can be used to either cause a trip or generate an alarm when the voltage drops below a specified voltage setting for a specified time delay.

Permissive Functions: The undervoltage feature may be used to block the functioning of external devices by operating an output relay when the voltage falls below the specified voltage setting. The undervoltage feature may also be used to block the functioning of other elements through the block feature of those elements.

Source Transfer Schemes: In the event of an undervoltage, a transfer signal may be generated to transfer a load from its normal source to a standby or emergency power source.

The undervoltage elements can be programmed to have a Definite Time delay characteristic. The Definite Time curve operates when the voltage drops below the pickup level for a specified period of time. The time delay is adjustable from 0 to 600.00 seconds in steps of 10 ms. The undervoltage elements can also be programmed to have an inverse time delay characteristic. The undervoltage delay setting defines the family of curves shown below.

$$T = \frac{D}{\left(1 - \frac{V}{V_{pickup}}\right)}$$

where: T = Operating Time
D = Undervoltage Delay Setting
(D = 0.00 operates instantaneously)
V = Secondary Voltage applied to the relay
V_{pickup} = Pickup Level

NOTE

At 0% of pickup, the operating time equals the UNDERVOLTAGE DELAY setting.

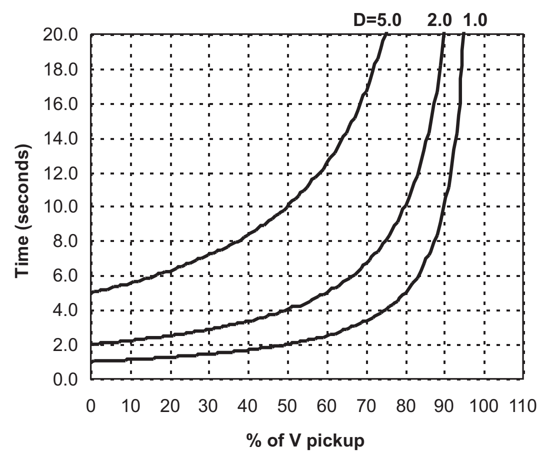

Figure 5–56: INVERSE TIME UNDERVOLTAGE CURVES

5.5.15 PHASE VOLTAGE

a) PHASE UV1 / UV2 (PHASE UNDERVOLTAGE: ANSI 27P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨ PHASE UNDERVOLTAGE1

■ PHASE ■ UNDERVOLTAGE1	PHASE UV1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	PHASE UV1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	PHASE UV1 MODE: Phase to Ground	Range: Phase to Ground, Phase to Phase
MESSAGE	PHASE UV1 PICKUP: 1.000 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	PHASE UV1 CURVE: Definite Time	Range: Definite Time, Inverse Time
MESSAGE	PHASE UV1 DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	PHASE UV1 MINIMUM VOLTAGE: 0.100 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	PHASE UV1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	PHASE UV1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	PHASE UV1 EVENTS: Disabled	Range: Disabled, Enabled

The phase undervoltage element may be used to give a desired time-delay operating characteristic versus the applied fundamental voltage (phase to ground or phase to phase for Wye VT connection, or phase to phase only for Delta VT connection) or as a simple Definite Time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage. The delay setting selects the minimum operating time of the phase undervoltage element. The minimum voltage setting selects the operating voltage below which the element is blocked (a setting of '0' will allow a dead source to be considered a fault condition).

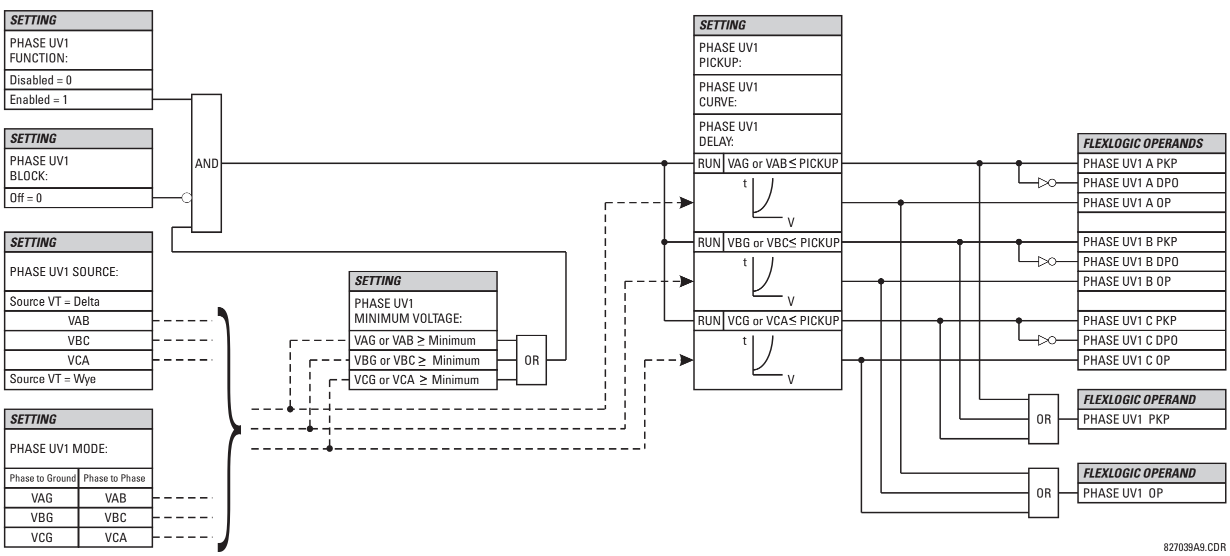

Figure 5–57: PHASE UV1 SCHEME LOGIC

b) PHASE OV1 (PHASE OVERVOLTAGE: ANSI 59P)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ PHASE OVERVOLTAGE1

```
■ PHASE
■ OVERVOLTAGE1
```

	PHASE OV1 FUNCTION: Disabled	Range: *Disabled, Enabled*
MESSAGE	PHASE OV1 SIGNAL SOURCE: SRC 1	Range: *SRC 1, SRC 2,..., SRC 6*
MESSAGE	PHASE OV1 PICKUP: 1.000 pu	Range: *0.000 to 3.000 pu in steps of 0.001*
MESSAGE	PHASE OV1 PICKUP DELAY: 1.00 s	Range: *0.00 to 600.00 s in steps of 0.01*
MESSAGE	PHASE OV1 RESET DELAY: 1.00 s	Range: *0.00 to 600.00 s in steps of 0.01*
MESSAGE	PHASE OV1 BLOCK: Off	Range: *FlexLogic™ Operand*
MESSAGE	PHASE OV1 TARGET: Self-reset	Range: *Self-reset, Latched, Disabled*
MESSAGE	PHASE OV1 EVENTS: Disabled	Range: *Disabled, Enabled*

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The phase overvoltage element may 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 on the logic diagram.

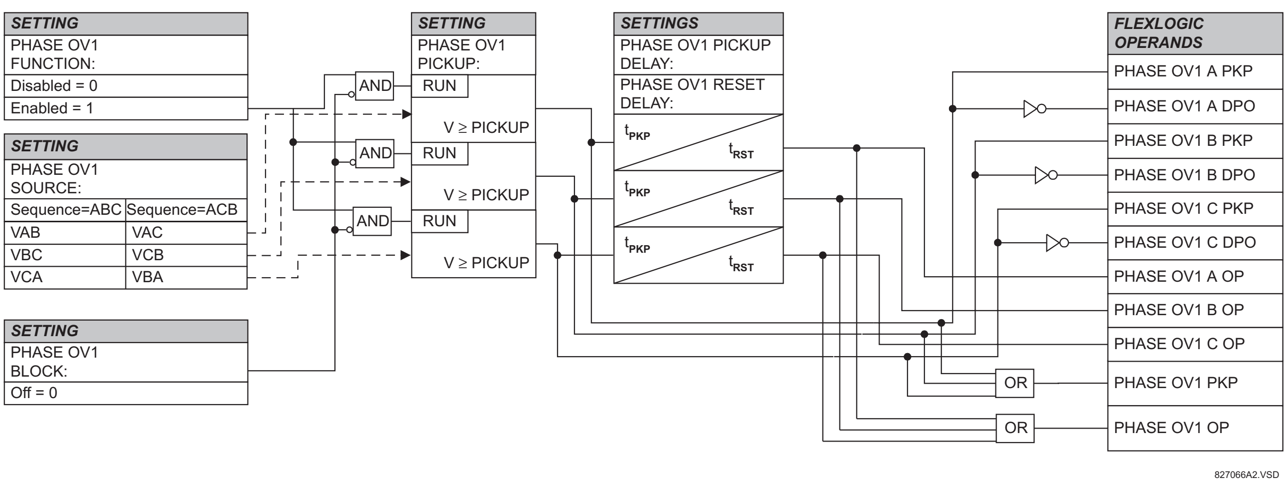

Figure 5–58: PHASE OV1 SCHEME LOGIC

5.5.16 NEUTRAL VOLTAGE

a) NEUTRAL OV1 (NEUTRAL OVERVOLTAGE: ANSI 59N)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEUTRAL OV1

■ NEUTRAL OV1 ■		NEUTRAL OV1 FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	NEUTRAL OV1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
	MESSAGE	NEUTRAL OV1 PICKUP: 0.300 pu	Range: 0.000 to 1.250 pu in steps of 0.001
	MESSAGE	NEUTRAL OV1 PICKUP: DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
	MESSAGE	NEUTRAL OV1 RESET: DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
	MESSAGE	NEUTRAL OV1 BLOCK: Off	Range: FlexLogic™ operand
	MESSAGE	NEUTRAL OV1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
	MESSAGE	NEUTRAL OV1 EVENTS: Disabled	Range: Disabled, Enabled

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 (3V_0), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇨⇩ VOLTAGE BANK ⇨ PHASE VT SECONDARY** is the p.u. base used when setting the pickup level.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be Wye connected.

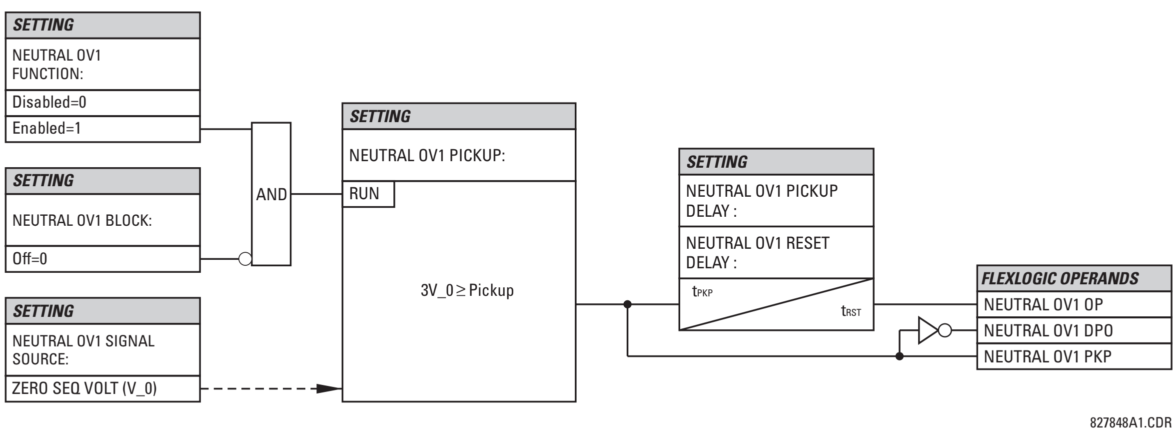

Figure 5–59: NEUTRAL OVERVOLTAGE SCHEME LOGIC

5.5.17 NEGATIVE SEQUENCE VOLTAGE

a) NEG SEQ OV (NEGATIVE SEQUENCE OVERVOLTAGE: ANSI 59_2)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ NEG SEQ OV

■ NEG SEQ OV ■	NEG SEQ OV FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	NEG SEQ OV SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	NEG SEQ OV PICKUP: 0.300 pu	Range: 0.000 to 1.250 pu in steps of 0.001
MESSAGE	NEG SEQ OV PICKUP DELAY: 0.50 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	NEG SEQ OV RESET DELAY: 0.50 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	NEG SEQ OV BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	NEG SEQ OV TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	NEG SEQ OV EVENTS: Disabled	Range: Disabled, Enabled

5

The negative sequence overvoltage element may 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.

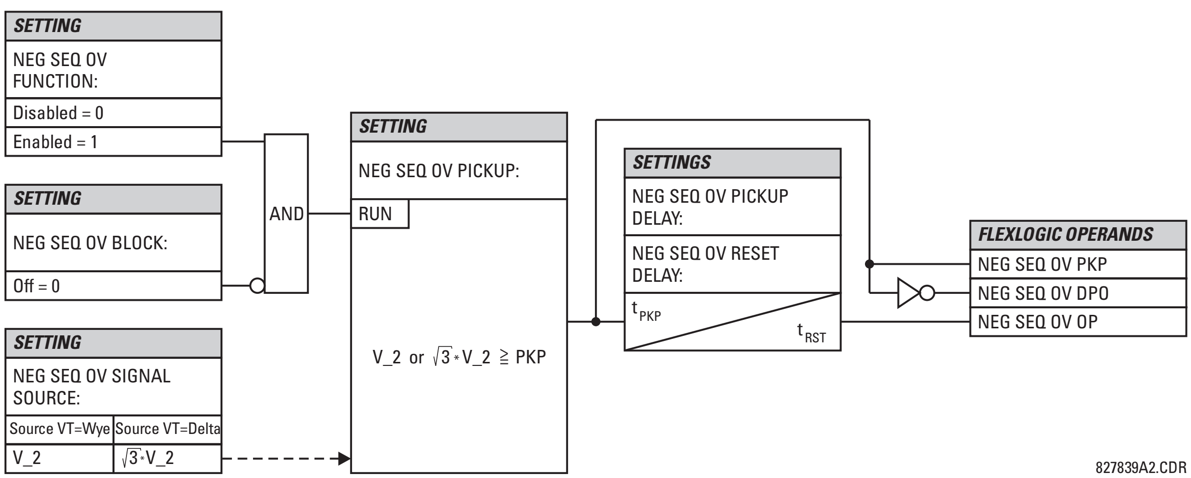

Figure 5–60: NEG SEQ OV SCHEME LOGIC

5.5.18 AUXILIARY VOLTAGE

a) AUXILIARY UV1 (AUXILIARY UNDERVOLTAGE: ANSI 27X)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY UV1

■ AUXILIARY UV1 ■	AUX UV1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	AUX UV1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	AUX UV1 PICKUP: 0.700 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	AUX UV1 CURVE: Definite Time	Range: Definite Time, Inverse Time
MESSAGE	AUX UV1 DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	AUX UV1 MINIMUM: VOLTAGE: 0.100 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	AUX UV1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	AUX UV1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	AUX UV1 EVENTS: Disabled	Range: Disabled, Enabled

5

This element is intended for monitoring undervoltage conditions of the auxiliary voltage. The **PICKUP** selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered under **SETTINGS ⇩ SYSTEM SETUP ⇨ AC INPUTS ⇩⇨ VOLTAGE BANK X5 / AUXILIARY VT X5 SECONDARY** is the p.u. base used when setting the pickup level.

The **DELAY** setting selects the minimum operating time of the phase undervoltage element. Both **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 operating characteristics and equations for both Definite and Inverse Time Delay are as for the Phase Undervoltage Element.

The element resets instantaneously. The minimum voltage setting selects the operating voltage below which the element is blocked.

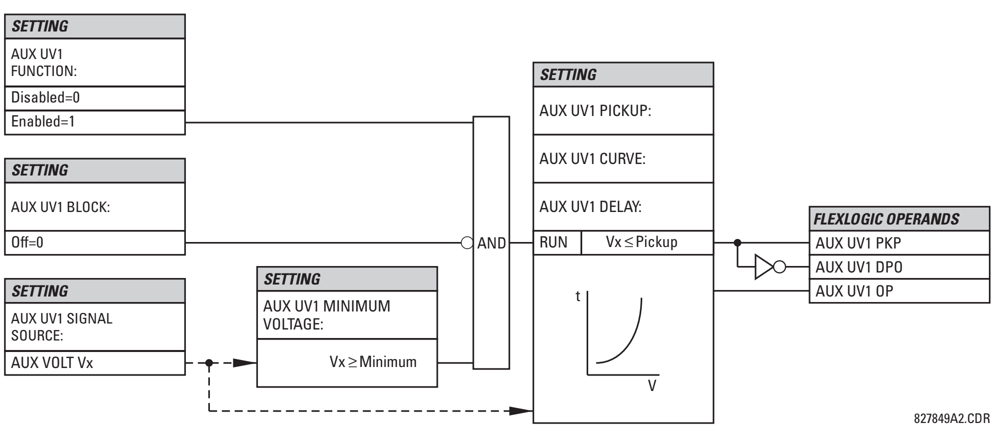

Figure 5–61: AUXILIARY UNDERVOLTAGE SCHEME LOGIC

b) AUXILIARY OV1 (AUXILIARY OVERVOLTAGE: ANSI 59X)

PATH: SETTINGS ⇨⇩ GROUPED ELEMENTS ⇨ SETTING GROUP 1(8) ⇨⇩ VOLTAGE ELEMENTS ⇨⇩ AUXILIARY OV1

	■ AUXILIARY OV1 ■	
	AUX OV1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	AUX OV1 SIGNAL SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	AUX OV1 PICKUP: 0.300 pu	Range: 0.000 to 3.000 pu in steps of 0.001
MESSAGE	AUX OV1 PICKUP DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	AUX OV1 RESET DELAY: 1.00 s	Range: 0.00 to 600.00 s in steps of 0.01
MESSAGE	AUX OV1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	AUX OV1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	AUX OV1 EVENTS: Disabled	Range: Disabled, Enabled

5

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 under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨ AC INPUTS ⇩⇨ VOLTAGE BANK X5 ⇩⇨ AUXILIARY VT X5 SECONDARY** is the p.u. base used when setting the pickup level.

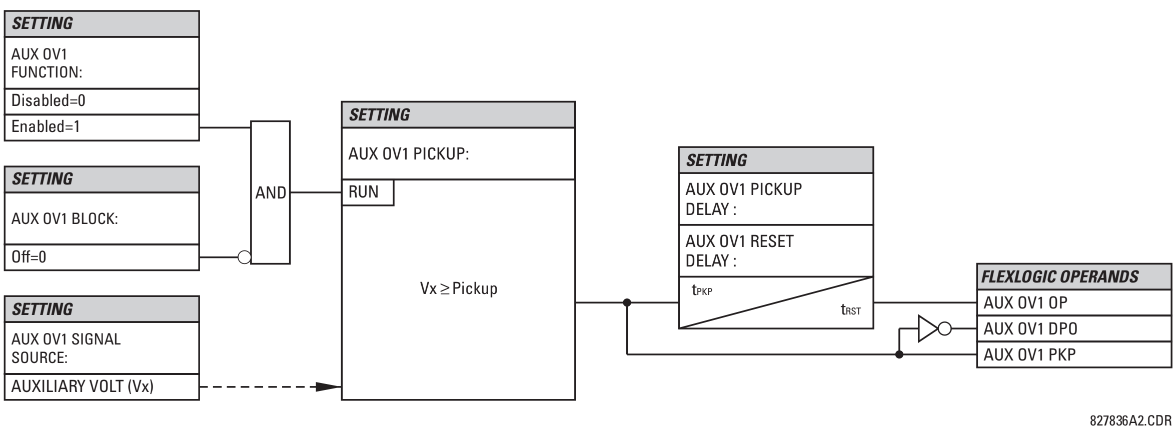

Figure 5–62: AUXILIARY OVERVOLTAGE SCHEME LOGIC

5.6.1 OVERVIEW

CONTROL elements are generally used for control rather than protection. See the INTRODUCTION TO ELEMENTS section at the front of this chapter for further information.

5.6.2 SETTING GROUPS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨ SETTINGS GROUPS

■ SETTING GROUPS ■	SETTING GROUPS FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	SETTING GROUPS BLK: Off	*Range: FlexLogic™ operand*
MESSAGE	GROUP 2 ACTIVATE ON: Off	*Range: FlexLogic™ operand*
	↓	
MESSAGE	GROUP 8 ACTIVATE ON: Off	*Range: FlexLogic™ operand*
MESSAGE	SETTING GROUP EVENTS: Disabled	*Range: Disabled, Enabled*

The Setting Groups menu controls the activation/deactivation of up to eight possible groups of settings in the **GROUPED ELEMENTS** settings menu. The faceplate 'SETTINGS IN USE' LEDs indicate which active group (with a non-flashing energized LED) is in service.

The **SETTING GROUPS BLK** setting prevents the active setting group from changing when the FlexLogic™ parameter is set to "On". This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

Each **GROUP ~ ACTIVATE ON** setting selects a FlexLogic™ operand which, when set, will make the particular setting group active for use by any grouped element. A priority scheme ensures that only one group is active at a given time – the highest-numbered group which is activated by its ACTIVATE ON parameter takes priority over the lower-numbered groups. There is no "activate on" setting for group 1 (the default active group), because group 1 automatically becomes active if no other group is active.

The relay can be set up via a FlexLogic™ equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic™ equation (see the figure below) illustrates requests via remote communications (e.g. VIRTUAL INPUT 1) or from a local contact input (e.g. H7a) 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 VIRTUAL OUTPUT 1 operand is used to control the ON state of a particular settings group.

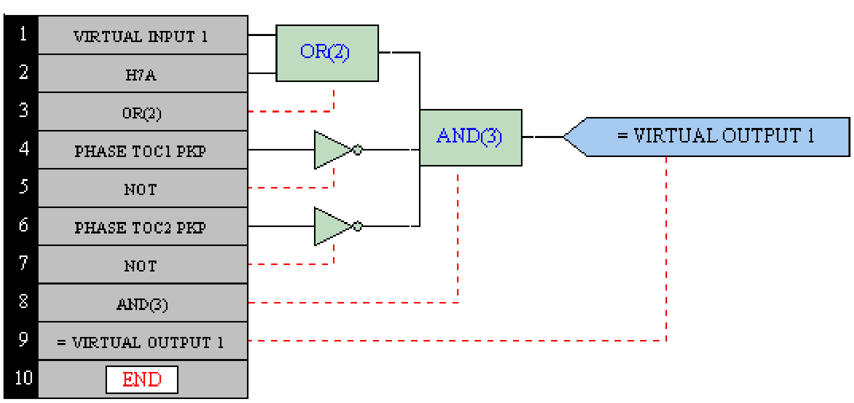

Figure 5–63: EXAMPLE FLEXLOGIC™ CONTROL OF A SETTINGS GROUP

5.6.3 TRIP OUTPUT

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ TRIP OUTPUT)

■ TRIP OUTPUT ■	TRIP MODE: Disabled	Range: Disabled, 3 Pole Only, 3 Pole & 1 Pole
MESSAGE	TRIP 3-POLE INPUT-1: Off	Range: FlexLogic™ operand
MESSAGE	TRIP 3-POLE INPUT-2: Off	Range: FlexLogic™ operand
	↓	
MESSAGE	TRIP 3-POLE INPUT-6: Off	Range: FlexLogic™ operand
MESSAGE	TRIP 1-POLE INPUT-1: Off	Range: FlexLogic™ operand
MESSAGE	TRIP 1-POLE INPUT-2: Off	Range: FlexLogic™ operand
	↓	
MESSAGE	TRIP 1-POLE INPUT-6: Off	Range: FlexLogic™ operand
MESSAGE	TRIP RECLOSE INPUT-1: Off	Range: FlexLogic™ operand
MESSAGE	TRIP RECLOSE INPUT-2: Off	Range: FlexLogic™ operand
	↓	
MESSAGE	TRIP RECLOSE INPUT-6: Off	Range: FlexLogic™ operand
MESSAGE	TRIP FORCE 3-POLE: Off	Range: FlexLogic™ operand
MESSAGE	TRIP PILOT PRIORITY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	BKR ΦA OPEN: Off	Range: FlexLogic™ operand
MESSAGE	BKR ΦB OPEN: Off	Range: FlexLogic™ operand
MESSAGE	BKR ΦC OPEN: Off	Range: FlexLogic™ operand
MESSAGE	TRIP EVENTS: Disabled	Range: Enabled, Disabled

This element is primarily used to collect trip requests from protection elements and other inputs to generate output operands to initiate trip operations. Three pole trips will only initiate reclosure if programmed to do so, whereas single pole trips will 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 faceplate TRIP indicator LED.

a) THREE POLE OPERATION

In applications where single pole tripping is not required this element provides a convenient method of collecting inputs to initiate tripping of circuit breakers, the reclose element and breaker failure elements.

b) SINGLE POLE OPERATION

NOTE **This element must be used in single pole operation applications.**

In these applications this element is used to:

- determine if a single pole operation should be performed
- collect inputs to initiate three pole tripping, the recloser and breaker failure elements
- collect inputs to initiate single pole tripping, the recloser and breaker failure elements
- assign a higher priority to pilot aided scheme outputs than to exclusively local inputs.

This element works in association with other elements in the relay (see the THEORY OF OPERATION chapter for a complete description of single pole operations) that must be fully programmed and in service for successful operation. The other necessary elements are: Recloser, Breaker Control, Open Pole Detector, and Phase Selector. The recloser 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 (DUTT, PUTT, POTT, Hybrid POTT, and Directional Blocking) a timer can be used to delay the output decision until data from a remote terminal is received from communications facilities, to prevent a three pole operation where a single pole operation is permitted.

5

c) SETTINGS

TRIP MODE:

This setting is used to select 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 will be asserted.

TRIP 3-POLE INPUT-1 (through 6):

This setting is used to select an operand representing a fault condition that is not desired to initiate a single pole operation, e.g. phase undervoltage. Use a FlexLogic OR-gate if more than six inputs are required.

TRIP 1-POLE INPUT-1 (through 6):

This setting is used to select an operand representing a fault condition that is desired to initiate a single pole trip-and-reclose if the fault is single phase to ground, e.g. 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.

8 msec after the single-pole reclosing is initiated, the AR FORCE 3-P TRIP operand is asserted by the autorecloser. This operand calls for three-pole trip if any protection element configured under **TRIP 1-POLE INPUT** is still picked-up. The Open Pole Detector provides blocking inputs to distance elements, and therefore the latter will reset immediately after the TRIP 1-POLE operand is asserted. For other protection elements used in single-pole tripping, the user must ensure they will reset immediately after tripping, otherwise the fact that they are still picked up will be detected as an evolving fault and the relay will trip three-poles. For example, if high-set phase IOC is used (**TRIP 1-POLE INPUT X:** "PHASE IOC1 OP"), then OPEN POLE OP ΦA shall be used for blocking phase A of the IOC element. In this way, after tripping phase A, the phase A IOC is forced to reset. Phases B and C are still operational and can detect an evolving fault as soon as 8 msec after tripping phase A. Neutral and negative-sequence IOCs shall be blocked from the OPEN POLE BLK N operand unless the pickup setting is high enough to prevent pickup during single-pole reclosing.

TRIP RECLOSE INPUT-1 (through 6):

This setting is used to select an operand representing a fault condition that is desired to initiate three pole reclosing, e.g. phase distance Zone 1. Use a FlexLogic™ OR-gate if more than six inputs are required.

TRIP FORCE 3-POLE:

This setting is used to select an operand that will force an input that is selected for single pole operation to produce a three pole operation, e.g. a Virtual Input that is asserted by an operator in some operating situations.

TRIP PILOT PRIORITY:

This setting is used to set 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.

BKR ΦA OPEN through BKR ΦC OPEN:

These settings specify FlexLogic™ operands that indicate open poles of the breaker(s). The trip signal produced by the feature is sealed-in as long as the breaker(s) remain closed and resets when the breaker(s) opens as conveyed by the breaker pole status. These settings shall be left "Off" if the D60 Open Pole feature is used. The latter passes the OPEN POLE BKR ΦA OP through OPEN POLE BKR ΦA OP operands that bear the breaker(s) position.

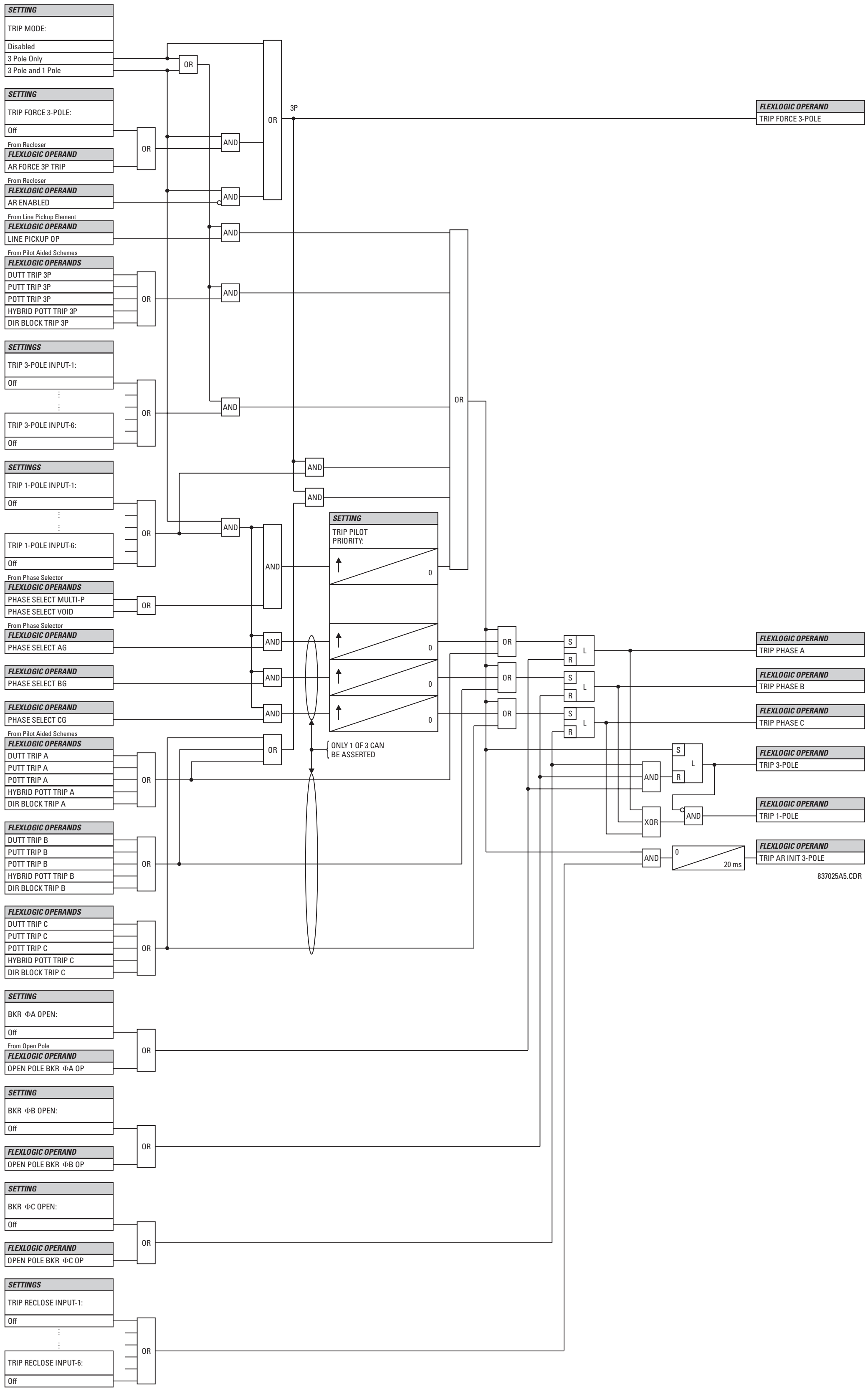

Figure 5–64: TRIP OUTPUT SCHEME LOGIC

5.6.4 SYNCHROCHECK

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1(2)

■ SYNCHROCHECK 1 ■	SYNCHK1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	SYNCHK1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	SYNCHK1 V1 SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	SYNCHK1 V2 SOURCE: SRC 2	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	SYNCHK1 MAX VOLT DIFF: 10000 V	Range: 0 to 100000 V in steps of 1
MESSAGE	SYNCHK1 MAX ANGLE DIFF: 30°	Range: 0 to 100° in steps of 1
MESSAGE	SYNCHK1 MAX FREQ DIFF: 1.00 Hz	Range: 0.00 to 2.00 Hz in steps of 0.01
MESSAGE	SYNCHK1 DEAD SOURCE SELECT: LV1 and DV2	Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2, DV1 Xor DV2, DV1 and DV2
MESSAGE	SYNCHK1 DEAD V1 MAX VOLT: 0.30 pu	Range: 0.00 to 1.25 pu in steps of 0.01
MESSAGE	SYNCHK1 DEAD V2 MAX VOLT: 0.30 pu	Range: 0.00 to 1.25 pu in steps of 0.01
MESSAGE	SYNCHK1 LIVE V1 MIN VOLT: 0.70 pu	Range: 0.00 to 1.25 pu in steps of 0.01
MESSAGE	SYNCHK1 LIVE V2 MIN VOLT: 0.70 pu	Range: 0.00 to 1.25 pu in steps of 0.01
MESSAGE	SYNCHK1 TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	SYNCHK1 EVENTS: Disabled	Range: Disabled, Enabled

SYNCHK1 V1 SOURCE:

This setting selects the source for voltage V1 (see **NOTES** below).

SYNCHK1 V2 SOURCE:

This setting selects the source for voltage V2, which must not be the same as used for the V1 (see **NOTES** below).

SYNCHK1 MAX VOLT DIFF:

This setting selects the maximum voltage difference in ‘kV’ between the two sources. A voltage magnitude difference between the two input voltages below this value is within the permissible limit for synchronism.

SYNCHK1 MAX ANGLE DIFF:

This setting selects the maximum angular difference in degrees between the two sources. An angular difference between the two input voltage phasors below this value is within the permissible limit for synchronism.

SYNCHK1 MAX FREQ DIFF:

This setting selects the maximum frequency difference in ‘Hz’ between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.

SYNCHK1 DEAD SOURCE SELECT:

This setting selects the combination of dead and live sources that will by-pass synchronism check function and permit the breaker to be closed when one or both of the two voltages (V1 or/and V2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level.

Six options are available:

None:	Dead Source function is disabled
LV1 and DV2:	Live V1 and Dead V2
DV1 and LV2:	Dead V1 and Live V2
DV1 or DV2:	Dead V1 or Dead V2
DV1 Xor DV2:	Dead V1 exclusive-or Dead V2 (one source is Dead and the other is Live)
DV1 and DV2:	Dead V1 and Dead V2

SYNCHK1 DEAD V1 MAX VOLT:

This setting establishes a maximum voltage magnitude for V1 in ‘pu’. Below this magnitude, the V1 voltage input used for synchrocheck will be considered "Dead" or de-energized.

SYNCHK1 DEAD V2 MAX VOLT:

This setting establishes a maximum voltage magnitude for V2 in ‘pu’. Below this magnitude, the V2 voltage input used for synchrocheck will be considered "Dead" or de-energized.

SYNCHK1 LIVE V1 MIN VOLT:

This setting establishes a minimum voltage magnitude for V1 in ‘pu’. Above this magnitude, the V1 voltage input used for synchrocheck will be considered "Live" or energized.

SYNCHK1 LIVE V2 MIN VOLT:

This setting establishes a minimum voltage magnitude for V2 in ‘pu’. Above this magnitude, the V2 voltage input used for synchrocheck will be considered "Live" or energized.

5

NOTES:

1. The selected Sources for synchrocheck inputs V1 and V2 (which must not be the same Source) may include both a three-phase and an auxiliary voltage. The relay will automatically select the specific voltages to be used by the synchrocheck element in accordance with the following table.

NO.	V1 OR V2 (SOURCE Y)	V2 OR V1 (SOURCE Z)	AUTO-SELECTED COMBINATION		AUTO-SELECTED VOLTAGE
			SOURCE Y	SOURCE Z	
1	Phase VTs and Auxiliary VT	Phase VTs and Auxiliary VT	Phase	Phase	VAB
2	Phase VTs and Auxiliary VT	Phase VT	Phase	Phase	VAB
3	Phase VT	Phase VT	Phase	Phase	VAB
4	Phase VT and Auxiliary VT	Auxiliary VT	Phase	Auxiliary	V auxiliary (as set for Source z)
5	Auxiliary VT	Auxiliary VT	Auxiliary	Auxiliary	V auxiliary (as set for selected sources)

The voltages V1 and V2 will be matched automatically so that the corresponding voltages from the two Sources will be used to measure conditions. A phase to phase voltage will be used if available in both sources; if one or both of the Sources have only an auxiliary voltage, this voltage will be used. For example, if an auxiliary voltage is programmed to VAG, the synchrocheck element will automatically select VAG 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 to be used for synchrocheck.

Exception: **Synchronism cannot be checked between Delta connected phase VTs and a Wye connected auxiliary voltage.**

2. The relay measures frequency and Volts/Hz from an input on a given Source with priorities as established by the configuration of input channels to the Source. The relay will use the phase channel of a three-phase set of voltages if programmed as part of that Source. The relay will use the auxiliary voltage channel only if that channel is programmed as part of the Source and a three-phase set is not.

The are two identical synchrocheck elements available, numbered 1 and 2.

The synchronism check function is intended for supervising the paralleling of two parts of a system which are to be joined by the closure of a circuit breaker. The synchrocheck elements are typically 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 (V1 and V2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences.

The time while 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 would take the voltage phasor V1 or V2 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:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F}$$

where: $\Delta\Phi$ = phase angle difference in degrees; ΔF = frequency difference in Hz.

As an example; for the default values ($\Delta\Phi = 30°$, $\Delta F = 0.1$ Hz), the time while the angle between the two voltages will be less than the set value is:

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$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F} = \frac{1}{\frac{360^\circ}{2 \times 30^\circ} \times 0.1\text{ Hz}} = 1.66\text{ sec.}$$

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to by-pass the synchrocheck measurements (Dead Source function).

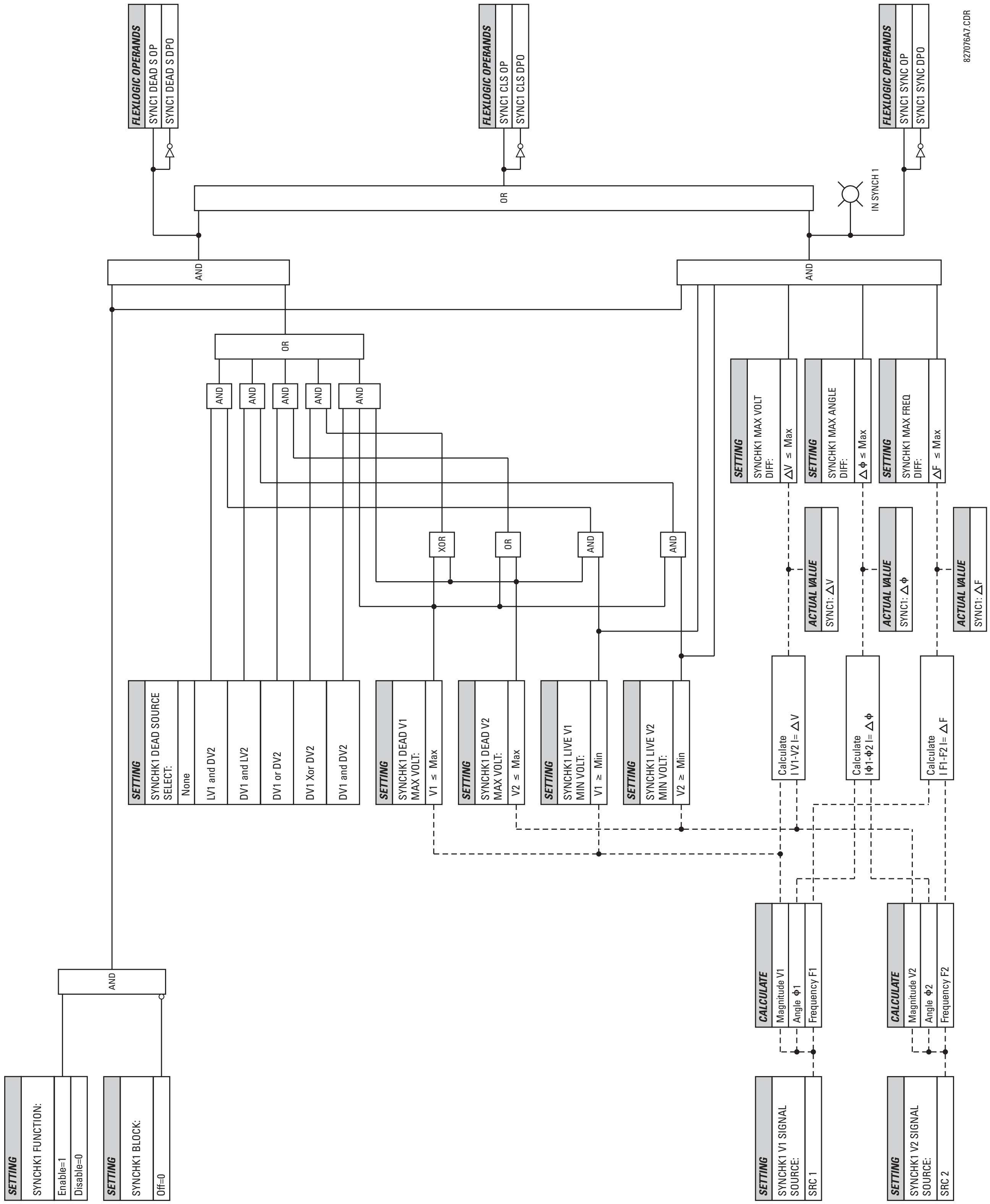

Figure 5–65: SYNCHROCHECK SCHEME LOGIC

5.6.5 AUTORECLOSE

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE

■ AUTORECLOSE ■	AR FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	AR MODE: 1 & 3 Pole	Range: 1 & 3 Pole, 1 Pole, 3 Pole-A, 3 Pole-B
MESSAGE	AR MAX NUMBER OF SHOTS: 2	Range: 1, 2
MESSAGE	AR BLOCK BKR1: Off	Range: FlexLogic™ operand
MESSAGE	AR CLOSE TIME BKR 1: 0.10 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR BKR MAN CLOSE: Off	Range: FlexLogic™ operand
MESSAGE	AR BLK TIME UPON MAN CLS: 10.00 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR 1P INIT: Off	Range: FlexLogic™ operand
MESSAGE	AR 3P INIT: Off	Range: FlexLogic™ operand
MESSAGE	AR 3P TD INIT: Off	Range: FlexLogic™ operand
MESSAGE	AR MULTI-P FAULT: Off	Range: FlexLogic™ operand
MESSAGE	BKR ONE POLE OPEN: Off	Range: FlexLogic™ operand
MESSAGE	BKR 3 POLE OPEN: Off	Range: FlexLogic™ operand
MESSAGE	AR 3-P DEAD TIME 1: 0.50 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR 3-P DEAD TIME 2: 1.20 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR EXTEND DEAD T 1: Off	Range: FlexLogic™ operand
MESSAGE	AR DEAD TIME 1 EXTENSION: 0.50 s	Range: 0.00 to 655.35 s in steps of 0.01
MESSAGE	AR RESET: Off	Range: FlexLogic™ operand
MESSAGE	AR RESET TIME: 60.00 s	Range: 0 to 655.35 s in steps of 0.01
MESSAGE	AR BKR CLOSED: Off	Range: FlexLogic™ operand
MESSAGE	AR BLOCK: Off	Range: FlexLogic™ operand

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MESSAGE	AR PAUSE: Off	Range: FlexLogic™ operand
MESSAGE	AR INCOMPLETE SEQ TIME: 5.00 s	Range: 0 to 655.35 s in steps of 0.01
MESSAGE	AR BLOCK BKR2: Off	Range: FlexLogic™ operand
MESSAGE	AR CLOSE TIME BKR2: Off	Range: FlexLogic™ operand
MESSAGE	AR TRANSFER 1 TO 2: No	Range: Yes, No
MESSAGE	AR TRANSFER 2 TO 1: No	Range: Yes, No
MESSAGE	AR BKR1 FAIL OPTION: Continue	Range: Continue, Lockout
MESSAGE	AR BKR2 FAIL OPTION: Continue	Range: Continue, Lockout
MESSAGE	AR 1-P DEAD TIME: 1.00 s	Range: 0 to 655.35 s in steps of 0.01
MESSAGE	AR BKR SEQUENCE: 1-2	Range: 1, 2, 1&2, 1–2, 2–1
MESSAGE	AR TRANSFER TIME: 4.00 s	Range: 0 to 655.35 s in steps of 0.01
MESSAGE	AR EVENT: Disabled	Range: Enabled, Disabled

5

a) DESCRIPTION

The autoreclose scheme is intended 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 two reclosing attempts. The second attempt always performs three pole reclosing and has an independent dead time delay.

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 should trip and reclose single pole or three pole, according to the fault type and reclose mode; the second breaker should always trip and reclose 3-Pole. When reclosing simultaneously, for the first shot both breakers should trip and reclose either single pole or three pole, according to the fault type and the reclose mode.

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.

OPERATION:

The autoreclose scheme has five operating states, defined below.

Table 5–25: AUTORECLOSE OPERATION

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

AR PROGRAMS:

The autorecloser provides four programs that can cause one or two reclose attempts (shots). The second reclose will always be 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 will go to Lockout upon another Initiate signal.

For the 3-pole reclose programs (modes 3 and 4), 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 5–26: AR PROGRAMS

MODE NO.	AR MODE	FIRST SHOT		SECOND SHOT	
		SINGLE-PHASE FAULT	MULTI-PHASE FAULT	SINGLE-PHASE FAULT	MULTI-PHASE FAULT
1	1 & 3 POLE	1 POLE	3 POLE	3 POLE or LO	3 POLE or LO
2	1 POLE	1 POLE	LO	3 POLE or LO	3 POLE or LO
3	3 POLE-A	3 POLE	LO	3 POLE or LO	LO
4	3 POLE-B	3 POLE	3 POLE	3 POLE or LO	3 POLE or LO

Note: LO = Lockout

- *MODE 1, 1 & 3 POLE*: When in this mode the autorecloser starts the **AR 1-P DEAD TIME** timer for the first shot if the autoreclose is single-phase initiated, the **AR 3-P DEAD TIME 1** timer if the autoreclose is three-phase initiated, and the **AR 3-P DEAD TIME 2** timer if the autoreclose is three-phase time delay initiated. If two shots are enabled, the second shot is always three-phase and the **AR 3-P DEAD TIME 2** timer is started.
- *MODE 2, 1 POLE*: When in this mode the autorecloser starts the **AR 1-P DEAD TIME** for the first shot if the fault is single phase. If the fault is three-phase the scheme goes to lockout without reclosing. If two shots are enabled, the second shot is always three-phase and starts **AR 3-P DEAD TIME 2**.
- *MODE 3, 3 POLE-A:* When in this mode the autorecloser is initiated only for single phase faults, although the trip is three pole. The autorecloser uses the "AR 3-P DEAD TIME 1" for the first shot if the fault is single phase. If the fault is multi phase the scheme will go to Lockout without reclosing. If two shots are enabled, the second shot is always three-phase and starts "AR 3-P DEAD TIME 2".
- *MODE 4, 3 POLE-B*: When in this mode the autorecloser is initiated for any type of fault and starts the **AR 3-P DEAD TIME 1** for the first shot. If the initiating signal is **AR 3P TD INIT** the scheme starts **AR 3-P DEAD TIME 2** for the first shot. If two shots are enabled, the second shot is always three-phase and starts **AR 3-P DEAD TIME 2**.

BASIC RECLOSING OPERATION:

Reclosing operation is determined primarily by the **AR MODE** and **AR BKR SEQUENCE** settings. The reclosing sequences are started by the initiate inputs. A reclose initiate signal will send the scheme into the Reclose In Progress (RIP) state, asserting the "AR RIP" operand. The scheme is latched into the RIP state and resets only when an "AR CLS BKR 1" (autoreclose breaker 1) or "AR CLS BKR 2" (autoreclose breaker 2) operand is generated or the scheme goes to the Lockout state.

The dead time for the initial reclose operation will be determined by either the **AR 1-P DEAD TIME**, **AR 3-P DEAD TIME 1**, or **AR 3-P DEAD TIME 2** setting, depending on the fault type and the mode selected. After the dead time interval the scheme will assert 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.

There are three initiate programs: single pole initiate, three pole initiate and three pole, time delay initiate. Any of these reclose initiate signals will 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.

The three-pole initiate and three-pole time delay initiate signals are latched until the "Close Bkr1 or Bkr2" or Lockout or Reset signal appears.

AR PAUSE:

The pause input offers the possibility of freezing the autoreclose cycle until the pause signal disappears. This may 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**.

This feature can be also used when a transformer is tapped from the protected line and a reclose is not desirable until the transformer is disconnected from the line. In this situation the reclose scheme will be "paused" until the transformer is disconnected.

The **AR PAUSE** input will force a three-pole trip through the **3-P DEADTIME 2** path.

EVOLVING FAULTS:

8 ms after the single pole dead time has been initiated, the "AR FORCE 3P TRIP" operand is set and it will be reset only when the scheme is reset or goes to Lockout. This will ensure that when a fault on one phase evolves to include another phase during the single pole dead time of the auto-recloser the scheme will force a 3 pole trip and reclose.

RECLOSING SCHEME OPERATION FOR ONE BREAKER:

- **Permanent Fault**: Consider mode No.1 which calls for 1-Pole or 3-Pole time delay No. 1 for the first reclosure and 3-Pole time delay No. 2 for the second reclosure, and assume a permanent fault on the line. Also assume the scheme is in the Reset state. For the first single-phase fault the **AR 1-P DEAD TIME** timer will be started, while for the first multi-phase fault the **AR 3-P DEAD TIME 1** timer will be started. If the **AR 3P TD INIT** signal is high, the **AR 3-P DEAD TIME 2** will be started for the first shot.

  If **AR MAX NO OF SHOTS** is set to "1", upon the first reclose the shot counter is set to 1. Upon reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the "AR SHOT COUNT >0" that will set 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 **AR MAX NO OF SHOTS** is set to "2", upon the first reclose the shot counter is set to 1. Upon reclosing, the fault is again detected by protection and reclose is initiated. The breaker is tripped three-pole through the "AR SHOT COUNT >0" that will set 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.

- **Transient Fault**: When a reclose output signal is sent to close the breaker the reset timer is started. If the reclosure sequence is successful (there is no initiating signal and the breaker is closed) the reset timer will time out returning the scheme to the reset state with the shot counter set to "0" making it ready for a new reclose cycle.

5

RECLOSING SCHEME OPERATION FOR TWO BREAKERS:

- **Permanent Fault**: The general method of operation is the same as that outlined for the one breaker applications except for the following description, which assumes **AR BKR SEQUENCE** is set to "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 will initiate 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 will stop the transfer timer. After the 3-P dead time times out the close breaker 1 signal will close first breaker again and will start the transfer timer. Since the fault is permanent the protection will trip again initiating the autoreclose scheme that will be sent to Lockout by the "Shot Count = Max" signal.

- **Transient Fault**: When the first reclose output signal is sent to close breaker 1, the reset timer is started. 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 are closed and there is no initiating signal) the reset timer will time out, returning the scheme to the reset state with the shot counter set to 0. The scheme will be ready for a new reclose cycle.

AR BKR1(2) RECLS FAIL:

If the selected sequence is "1–2" or "2–1" and after the first or second reclose attempt the breaker fails to close, there are two options. If the **AR BKR 1(2) FAIL OPTION** is set to "Lockout", the scheme will go to lockout state. If the **AR BKR 1(2) FAIL OPTION** is set to "Continue", the reclose process will continue with Breaker No. 2. At the same time the shot counter will be decreased (since the closing process was not completed).

SCHEME RESET AFTER RECLOSURE:

When a reclose output signal is sent to close either breaker 1 or 2 the reset timer is started. If the reclosure sequence is successful (there is no initiating signal and the breakers are closed) the reset timer will time out, returning the scheme to the reset state, with the shot counter set to 0, making it 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 will 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 will be sent to Lockout.

The reset timer will be stopped if the reclosure sequence is not successful: an initiating signal is present or the scheme is in the Lockout state. The reset timer will also be stopped if the breaker is manually closed or the scheme is otherwise reset from lockout.

LOCKOUT:

When a reclose sequence is started by an initiate signal the 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 goes to "Lockout".

There are four other conditions that can take the scheme to the Lockout state, as shown below:

- Receipt of "Block" input while in the Reclose in Progress state
- The reclosing program logic: when a 3P Initiate is present and the autoreclose mode is either 1 Pole or 3Pole-A (3 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 will be sent to Lockout. The scheme will be also sent to Lockout if one breaker fails to reclose and the setting **AR BKR FAIL OPTION** is set to "Lockout".

Once the Lockout state is set it will be latched in until the scheme is intentionally reset from Lockout or a breaker is manually closed.

5

BREAKER OPEN BEFORE FAULT:

A logic circuit is provided that inhibits the close breaker 1(2) output if a reclose initiate (RIP) indicator is not present within 30 ms of the "Breaker any phase open" input. This feature is intended to prevent reclosing if one of the breakers was open in advance of a reclose initiate input to the recloser. This logic circuit resets when the breaker is closed.

TRANSFER RECLOSE WHEN BREAKER IS BLOCKED:

1. When the reclosing sequence 1-2 is selected and breaker No. 1 is blocked (AR BKR1 BLK operand is set) the reclose signal can be transferred direct to the breaker No. 2 if **AR TRANSFER 1 TO 2** is set to "Yes". If set to "No", the scheme will be sent to LOCKOUT by the incomplete sequence timer.
2. When the reclosing sequence 2-1 is selected and breaker No. 2 is blocked (AR BKR2 BLK operand is set) the reclose signal can be transferred direct to the breaker No.1 if **AR TRANSFER 2 TO 1** is set to "YES". If set to "NO" the scheme will be sent to LOCKOUT by the incomplete sequence timer.

FORCE 3-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:

- Autoreclose scheme is Disabled.
- Autoreclose scheme is in the Lockout state.
- Autoreclose mode is programmed for three-pole operation
- The shot counter is not at 0, i.e. the scheme is not in the Reset state. This ensures a second trip will be three-pole when reclosing onto a permanent single phase fault.
- 8 ms after the single-pole reclose is initiated by the AR 1P INIT signal.

ZONE 1 EXTENT:

"Extended Zone 1" is 0 when the AR is in LO or Disabled and 1 when the AR is in Reset.

1. When "Extended Zone 1" is 0, the distance functions shall be set to normal underreach Zone 1 setting.
2. When "Extended Zone 1" is 1, the distance functions may be set to Extended Zone 1 Reach, which is an overreaching setting.
3. During a reclose cycle, "Extended Zone 1" goes to 0 as soon as the first CLOSE BREAKER signal is issued (AR SHOT COUNT > 0) and remains 0 until the recloser goes back to Reset.

b) USE OF SETTINGS

AR MODE: This setting selects the AR operating mode, which functions in conjunction with signals received at the initiation inputs as described previously.

AR MAX NUMBER OF SHOTS: This setting specifies the number of reclosures that can be attempted before reclosure goes to Lockout when the fault is permanent.

AR BLOCK BKR1: This input selects an operand that will block the reclose command for breaker No.1. This condition can be for example: 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™.

AR CLOSE TIME BKR1:This setting represents the closing time for the breaker No. 1 from the moment the "Close" command is sent to the moment the contacts are closed.

AR BKR MAN CLOSE: This setting selects a FlexLogic™ operand that represents manual close command to a breaker associated with the autoreclose scheme

AR BLK TIME UPON MAN CLS: The autoreclose scheme can be disabled for a programmable time delay after an associated circuit breaker is manually commanded 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.

AR 1P INIT: This setting selects a FlexLogic™ operand that is intended to initiate single Pole autoreclosure.

AR 3P INIT: This setting selects a FlexLogic™ operand that is intended to initiate three Pole autoreclosure, first timer (AR 3P DEAD TIME 1) that can be used for a high-speed autoreclosure.

AR 3P TD INIT: This setting selects a FlexLogic™ operand that is intended to initiate three Pole autoreclosure, second timer (AR 3P DEAD TIME 2) that can be used for a time-delay autoreclosure.

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AR MULTI-P FAULT: This setting selects a FlexLogic™ operand that indicates a multi-phase fault. The operand value should be zero for single-phase to ground faults.

BKR ONE POLE OPEN: This setting selects a FlexLogic™ operand which indicates that the breaker(s) has opened correctly following a single phase to ground fault and the autoreclose scheme can start timing the single pole dead time (for 1-2 reclose sequence for example, breaker No. 1 should trip single pole and breaker No. 2 should trip 3 pole).

The scheme has a pre-wired input that indicates breaker(s) status.

BKR 3 POLE OPEN: This setting selects a FlexLogic™ operand which indicates that the breaker(s) has 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(s) status.

AR 3-P DEAD TIME 1: This is the dead time following the first three pole trip. This intentional delay can be used for a high-speed three-pole autoreclose. However, it should be set longer than the estimated de-ionizing time following the three-pole trip.

AR 3-P DEAD TIME 2: This is the dead time following the second three-pole trip or initiated by the AR 3P TD INIT input. This intentional delay is typically used for a time delayed three-pole autoreclose (as opposed to high speed three-pole autoreclose).

AR EXTEND DEAD T 1: This setting selects an operand that will 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

AR DEAD TIME 1 EXTENSION: This timer is used to set the length of the dead time 1 extension for possible non-simultaneous tripping of the two ends of the line.

AR RESET: 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.

AR RESET TIME: 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.

AR BKR CLOSED: 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.

AR BLOCK: This setting selects the operand that blocks the Autoreclose scheme (it can be a sum of conditions such as: Time Delayed Tripping, Breaker Failure, Bus Differential Protection, etc.). If the block signal is present before autoreclose scheme initiation the AR DISABLED FlexLogic™ operand will be set. If the block signal occurs when the scheme is in the RIP state the scheme will be sent to Lockout.

AR PAUSE: The pause input offers the ability to freeze the autoreclose cycle until the pause signal disappears. This may 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. When the "pause" signal disappears the autoreclose cycle is resumed. This feature can also be used when a transformer is tapped from the protected line and a reclose is not desirable until the it is disconnected from the line. In this situation, the reclose scheme is "paused" until the transformer is disconnected.

AR INCOMPLETE SEQ TIME: This timer is used to set 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 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-P Dead Time 2" timer setting. Settings beyond this will determine the "wait" time for the breaker to open so that the reclose cycle can continue and/or for the AR 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.

AR BLOCK BKR2: This input selects an operand that will block the reclose command for breaker No.2. This condition can be for example: 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™.

AR BKR2 MNL CLOSE: This setting selects an operand asserted when breaker No. 2 is manually commanded to close.

AR CLOSE TIME BKR2: This setting represents the closing time for the breaker No. 2 from the moment the "Close" command is sent to the moment the contacts are closed.

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AR TRANSFER 1 TO 2: This setting establishes how the scheme performs when the breaker closing sequence is 1-2 and breaker No. 1 is blocked. When set to "YES" the closing command will be transferred direct to breaker No. 2 without waiting the transfer time. When set to "NO" the closing command will be blocked by the AR BKR1 BLK signal and the scheme will be sent to LOCKOUT by the incomplete sequence timer.

AR TRANSFER 2 TO 1: This setting establishes how the scheme performs when the breaker closing sequence is 2-1 and breaker No. 2 is blocked. When set to "YES" the closing command will be transferred direct to breaker No. 1 without waiting the transfer time. When set to "NO" the closing command will be blocked by the AR BKR2 BLK signal and the scheme will be sent to LOCKOUT by the incomplete sequence timer.

AR BKR1 FAIL OPTION: This setting establishes how the scheme performs when the breaker closing sequence is 1-2 and breaker No. 1 has failed to close. When set to "Continue" the closing command will be transferred to breaker No. 2 which will continue the reclosing cycle until successful (the scheme will reset) or unsuccessful (the scheme will go to Lockout). When set to "Lockout" the scheme will go to lockout without attempting to reclose breaker No. 2.

AR BKR2 FAIL OPTION: This setting establishes how the scheme performs when the breaker closing sequence is 2-1 and breaker No. 2 has failed to close. When set to "Continue" the closing command will be transferred to breaker No. 1 which will continue the reclosing cycle until successful (the scheme will reset) or unsuccessful (the scheme will go to Lockout). When set to "Lockout" the scheme will go to lockout without attempting to reclose breaker No. 1.

AR 1-P DEAD TIME: Set this intentional delay longer than the estimated de-ionizing time following the first single-pole trip.

AR BREAKER SEQUENCE: This setting selects the breakers reclose sequence:

1 = reclose breaker 1 only
2 = reclose breaker 2 only
1&2 = reclose both breakers simultaneously
1-2 = reclose breakers sequentially; breaker No. 1 first
2-1 = reclose breakers sequentially; breaker No. 2 first

AR TRANSFER TIME: The transfer time is used only for breaker closing sequence 1-2 or 2-1, when the two breakers are reclosed sequentially. The transfer timer is initiated by a close signal to the first breaker. The transfer timer transfers the reclose signal from the breaker selected to close first to the second breaker. The time delay setting is based on the maximum time interval between the autoreclose signal and the protection trip contact closure assuming a permanent fault (unsuccessful reclose). Therefore, the minimum setting is equal to the maximum breaker closing time plus the maximum line protection operating time plus a suitable margin. This setting will prevent the autoreclose scheme from transferring the close signal to the second breaker unless a successful reclose of the first breaker occurs.

NOTE

For correct operation of the autoreclose scheme, the Breaker Control feature must be enabled and configured properly. When the breaker reclose sequence is "1-2" or "2-1" the breaker that will reclose second in sequence (breaker No. 2 for sequence 1-2 and breaker No. 1 for sequence 2-1) must be configured to trip three-pole for any type of fault

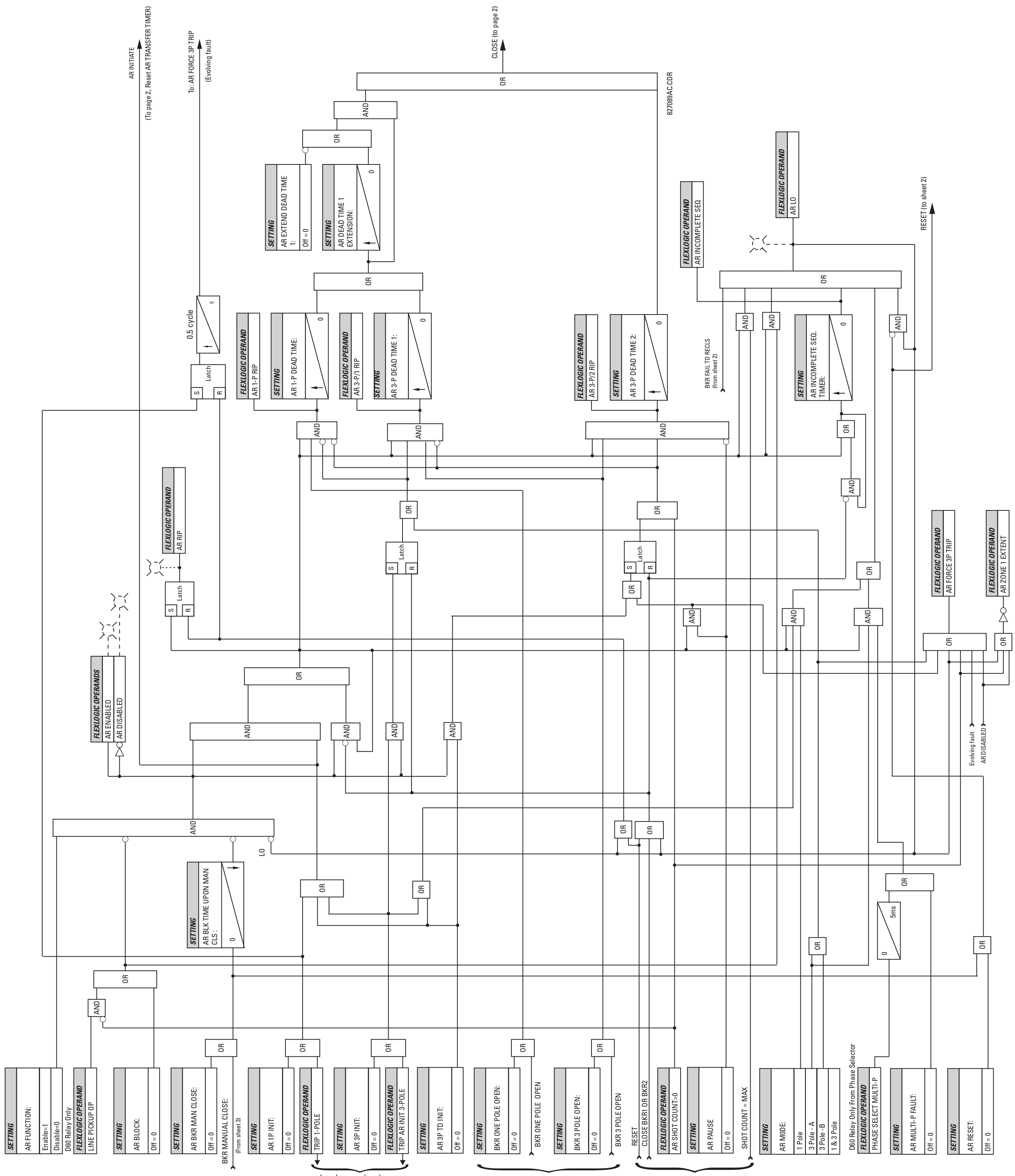

Figure 5–66: SINGLE-POLE AUTORECLOSE LOGIC (SHEET 1 OF 3)

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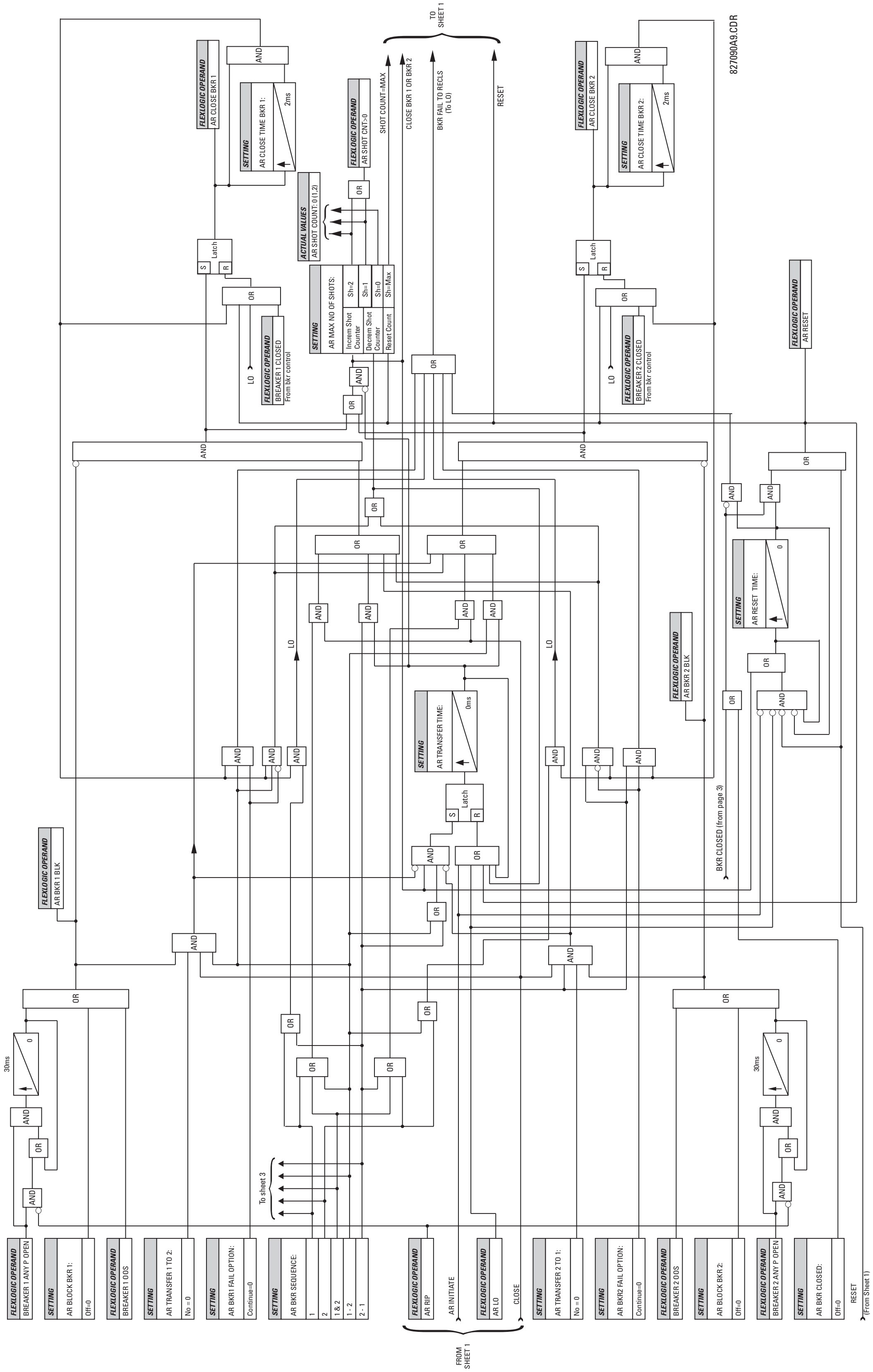

Figure 5–67: SINGLE-POLE AUTORECLOSE LOGIC (SHEET 2 OF 3)

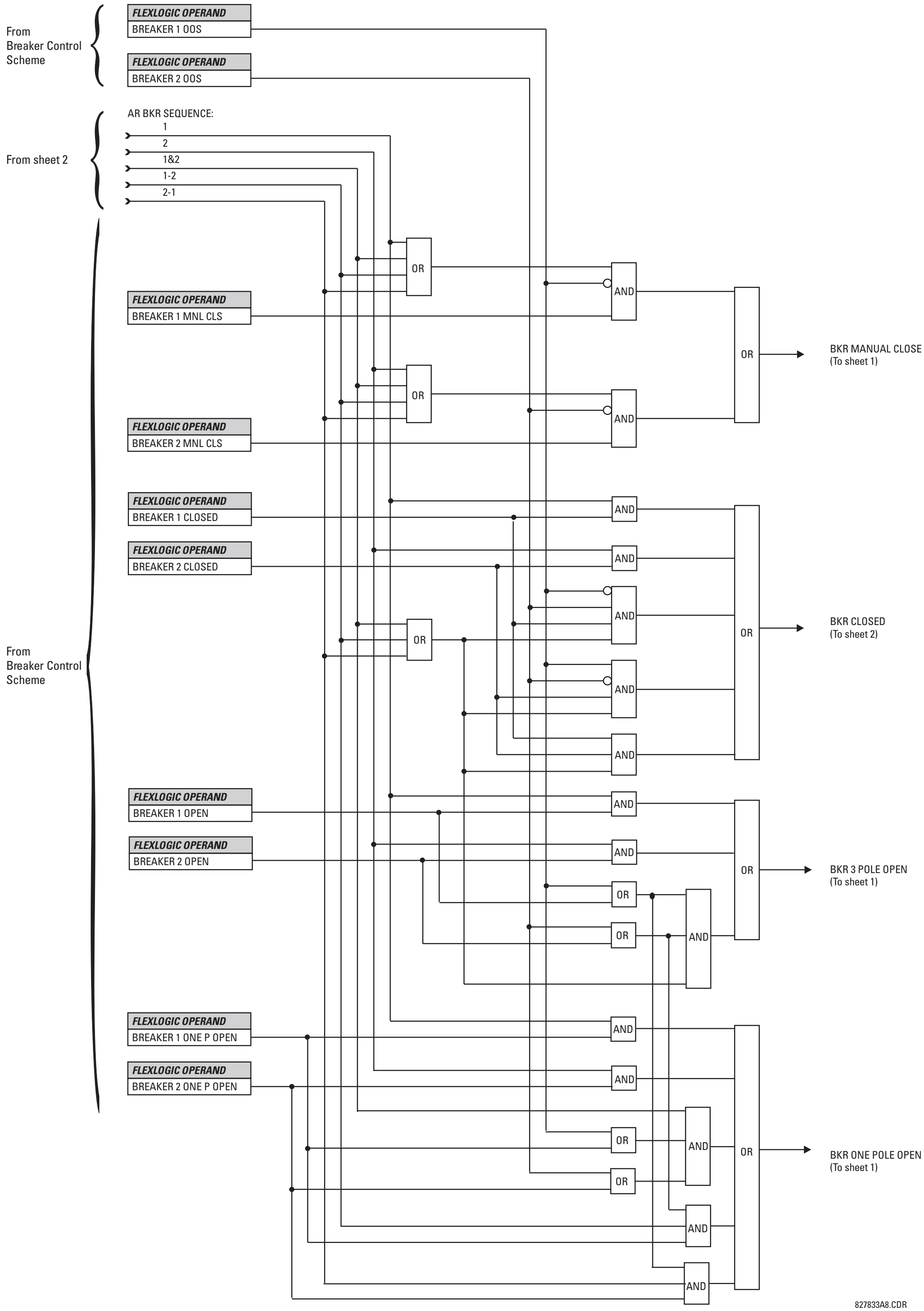

Figure 5–68: SINGLE-POLE AUTORECLOSE LOGIC (SHEET 3 OF 3)

5

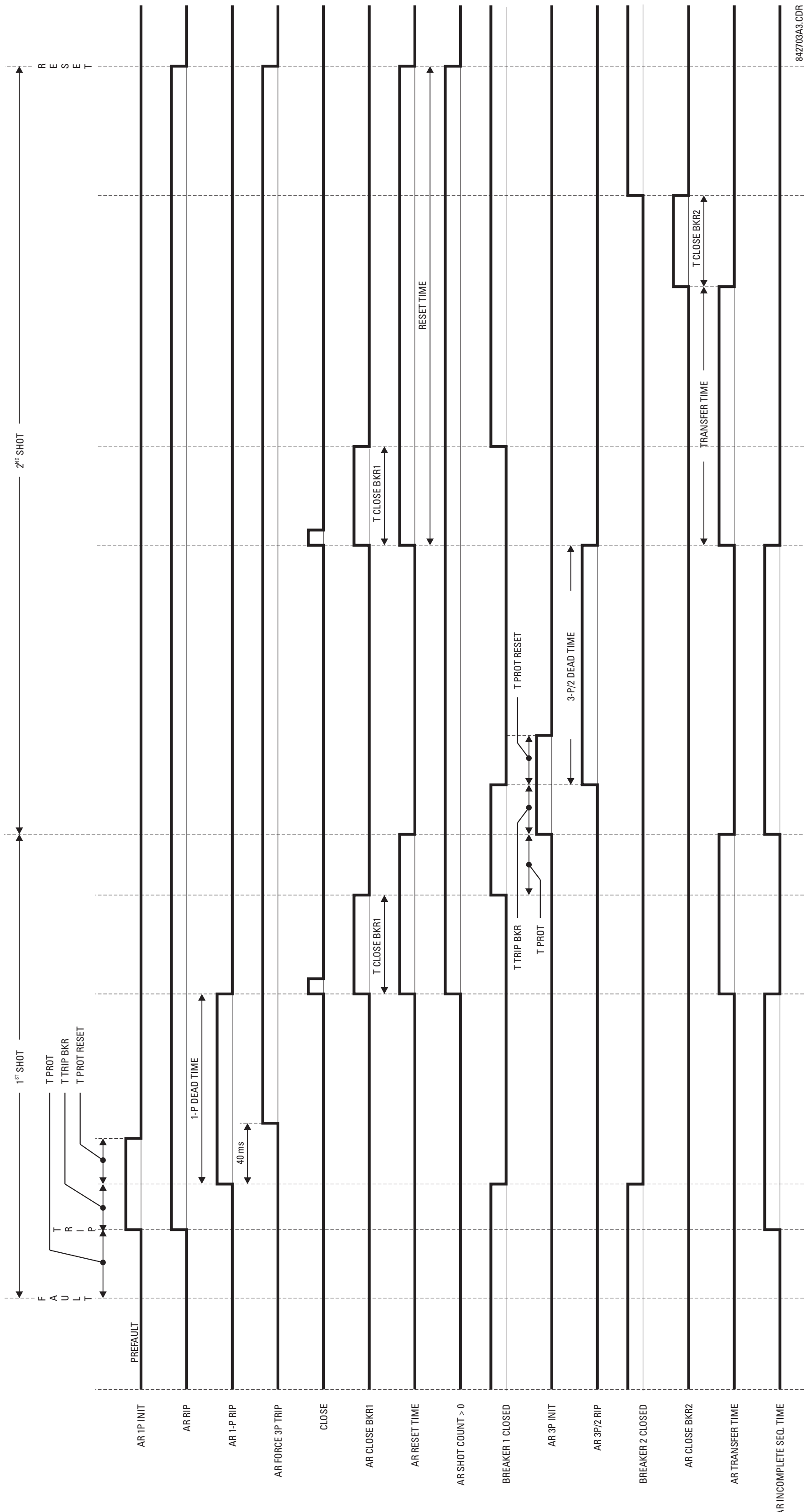

Figure 5–69: EXAMPLE RECLOSING SEQUENCE

5.6.6 DIGITAL ELEMENTS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL ELEMENTS

```
■ DIGITAL ELEMENTS
■

        ■ DIGITAL ELEMENT 1
        ■

MESSAGE     DIGITAL ELEMENT  1          Range: Disabled, Enabled
            FUNCTION: Disabled

MESSAGE     DIG ELEM  1 NAME:           Range: 16 alphanumeric characters
            Dig Element 1

MESSAGE     DIG ELEM  1 INPUT:          Range: FlexLogic™ operand
            Off

MESSAGE     DIG ELEM  1 PICKUP          Range: 0.000 to 999999.999 s in steps of 0.001
            DELAY:      0.000 s

MESSAGE     DIG ELEM  1 RESET           Range: 0.000 to 999999.999 s in steps of 0.001
            DELAY:      0.000 s

MESSAGE     DIG ELEM  1 BLOCK:          Range: FlexLogic™ operand
            Off

MESSAGE     DIGITAL ELEMENT  1          Range: Self-reset, Latched, Disabled
            TARGET: Self-reset

MESSAGE     DIGITAL ELEMENT  1          Range: Disabled, Enabled
            EVENTS: Disabled

        ■ DIGITAL ELEMENT 2
        ■
                  ↓
        ■ DIGITAL ELEMENT 16
        ■
```

There are 16 identical Digital Elements available, numbered 1 to 16. A Digital Element can monitor any FlexLogic™ operand and present a target message and/or enable events recording depending on the output operand state. The digital element settings include a 'name' which will be referenced in any target message, a blocking input from any selected FlexLogic™ operand, and a timer for pickup and reset delays for the output operand.

DIGITAL ELEMENT 1 INPUT: Selects a FlexLogic™ operand to be monitored by the Digital Element.

DIGITAL ELEMENT 1 PICKUP DELAY: Sets the time delay to pickup. If a pickup delay is not required, set to "0".

DIGITAL ELEMENT 1 RESET DELAY: Sets the time delay to reset. If a reset delay is not required, set to "0".

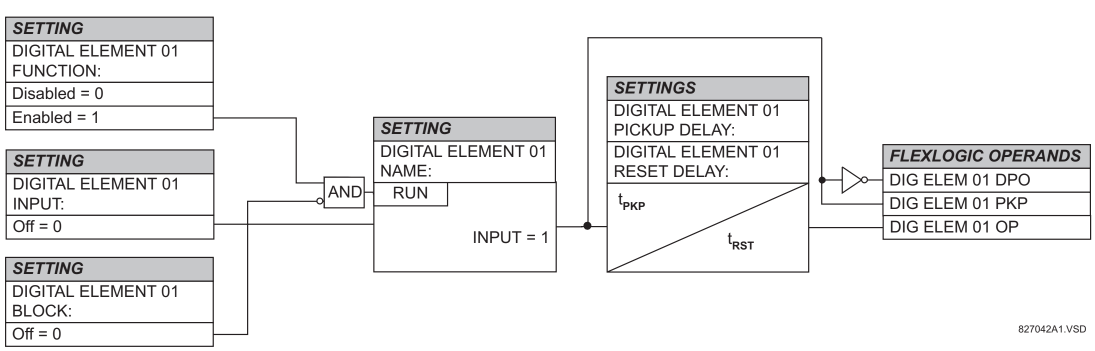

Figure 5–70: DIGITAL ELEMENT SCHEME LOGIC

5

a) CIRCUIT MONITORING APPLICATIONS

Some versions of the digital input modules include an active Voltage Monitor circuit connected across Form-A contacts. The Voltage Monitor circuit limits the trickle current through the output circuit (see Technical Specifications for Form-A).

As long as the current through the Voltage Monitor is above a threshold (see Technical Specifications for Form-A), the FlexLogic™ operand "Cont Op # VOn" will be set. (# represents the output contact number). If the output circuit has a high resistance or the DC current is interrupted, the trickle current will drop below the threshold and the FlexLogic™ operand "Cont Op # VOff" will be set. Consequently, the state of these operands can be used as indicators of the integrity of the circuits in which Form-A contacts are inserted.

b) BREAKER TRIP CIRCUIT INTEGRITY MONITORING – EXAMPLE 1

In many applications it is desired to monitor the breaker trip circuit integrity so problems can be detected before a trip operation is required. The circuit is considered to be healthy when the Voltage Monitor connected across the trip output contact detects a low level of current, well below the operating current of the breaker trip coil. If the circuit presents a high resistance, the trickle current will fall below the monitor threshold and an alarm would be declared.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact which is open when the breaker is open (see diagram below). To prevent unwanted alarms in this situation, the trip circuit monitoring logic must include the breaker position.

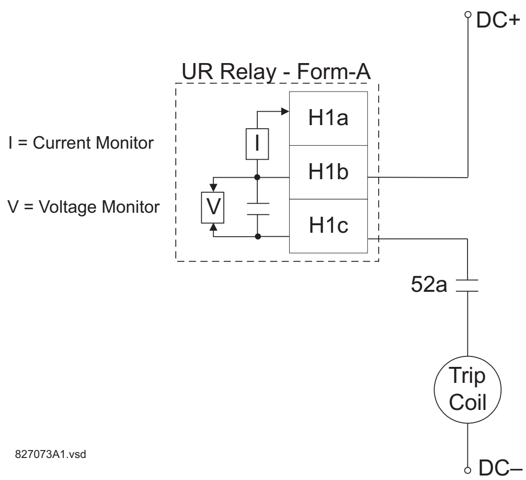

Figure 5–71: TRIP CIRCUIT EXAMPLE 1

Assume the output contact H1 is a trip contact. Using the contact output settings, this output will be given an ID name, e.g. "Cont Op 1". Assume a 52a breaker auxiliary contact is connected to contact input H7a to monitor breaker status. Using the contact input settings, this input will be given an ID name, e.g. "Cont Ip 1" and will be set "ON" when the breaker is closed. Using Digital Element 1 to monitor the breaker trip circuit, the settings will be:

■ DIGITAL ELEMENT 1 ■		DIGITAL ELEMENT 1 FUNCTION: Enabled
	MESSAGE	DIG ELEM 1 NAME: Bkr Trip Cct Out
	MESSAGE	DIG ELEM 1 INPUT: Cont Op 1 VOff
	MESSAGE	DIG ELEM 1 PICKUP DELAY: 0.200 s
	MESSAGE	DIG ELEM 1 RESET DELAY: 0.100 s
	MESSAGE	DIG ELEM 1 BLOCK: Cont Ip 1 Off

```
MESSAGE   DIGITAL ELEMENT  1
          TARGET: Self-reset

MESSAGE   DIGITAL ELEMENT  1
          EVENTS: Enabled
```

NOTE: The PICKUP DELAY setting should be greater than the operating time of the breaker to avoid nuisance alarms.

c) BREAKER TRIP CIRCUIT INTEGRITY MONITORING – EXAMPLE 2

If it is required to monitor the trip circuit continuously, independent of the breaker position (open or closed), a method to maintain the monitoring current flow through the trip circuit when the breaker is open must be provided (as shown in Figure: TRIP CIRCUIT - EXAMPLE 2). This can be achieved by connecting a suitable resistor (as listed in the VALUES OF RESISTOR 'R' table) across the auxiliary contact in the trip circuit. In this case, it is not required to supervise the monitoring circuit with the breaker position - the BLOCK setting is selected to Off. In this case, the settings will be:

```
■ DIGITAL ELEMENT  1      DIGITAL ELEMENT  1
■                         FUNCTION: Enabled

MESSAGE                   DIG ELEM  1 NAME:
                          Bkr Trip Cct Out

MESSAGE                   DIG ELEM  1 INPUT:
                          Cont Op 1 VOff

MESSAGE                   DIG ELEM  1 PICKUP
                          DELAY:      0.200 s

MESSAGE                   DIG ELEM  1 RESET
                          DELAY:      0.100 s

MESSAGE                   DIG ELEM  1 BLOCK:
                          Off

MESSAGE                   DIGITAL ELEMENT  1
                          TARGET: Self-reset

MESSAGE                   DIGITAL ELEMENT  1
                          EVENTS: Enabled
```

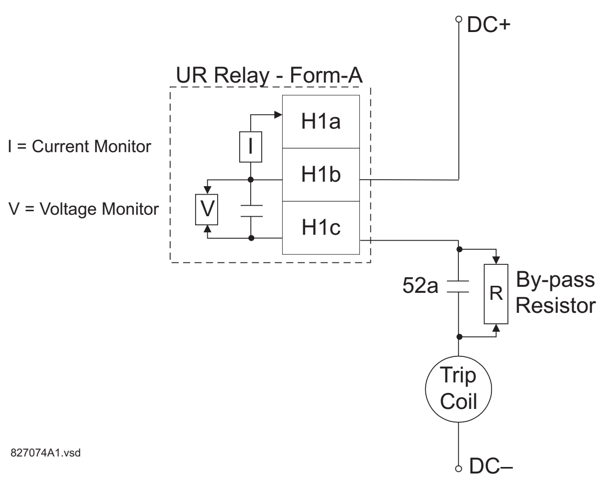

Figure 5–72: TRIP CIRCUIT EXAMPLE 2

Table 5–27: VALUES OF RESISTOR 'R'

POWER SUPPLY (V DC)	RESISTANCE (OHMS)	POWER (WATTS)
24	1000	2
30	5000	2
48	10000	2
110	25000	5
125	25000	5
250	50000	5

5.6.7 DIGITAL COUNTERS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ DIGITAL COUNTERS ⇨ COUNTER 1(8)

■ COUNTER 1 ■	◁▷	COUNTER 1 FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	△▽	COUNTER 1 NAME: Counter 1	Range: 12 alphanumeric characters
MESSAGE	△▽	COUNTER 1 UNITS:	Range: 6 alphanumeric characters
MESSAGE	△▽	COUNTER 1 PRESET: 0	Range: –2,147,483,647 to +2,147,483,647
MESSAGE	△▽	COUNTER 1 COMPARE: 0	Range: –2,147,483,647 to +2,147,483,647
MESSAGE	△▽	COUNTER 1 UP: Off	Range: FlexLogic™ operand
MESSAGE	△▽	COUNTER 1 DOWN: Off	Range: FlexLogic™ operand
MESSAGE	△▽	COUNTER 1 BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	△▽	CNT1 SET TO PRESET: Off	Range: FlexLogic™ operand
MESSAGE	△▽	COUNTER 1 RESET: Off	Range: FlexLogic™ operand
MESSAGE	△▽	COUNT1 FREEZE/RESET: Off	Range: FlexLogic™ operand
MESSAGE	△	COUNT1 FREEZE/COUNT: Off	Range: FlexLogic™ operand

There are 8 identical digital counters, numbered from 1 to 8. A digital counter counts the number of state transitions from Logic 0 to Logic 1. The counter is used to count operations such as the pickups of an element, the changes of state of an external contact (e.g. breaker auxiliary switch), or pulses from a watt-hour meter.

COUNTER 1 UNITS:

Assigns a label to identify the unit of measure pertaining to the digital transitions to be counted. The units label will appear in the corresponding Actual Values status.

COUNTER 1 PRESET:

Sets 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.

COUNTER 1 COMPARE:

Sets the value to which the accumulated count value is compared. Three FlexLogic™ output operands are provided to indicate if the present value is "more than (HI)", "equal to (EQL)", or "less than (LO)" the set value.

COUNTER 1 UP:

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 will rollover to –2,147,483,647.

COUNTER 1 DOWN:

Selects the FlexLogic™ operand for decrementing the counter. If an enabled DOWN input is received when the accumulated value is at the limit of -2,147,483,647 counts, the counter will rollover to +2,147,483,647.

COUNTER 1 BLOCK:

Selects the FlexLogic™ operand for blocking the counting operation.

CNT1 SET TO PRESET:

Selects the FlexLogic™ operand used to set the count to the preset value. The counter will be set to the preset value in the following situations:

1. When the counter is enabled and the "CNT1 SET TO PRESET" operand has the value 1 (when the counter is enabled and "CNT1 SET TO PRESET" is 0, the counter will be set to 0.)
2. When the counter is running and the "CNT1 SET TO PRESET" operand changes the state from 0 to 1 ("CNT1 SET TO PRESET" changing from 1 to 0 while the counter is running has no effect on the count).
3. When a reset or reset/freeze command is sent to the counter and the "CNT1 SET TO PRESET" operand has the value 1 (when a reset or reset/freeze command is sent to the counter and the "CNT1 SET TO PRESET" operand has the value 0, the counter will be set to 0).

COUNTER 1 RESET:

Selects the FlexLogic™ operand for setting the count to either '0' or the preset value depending on the state of the "CNT1 SET TO PRESET" operand.

COUNTER 1 FREEZE/RESET:

Selects the FlexLogic™ 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' or the preset value.

COUNTER 1 FREEZE/COUNT:

Selects the FlexLogic™ operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and continuing counting. The present accumulated value and captured frozen value with the associated date/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.

5

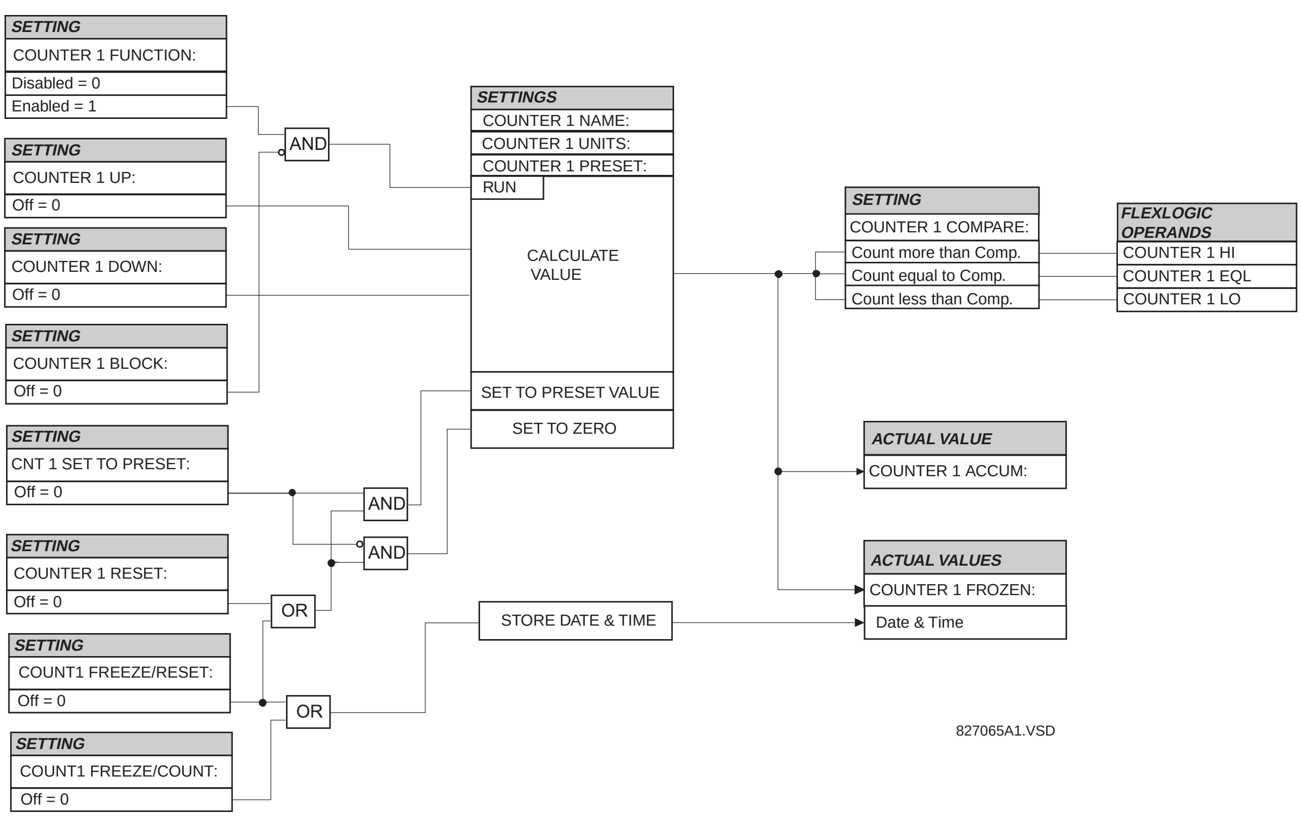

Figure 5–73: DIGITAL COUNTER SCHEME LOGIC

5.6.8 MONITORING ELEMENTS

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS

■ MONITORING ■ ELEMENTS	◁▷	■ BREAKER 1 ■ ARCING CURRENT	
MESSAGE	△▽	■ BREAKER 2 ■ ARCING CURRENT	
MESSAGE	△▽	■ VT FUSE FAILURE ■	
MESSAGE	△	■ OPEN POLE ■	

a) BREAKER 1(2) ARCING CURRENT

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨ BREAKER 1 ARCING CURRENT

■ BREAKER 1 ■ ARCING CURRENT	◁▷	BKR 1 ARC AMP FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	△▽	BKR 1 ARC AMP SOURCE: SRC 1	Range: SRC 1, SRC 2,..., SRC 6
MESSAGE	△▽	BKR 1 ARC AMP INIT: Off	Range: FlexLogic™ operand
MESSAGE	△▽	BKR 1 ARC AMP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	△▽	BKR 1 ARC AMP LIMIT: 1000 kA2-cyc	Range: 0 to 50000 kA^2-cycle in steps of 1
MESSAGE	△▽	BKR 1 ARC AMP BLOCK: Off	Range: FlexLogic™ operand
MESSAGE	△▽	BKR 1 ARC AMP TARGET: Self-reset	Range: Self-reset, Latched, Disabled
MESSAGE	△	BKR 1 ARC AMP EVENTS: Disabled	Range: Disabled, Enabled

5

There are 2 identical Breaker Arcing Current features available for Breakers 1 and 2. This element calculates an estimate of the per-phase wear on the breaker contacts by measuring and integrating the current squared passing through the breaker contacts as an arc. These per-phase values are added to accumulated totals for each phase and compared to a programmed threshold value. When the threshold is exceeded in any phase, the relay can set an output operand to "1". The accumulated value for each phase can be displayed as an actual value.

The operation of the scheme is shown in the following logic diagram. The same output operand that is selected to operate the output relay used to trip the breaker, indicating a tripping sequence has begun, is used to initiate this feature. A time delay is introduced between initiation and the starting of integration to prevent integration of current flow through the breaker before the contacts have parted. This interval includes the operating time of the output relay, any other auxiliary relays and the breaker mechanism. For maximum measurement accuracy, the interval between change-of-state of the operand (from 0 to 1) and contact separation should be measured for the specific installation. Integration of the measured current continues for 100 milliseconds, which is expected to include the total arcing period.

BKR 1 ARC AMP INIT:

Selects the same output operand that is selected to operate the output relay used to trip the breaker.

BKR 1 ARC AMP DELAY:

This setting is used to program the delay interval between the time the tripping sequence is initiated and the time the breaker contacts are expected to part, starting the integration of the measured current.

BKR 1 ARC AMP LIMIT:

Selects the threshold value above which the output operand is set.

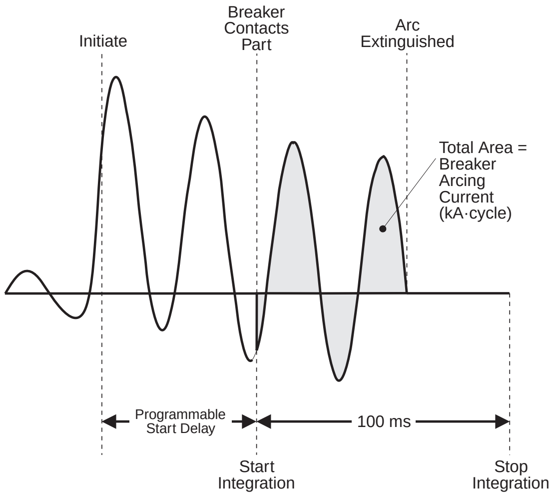

Figure 5–74: ARCING CURRENT MEASUREMENT

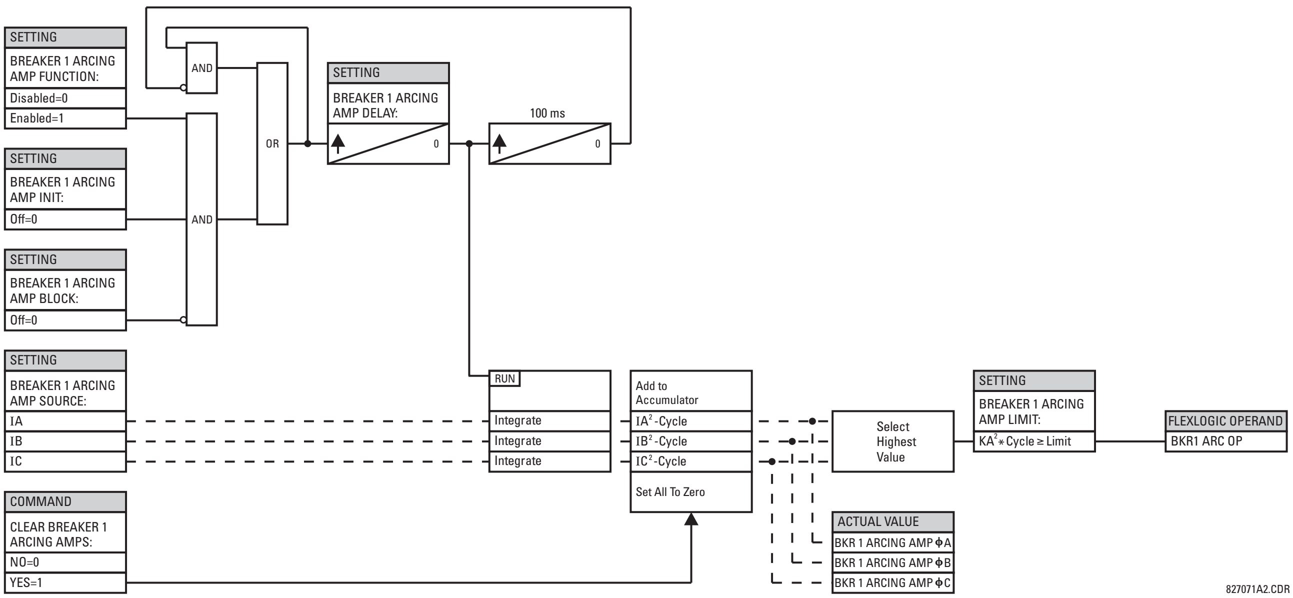

Figure 5–75: BREAKER ARCING CURRENT SCHEME LOGIC

b) VT FUSE FAILURE

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ VT FUSE FAILURE

■ VT FUSE FAILURE ■	VT FUSE FAILURE FUNCTION: Disabled	*Range: Disabled, Enabled*

Every signal source includes a fuse failure scheme.

The VT fuse failure detector can be used to raise an alarm and/or block elements that may operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that might be blocked (via the BLOCK input) are distance, voltage restrained overcurrent, and directional current.

There are two classes of fuse failure that may occur: (A) loss of one or two phases, and (B) loss of all three phases. A different means of detection is 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 could 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 will be 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.

The common FUNCTION setting will Enable/Disable the fuse failure feature for all 6 sources.

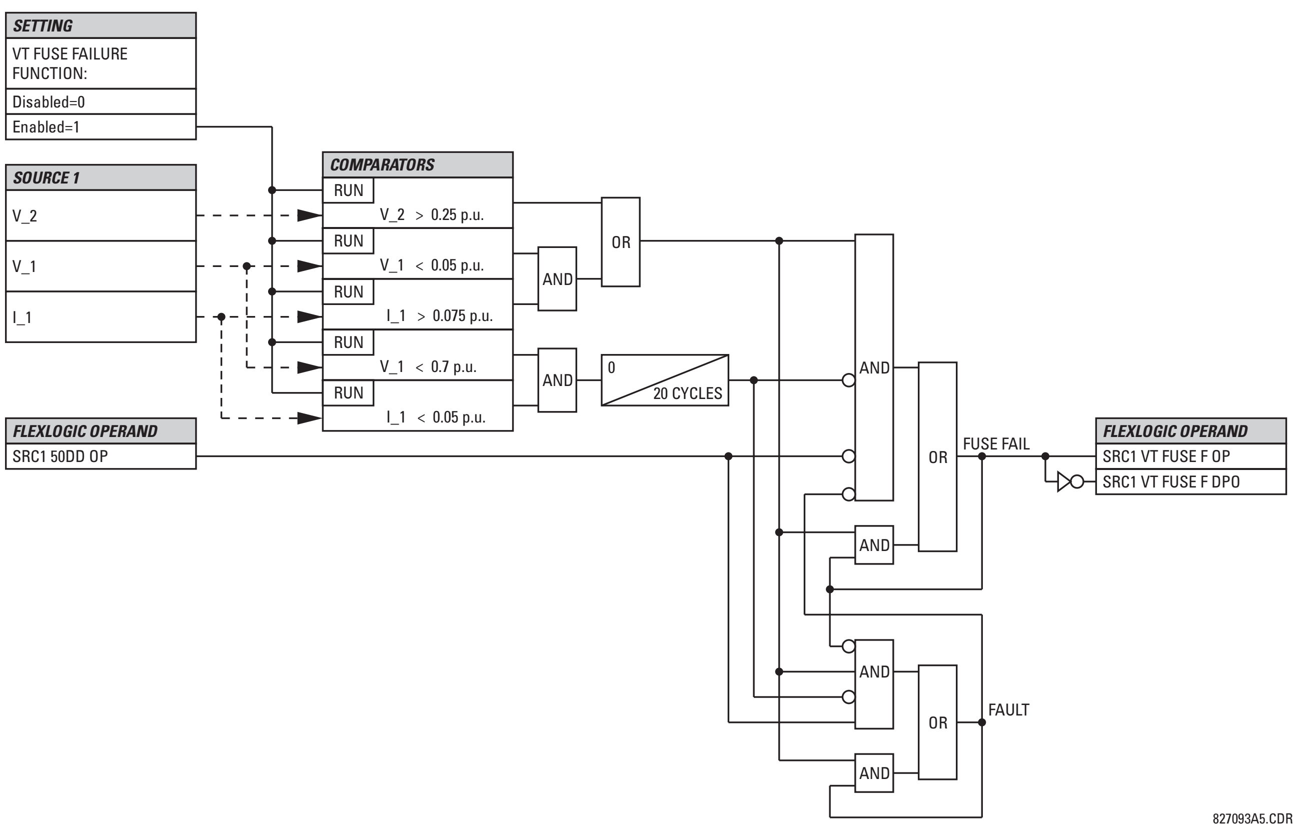

Figure 5–76: VT FUSE FAIL SCHEME LOGIC

c) OPEN POLE DETECTOR

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ MONITORING ELEMENTS ⇨⇩ OPEN POLE

■ OPEN POLE ■		OPEN POLE FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	OPEN POLE BLOCK: Off	Range: FlexLogic™ operand
	MESSAGE	OPEN POLE VOLTAGE SUPV: Disabled	Range: Disabled, Enabled
	MESSAGE	OPEN POLE CURRENT PKP: 0.050 pu	Range: 0.000 to 30.000 pu in steps of 0.001
	MESSAGE	OPEN POLE TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
	MESSAGE	OPEN POLE EVENTS: Disabled	Range: Enabled, Disabled

The open pole detector is intended to identify an open pole of the line circuit breaker. The scheme monitors the breakers auxiliary contacts, current in the circuit and optionally voltage 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. 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:

- both breakers have an open pole on the same phase or
- the current on the line drops below a threshold or
- the current and voltage on the line drop below a threshold.

The OPEN POLE logic becomes operational only when a TRIP 1-POLE command is issued and resets 150 ms (time for breaker to close) after the AR 1-P RIP operand resets. The intention is for the OPEN POLE logic to operate only when an open pole condition occurs following a single pole trip during a single phase fault. An open pole condition should not be declared, and protections and the phase selector blocked, when a pole is accidentally open (without a trip command) or for a remote end open (single or three phase).

The Open Pole feature uses signals defined by the SOURCE setting under the Common Distance Settings.

Voltage supervision can be used only with wye VTs on the line side of the breaker(s).

The **OPEN POLE CURRENT PICKUP** setting establishes the current threshold below which an open pole is declared.

For convenience, the position of the breaker poles defined in the Breaker Control feature and available as FlexLogic™ operand BREAKER 1/2 ΦA CLSD through BREAKER 1/2 ΦC CLSD and BREAKER 1/2 OOS are used by the Open Pole feature. For correct operation of the Open Pole Detector, the Breaker Control, Trip Output, and Single Pole Autoreclose features must be enabled and configured properly. When used in configuration with only one breaker, the **BREAKER 2 FUNCTION** should be "Enabled" and the **BREAKER 2 OUT OF SV** setting should be "On" (see the BREAKER CONTROL section for additional details).

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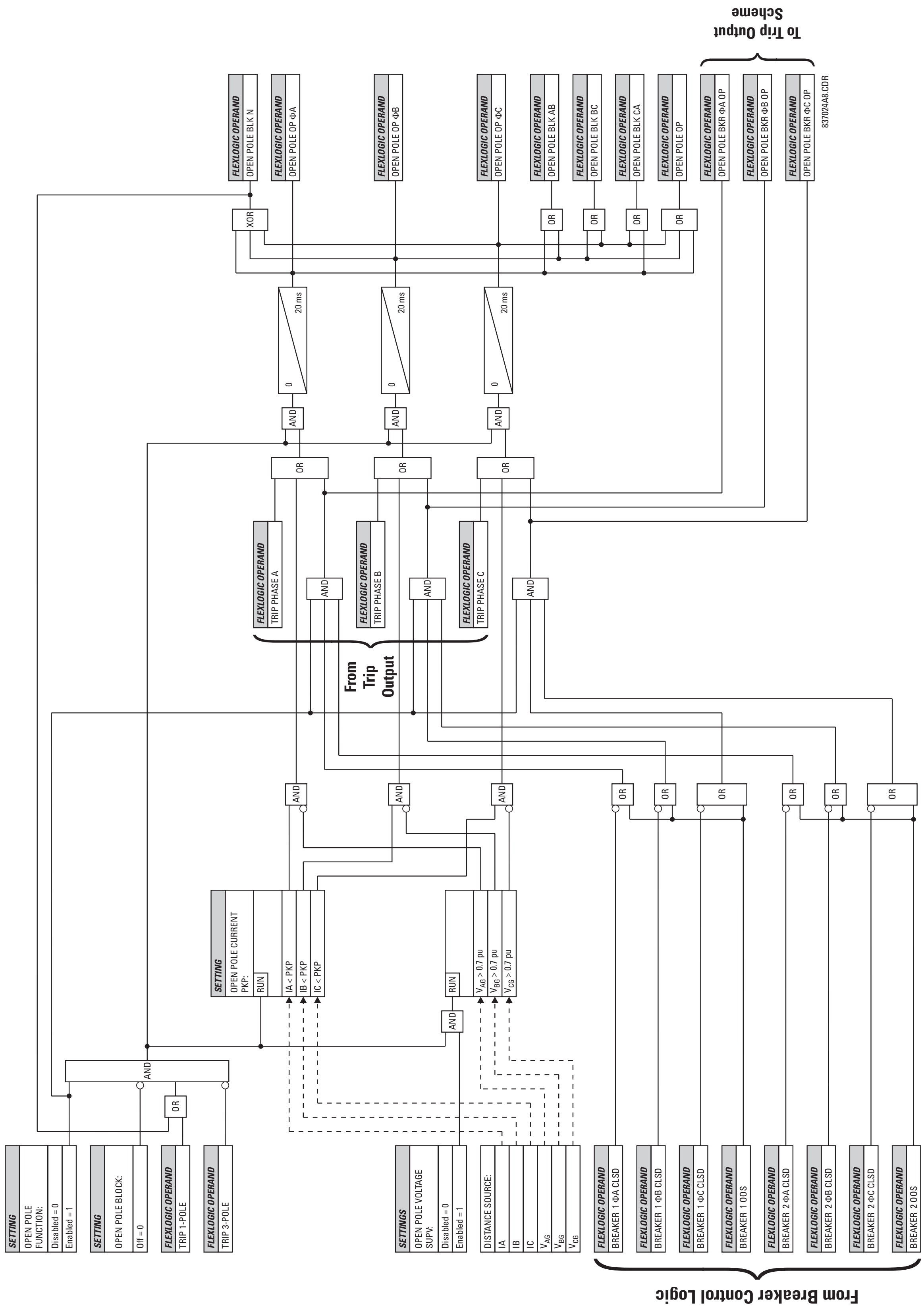

Figure 5–77: OPEN POLE DETECTOR LOGIC

5.6.9 PILOT SCHEMES

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES

■ PILOT SCHEMES ■		■ DUTT SCHEME ■
	MESSAGE	■ PUTT SCHEME ■
	MESSAGE	■ POTT SCHEME ■
	MESSAGE	■ HYBRID POTT SCHEME ■
	MESSAGE	■ BLOCKING SCHEME ■

This menu allows the selection and the setting up (see the following sub-menus) of a protection signaling scheme. See also, the section on Protection Signaling Schemes in the APPLICATION OF SETTINGS chapter.

a) DIRECT UNDER-REACHING TRANSFER TRIP (DUTT)

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨ DUTT SCHEME

■ DUTT SCHEME ■		DUTT SCHEME FUNCTION: Disabled	Range: Disabled, Enabled
	MESSAGE	DUTT SEAL-IN DELAY: 0.010 s	Range: 0.000 to 65.535 s in steps of 0.001
	MESSAGE	DUTT NO OF COMM BITS: 1	Range: 1, 2, or 4
	MESSAGE	DUTT RX1: Off	Range: FlexLogic™ operand
	MESSAGE	DUTT RX2: Off	Range: FlexLogic™ operand
	MESSAGE	DUTT RX3: Off	Range: FlexLogic™ operand
	MESSAGE	DUTT RX4: Off	Range: FlexLogic™ operand
	MESSAGE	DUTT SCHEME TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
	MESSAGE	DUTT SCHEME EVENTS: Disabled	Range: Disabled, Enabled

This scheme uses an under-reaching Zone 1 distance element to key a transfer trip signal(s) to the remote end(s), 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 per rules of distance relaying.

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(s). The latter may 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 end(s). Choices of communications channel include Remote Inputs/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operands should 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 scheme output operands must be configured to interface with other relay functions, output contacts in particular. Typically, the output operands should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application. When used in conjunction with the Trip Output, the scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

DUTT SEAL-IN DELAY:

The output FlexLogic™ operand (DUTT OP) is produced according to the DUTT scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels such as a Power Line Carrier. The **DUTT SEAL-IN DELAY** is a minimum guaranteed duration of the DUTT OP pulse. As this operand activates the Trip Table of the DUTT scheme, the trip operands DUTT TRIP A, B, C and 3P are sealed-in for the same period of time.

DUTT NO OF COMM BITS:

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 no.1 (DUTT TX1 operand) and responds to the direct trip command received on bit no. 1 (DUTT RX1 setting). The scheme uses only local fault type identification provided by the PHASE SELECTOR to assert the Output Operands DUTT TRIP A, B, C and 3P (see the THEORY OF OPERATION chapter for details on the use of communication channels.)

DUTT RX1 through DUTT RX4:

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 TX signal (often via different paths) and building appropriate security logic (such as series (AND gate) or 2-out-of-3 voting logic) with FlexLogic™. The DUTT RX settings should be associated with the final (secure) TX signals.

5

In single-bit applications, **DUTT RX1** must be used. In two-bit applications, **DUTT RX1** and **DUTT RX2** must be used. In four-bit applications, **DUTT RX1**, **DUTT RX2**, **DUTT RX3**, and **DUTT RX4** must be used. In multi-terminal applications, the RX signals from two or more remote terminals should be connected through OR gates in the FlexLogic™ and the resulting signals should be configured as the DUTT RX inputs.

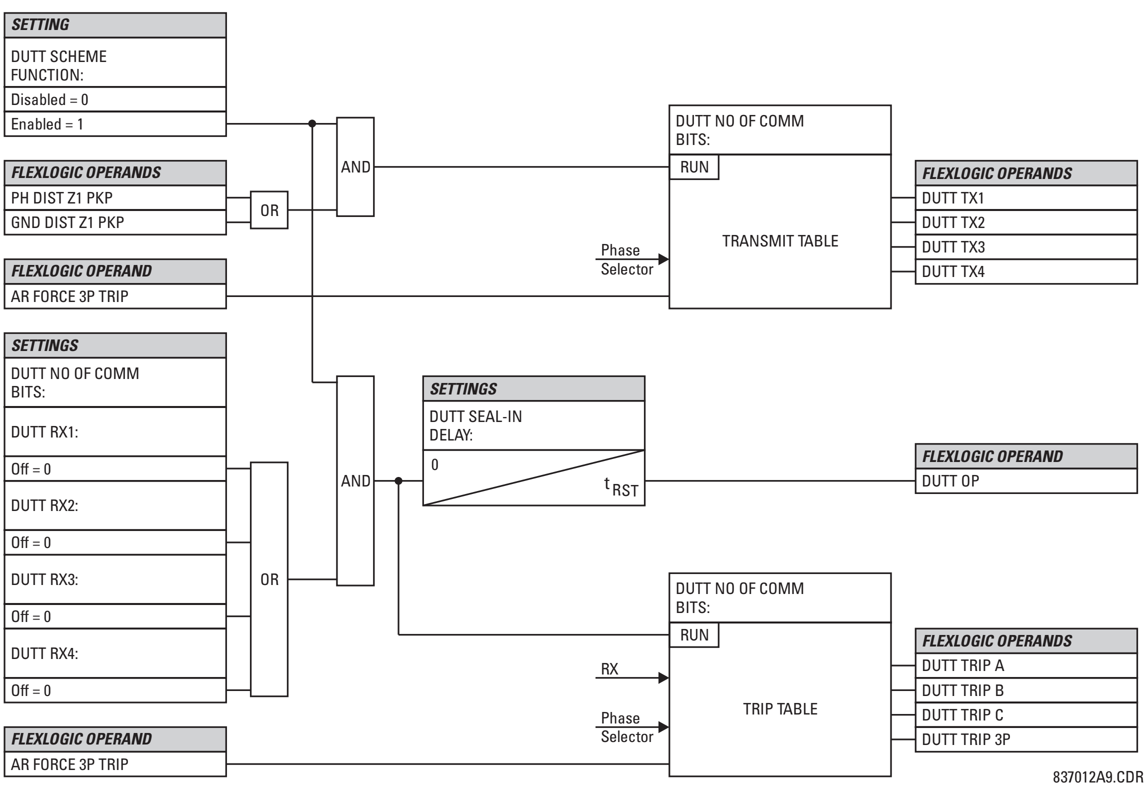

Figure 5–78: DUTT SCHEME LOGIC

b) PERMISSIVE UNDER-REACHING TRANSFER TRIP (PUTT)

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨⇩ PUTT SCHEME

■ PUTT SCHEME ■		
	PUTT SCHEME FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	PUTT RX PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	PUTT SEAL-IN DELAY: 0.010 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE	PUTT NO OF COMM BITS: 1	Range: 1, 2, or 4
MESSAGE	PUTT RX1: Off	Range: FlexLogic™ operand
MESSAGE	PUTT RX2: Off	Range: FlexLogic™ operand
MESSAGE	PUTT RX3: Off	Range: FlexLogic™ operand
MESSAGE	PUTT RX4: Off	Range: FlexLogic™ operand
MESSAGE	PUTT SCHEME TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
MESSAGE	PUTT SCHEME EVENTS: Disabled	Range: Disabled, Enabled

This scheme uses an under-reaching Zone 1 distance element to key a transfer trip signal(s) to the remote terminal(s) where it is 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 per rules of distance relaying.

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(s). The scheme generates output operands (PUTT TX1 through PUTT TX4) that are used to transmit the signal to the remote end(s). Choices of communications channel include Remote Inputs/ Outputs and telecommunications interfaces. When used with telecommunications facilities the output operands should 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 scheme output operands must be configured to interface with other relay functions, output contacts in particular. Typically, the output operands should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application. When used in conjunction with the Trip Output element, the scheme is pre-configured to initiate trip, breaker fail and single-pole autoreclose actions.

PUTT RX PICKUP DELAY:

This setting enables the relay to cope with spurious receive signals. This delay should be set longer than the longest spurious TX signal that can be received simultaneously with the zone 1 pickup. The selected delay will increase the response time of the scheme.

PUTT SEAL-IN DELAY:

The output FlexLogic™ operand (PUTT OP) is produced according to the PUTT scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels such as a Power Line Carrier. The **PUTT SEAL-IN DELAY** is a minimum guaranteed duration of the PUTT OP pulse. As this operand activates the Trip Table of the PUTT scheme, the trip operands PUTT TRIP A, B, C and 3P are sealed-in for the same period of time.

PUTT NO OF COMM BITS:

This setting specifies the number of bits of the communications channel available for the scheme. The transmit codes and trip table of the PUTT scheme are identical as those for the direct under-reaching transfer trip scheme. Please refer to the THEORY OF OPERATION chapter for more information.

PUTT RX1 through PUTT RX4:

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. In single-bit applications, PUTT RX1 must be used. In two-bit applications, **PUTT RX1** and **PUTT RX2** must be used. In four-bit applications, **PUTT RX1**, **PUTT RX2**, **PUTT RX3**, and **PUTT RX4** must be used. In multi-terminal applications, the RX signals from two or more remote terminals should be connected through OR gates in the FlexLogic™ and the resulting signals should be configured as the PUTT RX inputs.

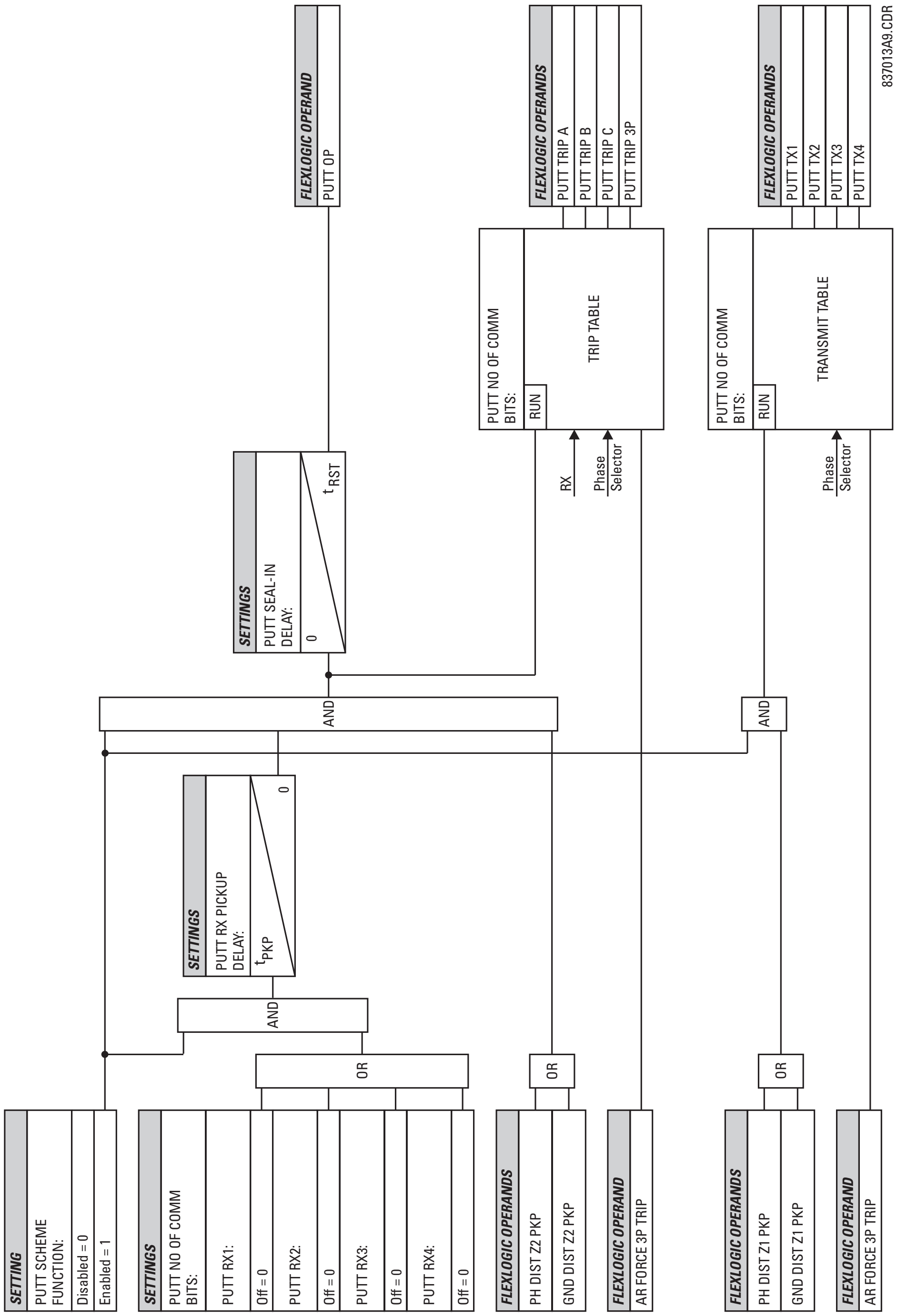

Figure 5–79: PUTT SCHEME LOGIC

c) PERMISSIVE OVER-REACHING TRANSFER TRIP (POTT)

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨⇩ POTT SCHEME

■ POTT SCHEME ■	POTT SCHEME FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE	POTT PERMISSIVE ECHO: Disabled	Range: Disabled, Enabled
MESSAGE	POTT RX PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	TRANS BLOCK PICKUP DELAY: 0.020 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	TRANS BLOCK RESET DELAY: 0.090 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	ECHO DURATION: 0.100 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	ECHO LOCKOUT: 0.250 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	LINE END OPEN PICKUP DELAY: 0.050 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	POTT SEAL-IN DELAY: 0.010 s	Range: 0.000 to 65.535 sec. in steps of 0.001
MESSAGE	GND DIR O/C FWD: Off	Range: FlexLogic™ operand
MESSAGE	POTT NO OF COMM BITS: 1	Range: 1, 2, or 4
MESSAGE	POTT RX1: Off	Range: FlexLogic™ operand
MESSAGE	POTT RX2: Off	Range: FlexLogic™ operand
MESSAGE	POTT RX3: Off	Range: FlexLogic™ operand
MESSAGE	POTT RX4: Off	Range: FlexLogic™ operand
MESSAGE	POTT SCHEME TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
MESSAGE	POTT SCHEME EVENTS: Disabled	Range: Disabled, Enabled

This scheme is intended for two-terminal line applications only. The scheme uses an over-reaching Zone 2 distance element to essentially 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, configured and set per rules of distance relaying. The Line Pickup element should be enabled, configured and set properly to detect line-end-open/weak-infeed conditions. If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set accordingly.

5

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/ Outputs and telecommunications interfaces. When used with telecommunications facilities the output operands should 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 scheme output operands must be configured to interface with other relay functions, output contacts in particular. Typically, the output operands should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application.

When used in conjunction with the Trip Output element, the scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

POTT PERMISSIVE ECHO:

If set to "Enabled" this setting will result in sending a permissive echo signal(s) to the remote end under certain conditions. (See the THEORY OF OPERATION chapter.) 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 settable as **ECHO DURATION**.

The echo is sent back only if none of the overreaching protection elements operates.

POTT RX PICKUP DELAY:

This setting enables the relay to cope with spurious receive signals. The delay should be set longer than the longest spurious TX signal that can be received simultaneously with the Zone 2 pickup. The selected delay will increase the response time of the scheme.

TRANS BLOCK PICKUP DELAY:

5

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 RX signal to be passed and aligned with the **GND DIR O/C FWD** indication only for a period of time defined as **TRANS BLOCK PICKUP DELAY**. After that the ground directional overcurrent path will be virtually disabled for a period of time specified as **TRANS BLOCK RESET DELAY**.

The **TRANS BLOCK PICKUP DELAY** should be long enough to give the selected ground directional overcurrent function time to operate, but not longer 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.

This setting should take into account the **POTT RX PICKUP DELAY**. The POTT RX signal is shaped for aligning with the ground directional indication as follows: the original RX signal is delayed by the **POTT RX PICKUP DELAY**, then terminated at **TRANS BLOCK PICKUP DELAY** after the pickup of the original POTT TX signal, and eventually locked-out for **TRANS BLOCK RESET DELAY**.

TRANS BLOCK RESET DELAY:

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 (see the **TRANS BLOCK PICKUP DELAY**).

This delay should be selected 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 may be considered to make sure that the ground directional function is not jeopardized during delayed breaker operations.

ECHO DURATION:

This setting defines 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:

This setting defines the lockout period for the echo logic after sending the echo pulse.

LINE END OPEN PICKUP DELAY:

This setting defines the pickup setting 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). The value of this setting should take into account the principle of operation and settings of the Line Pickup element.

POTT SEAL-IN DELAY:

The output FlexLogic™ operand (POTT OP) is produced according to the POTT scheme logic. A seal-in time delay is applied to this operand for coping with noisy communication channels. The **POTT SEAL-IN DELAY** defines a minimum guaranteed duration of the POTT OP pulse. As this operand activates the Trip Table of the POTT scheme, the trip operands POTT TRIP A, B, C and 3P are sealed-in for the same period of time.

GND DIR O/C FWD:

This setting defines the FlexLogic™ operand (if any) of a protection element that is used in addition to the 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 as **GND DIR O/C FWD**. Even though any FlexLogic™ operand could be used as **GND DIR O/C FWD** allowing 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 IOC or Neutral Directional IOC. Both of these elements have separate forward (FWD) and reverse (REV) output operands. The forward indication should be used (**NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**).

POTT NO OF COMM BITS:

This setting specifies the number of bits of the communications channel available for the scheme. The transmit codes and Trip Tables of the POTT scheme are the same as those for the permissive under-reaching transfer trip scheme. Please refer to the description of the PUTT scheme for more information.

POTT RX1 through POTT RX4:

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. In single-bit applications, POTT RX1 must be used. In two-bit applications, **POTT RX1** and **POTT RX2** must be used. In four-bit applications, **POTT RX1**, **POTT RX2**, **POTT RX3**, and **POTT RX4** must be used.

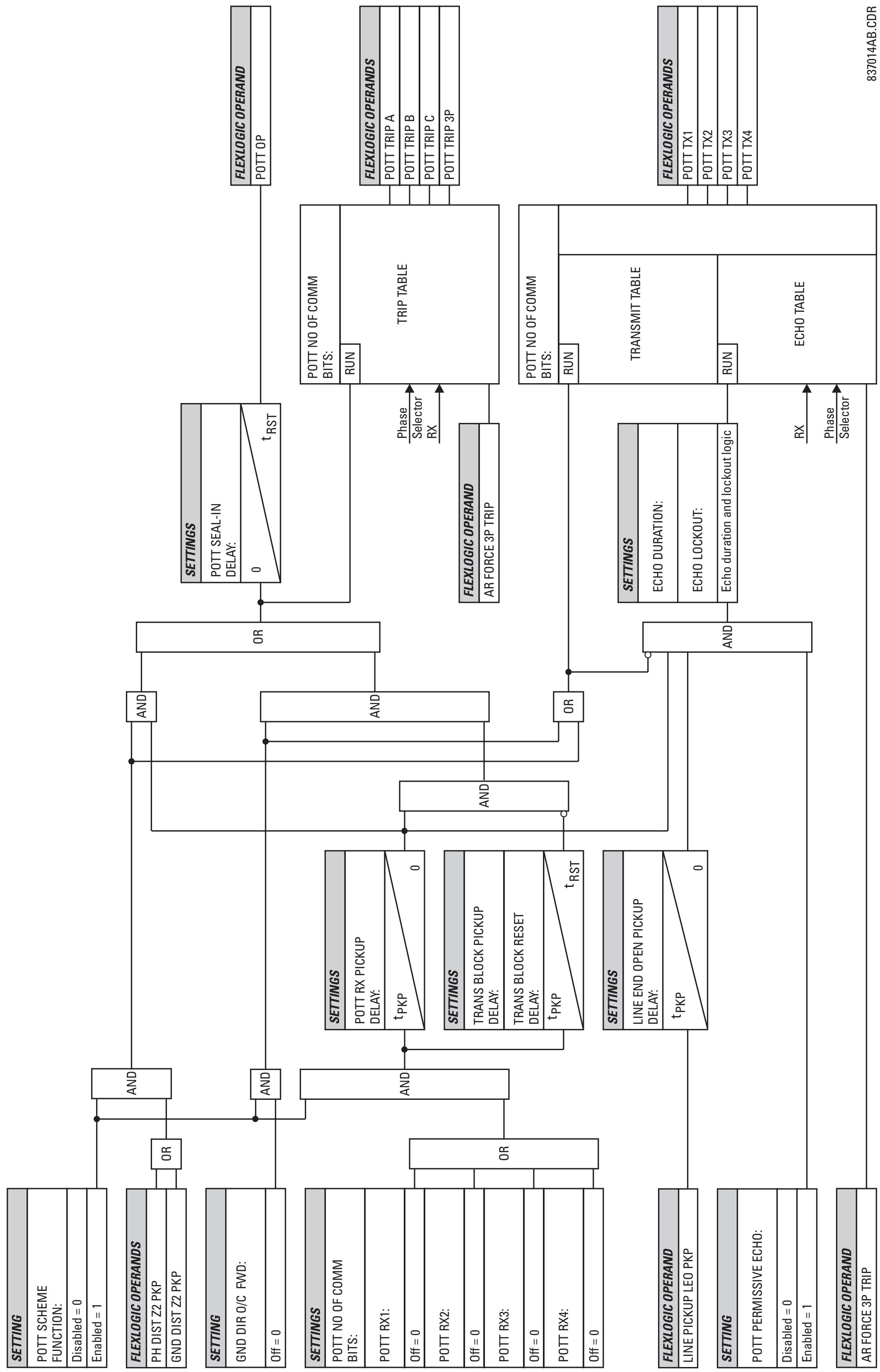

Figure 5–80: POTT SCHEME LOGIC

d) HYBRID PERMISSIVE OVER-REACHING TRANSFER TRIP

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨⇩ HYBRID POTT SCHEME

■ HYBRID POTT SCHEME ■		HYB POTT SCHEME FUNCTION: Disabled	Range: Disabled, Enabled
MESSAGE		HYB POTT PERMISSIVE ECHO: Disabled	Range: Disabled, Enabled
MESSAGE		HYB POTT RX PICKUP DELAY: 0.000 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		TRANS BLOCK PICKUP DELAY: 0.020 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		TRANS BLOCK RESET DELAY: 0.090 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		ECHO DURATION: 0.100 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		ECHO LOCKOUT: 0.250 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		HYB POTT SEAL-IN DELAY: 0.010 s	Range: 0.000 to 65.535 s in steps of 0.001
MESSAGE		GND DIR O/C FWD: Off	Range: FlexLogic™ operand
MESSAGE		GND DIR O/C REV: Off	Range: FlexLogic™ operand
MESSAGE		HYB POTT NO OF COMM BITS: 1	Range: 1, 2, or 4
MESSAGE		HYB POTT RX1: Off	Range: FlexLogic™ operand
MESSAGE		HYB POTT RX2: Off	Range: FlexLogic™ operand
MESSAGE		HYB POTT RX3: Off	Range: FlexLogic™ operand
MESSAGE		HYB POTT RX4: Off	Range: FlexLogic™ operand
MESSAGE		HYB POTT SCHEME TARGET: Self-Reset	Range: Self-Reset, Latched, Disabled
MESSAGE		HYB POTT EVENT: Disabled	Range: Disabled, Enabled

Generally, this scheme uses an overreaching Zone 2 distance element to essentially compare the direction to a fault at all terminals of the line. Ground directional overcurrent functions available in the D60 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 may be required for three-terminal applications, transient blocking logic is provided for both distance and ground directional overcurrent elements. In order to cope with weak-infeed conditions an echo feature is made available.

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 the Zone 4.

For proper operation, the Zone 2 and 4 phase and ground distance elements must be enabled, configured and set per rules of distance relaying. The Line Pickup element should be enabled, configured and set properly to detect line-end-open/ weak-infeed and undervoltage conditions. If used by the scheme, the selected ground directional overcurrent function(s) must be enabled, configured, and set 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 (HYBRID POTT TX1 through HYBRID POTT TX4) that are used to transmit the signal to the remote terminal(s). Choices of communications channel include Remote Inputs/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface. When used with telecommunications facilities the output operands should 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 scheme output operands must be configured to interface with other relay functions, output contacts in particular. Typically, the output operands should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application.

When used in conjunction with the Trip Output element, the scheme is pre-configured to initiate trip, breaker fail and single-pole autoreclose actions.

HYB POTT PERMISSIVE ECHO:

If set to "Enabled" this setting will result in sending a permissive echo signal to the remote end(s) under certain conditions. (See the THEORY OF OPERATION chapter). The echo is sent only once and then the echo logic locks out for the time specified by the **ECHO LOCKOUT**. The duration of the echo pulse is settable as **ECHO DURATION**.

The echo is sent back only if none of the overreaching protection elements operates.

5

HYB POTT RX PICKUP DELAY:

This setting enables the relay to cope with spurious received signals. The delay should be set longer than the longest spurious TX signal that can be received simultaneously with the Zone 2 pickup. The selected delay will increase the response time of the scheme.

TRANS BLOCK PICKUP DELAY:

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 **TRANS BLOCK PICKUP DELAY**, the blocking operation will be extended by the transient blocking timer for **TRANS BLOCK RESET DELAY**. This allows riding through current reversal conditions.

The **TRANS BLOCK PICKUP DELAY** should not be longer than the fastest possible trip time for faults on an adjacent line so that extended blocking action could be established. This should take into account the pickup time of the reverse-looking elements of the scheme.

The delay defined by this setting should not be too short in order to avoid locking up a spurious reverse fault indication that can occur during internal fault conditions.

TRANS BLOCK RESET DELAY:

This setting defines 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 **TRANS BLOCK PICKUP DELAY**).

This delay should be selected 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). The breaker failure time of the surrounding protection systems within the reach of the ground directional function used by the Hybrid POTT scheme should be considered to make sure that the ground directional function is not jeopardized during delayed breaker operations.

ECHO DURATION:

This setting defines 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:

This setting defines 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.

POTT SEAL-IN DELAY:

The output FlexLogic™ operand (HYB POTT OP) is produced according to the HYBRID POTT scheme logic. The **POTT SEAL-IN DELAY** defines a minimum guaranteed duration of the HYB POTT OP pulse. As this operand runs the Trip Table of the Hybrid POTT scheme, the trip operands HYB POTT TRIP A, B, C and 3P are sealed-in for the same period of time.

GND DIR O/C FWD:

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 (both through the transient blocking logic). Good directional integrity is the key requirement for an over-reaching forward-looking protection element used as **GND DIR O/C FWD**.

Even though any FlexLogic™ operand could be used as **GND DIR O/C FWD** 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 IOC or Neutral Directional IOC. Both these elements have separate forward (FWD) and reverse (REV) output operands. The forward indication should be used (**NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**).

The selected protection element (or elements in combination) should be coordinated with the selection of **GND DIR O/C REV**. For all the forward external faults seen by an element used as **GND DIR O/C FWD** at one end of the line, the reverse-looking element used as **GND DIR O/C REV** at the other end should pickup and provide a blocking signal.

GND DIR O/C REV:

This setting defines the FlexLogic™ operand (if any) of a protection element that is 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 as **GND DIR O/C REV**.

Even though any FlexLogic™ operand could be used as **GND DIR O/C REV** 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 IOC or Neutral Directional IOC. Both these elements have separate forward (FWD) and reverse (REV) output operands. The reverse indication should be used (**NEG SEQ DIR OC1 REV** or **NEUTRAL DIR OC1 REV**).

The selected protection element (or elements in combination) should be coordinated with the selection of **GND DIR O/C FWD**. For all the forward external faults seen by an element used as **GND DIR O/C FWD** at one end of the line, the reverse-looking element used as **GND DIR O/C REV** at the other end should pickup and provide a blocking signal.

HYB POTT NO OF COMM BITS:

This setting specifies the number of bits of the communications channel available for the scheme. The transmit codes and Trip Table of the Hybrid POTT scheme are the same as those for the permissive under-reaching transfer trip scheme. Please refer to the description of the PUTT scheme for more information.

HYB POTT RX1 through HYB POTT RX4:

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. In single-bit applications, HYB POTT RX1 must be used. In two-bit applications, **HYB POTT RX1** and **HYB POTT RX2** must be used. In four-bit applications, **HYB POTT RX1**, **HYB POTT RX2**, **HYB POTT RX3**, and **HYB POTT RX4** must be used.

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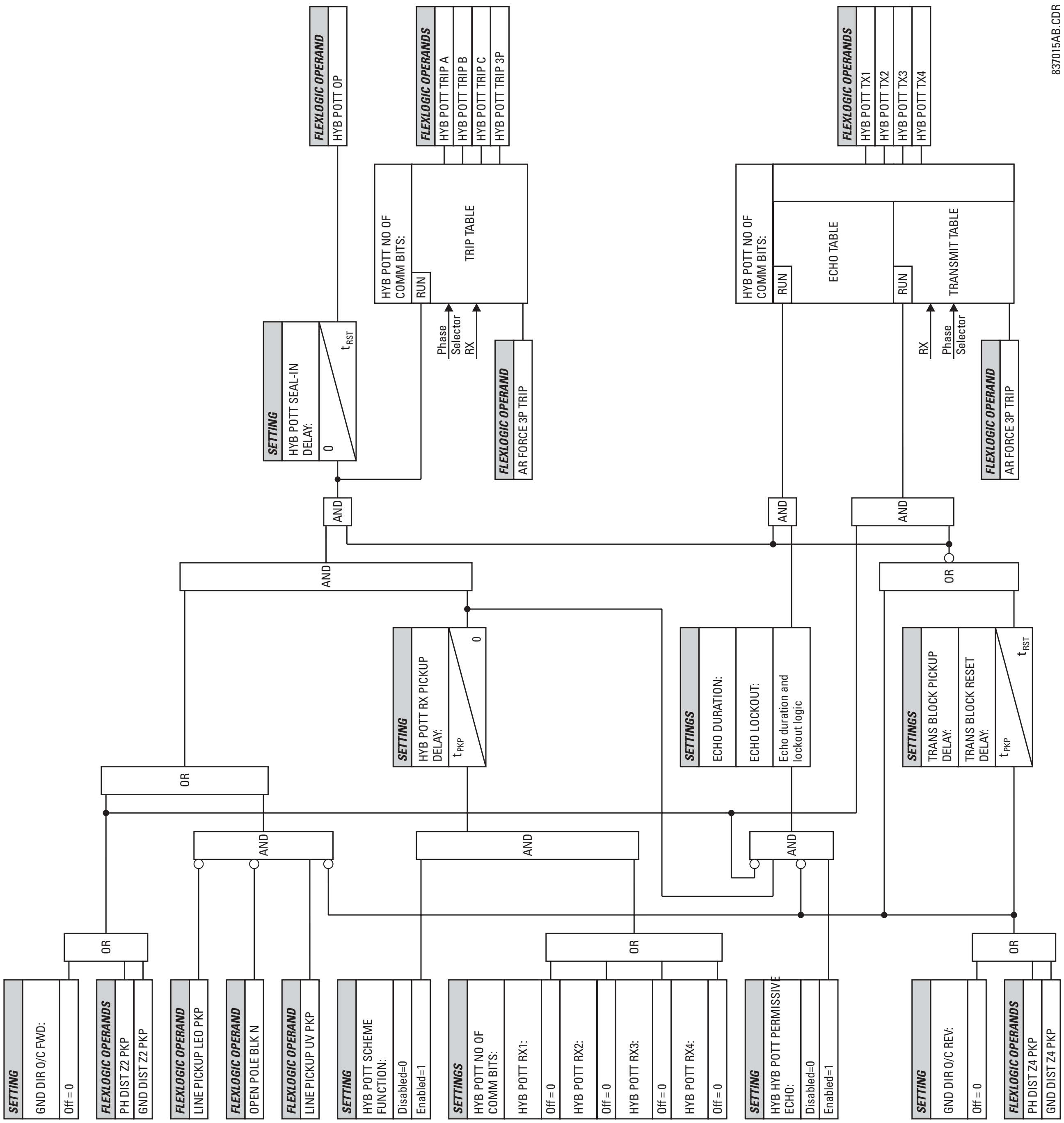

Figure 5–81: HYBRID POTT SCHEME

e) DIRECTIONAL COMPARISON BLOCKING

PATH: SETTINGS ⇨⇩ CONTROL ELEMENTS ⇨⇩ PILOT SCHEMES ⇨⇩ BLOCKING SCHEME

■ BLOCKING SCHEME ■	◁▷	BLOCKING SCHEME FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	△▽	BLOCK RX CO-ORD PKP DELAY: 0.010 s	*Range: 0.000 to 65.535 s in steps of 0.001*
MESSAGE	△▽	TRANS BLOCK PICKUP DELAY: 0.030 s	*Range: 0.000 to 65.535 s in steps of 0.001*
MESSAGE	△▽	TRANS BLOCK RESET DELAY: 0.090 s	*Range: 0.000 to 65.535 s in steps of 0.001*
MESSAGE	△▽	BLOCK SCHEME SEAL-IN DELAY: 0.010 s	*Range: 0.000 to 65.535 s in steps of 0.001*
MESSAGE	△▽	GND DIR O/C FWD: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	GND DIR O/C REV: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	BLOCK SCHEME NO OF COMM BITS: 1	*Range: 1, 2, or 4*
MESSAGE	△▽	BLOCK SCHEME RX1: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	BLOCK SCHEME RX2: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	BLOCK SCHEME RX3: Off	*Range: FlexLogic™ operand*
MESSAGE	△▽	BLOCK SCHEME RX4: Off	*Range: FlexLogic™ operand*
MESSAGE	△	BLOCK SCHEME EVENT: Off	*Range: FlexLogic™ operand*

Generally, the 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 this scheme uses only a forward-looking over-reaching 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 to identify reverse faults. Ground directional overcurrent functions available in the relay 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, configured and set per rules of distance relaying. If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set 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 (DIR BLOCK TX INIT and DIR BLOCK TX1 STOP through DIR BLOCK TX4 STOP) that control the transmission of signals to the remote end(s). When used with telecommunications facilities the output operands should be assigned to operate output contacts connected to key the transmitter at the interface.

The output operand from the scheme (DIR BLOCK A, B, C and 3P) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application.

To make the scheme fully operational as a stand-alone feature, the scheme output operands must be configured to interface with other relay functions, output contacts in particular. Typically, the output operands should be programmed to initiate a trip, breaker fail, and autoreclose, and drive a user-programmable LED as per user application.

When used in conjunction with the Trip Output element, the scheme is pre-configured to initiate trip, breaker fail, and single-pole autoreclose actions.

BLOCK RX CO-ORD PKP DELAY:

This setting defines a delay for the forward-looking protection elements used by the scheme for coordination with the blocking response from the remote end(s). This setting should 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.

TRANS BLOCK PICKUP DELAY:

This setting defines a transient blocking mechanism embedded in the 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 **TRANS BLOCK PICKUP DELAY**, the blocking operation will be extended by the transient blocking timer for **TRANS BLOCK RESET DELAY**. This allows riding through current reversal conditions.

The **TRANS BLOCK PICKUP DELAY** should not be longer than the fastest possible trip time for faults on an adjacent line so that the extended blocking action could be established. This should take into account the pickup time of the reverse-looking elements of the scheme. The delay defined by this setting should not be too short in order to avoid locking up a spurious reverse fault indication that can occur during internal fault conditions.

5

TRANS BLOCK RESET DELAY:

This setting defines a transient blocking mechanism embedded in the Blocking scheme for coping with the exposure of the overreaching protection functions to current reversal conditions (see also the **TRANS BLOCK PICKUP DELAY**).

This delay should be selected 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.

BLOCK SCHEME SEAL-IN DELAY:

The output FlexLogic™ operand (DIR BLOCK OP) is produced according to the Blocking scheme logic. The **BLOCK SCHEME SEAL-IN DELAY** defines a minimum guaranteed duration of the DIR BLOCK OP pulse. As this operand runs the Trip Table of the Blocking scheme, the trip operands DIR BLOCK TRIP A, B, C and 3P are sealed-in for the same period of time.

GND DIR O/C FWD:

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 initiating operation of the scheme. Good directional integrity is the key requirement for an over-reaching forward-looking protection element used as **GND DIR O/C FWD**.

Even though any FlexLogic™ operand could be used as **GND DIR O/C FWD** 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 IOC or Neutral Directional IOC. Both these elements have separate forward (FWD) and reverse (REV) output operands.

The forward indication should be used (**NEG SEQ DIR OC1 FWD** or **NEUTRAL DIR OC1 FWD**).

The selected protection element (or elements in combination) should be coordinated with the selection of **GND DIR O/C REV**. For all the forward external faults seen by an element used as **GND DIR O/C FWD** at one end of the line, the reverse-looking element used as **GND DIR O/C REV** at the other end should pickup and provide a blocking signal.

GND DIR O/C REV:

This setting defines 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 may be used as **GND DIR O/C REV**.

Even though any FlexLogic™ operand could be used as **GND DIR O/C REV**, 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 IOC, Neutral Directional IOC, or a non-directional IOC.

The selected protection element (or elements in combination) should be coordinated with the selection of **GND DIR O/C FWD**. For all the forward external faults seen by an element used as **GND DIR O/C FWD** at one end of the line, the reverse-looking element used as **GND DIR O/C REV** at the other end should pickup and provide a blocking signal.

BLOCK SCHEME NO OF COMM BITS:

This setting specifies the number of bits of the communications channel available for the scheme.

With only one bit available, the scheme sends the blocking signal by asserting the DIR BLOCK TX INIT FlexLogic™ operand. This operand should be used 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 scheme responds to lack of the blocking signal on bit no. 1 (**BLOCK SCHEME RX1** setting). The scheme uses only local fault type identification provided by the Phase Selector to assert the Output Operands DUTT TRIP A, B, C and 3P. Please refer to the THEORY OF OPERATION chapter for more information on communications.

To take advantage of the four-bit blocking scheme, the blocking signals should be initiated from a disturbance detector. This can be accomplished by using both 50DD and DIR BLOCK TX INIT to assert the blocking signal. Subsequently, specific bits will be de-asserted by the scheme based on the phase selection providing the peer relay with more information on the fault type. Otherwise, the peer relay issues a three-pole trip upon receiving the bit pattern (0,0,0,0).

BLOCK SCHEME RX1 through BLOCK SCHEME RX4:

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.

In single-bit applications, **BLOCK SCHEME RX1** must be used. In two-bit applications, **BLOCK SCHEME RX1** and **BLOCK SCHEME RX2** must be used. In four-bit applications, **BLOCK SCHEME RX1**, **BLOCK SCHEME RX2**, **BLOCK SCHEME RX3**, and **BLOCK SCHEME RX4** must be used.

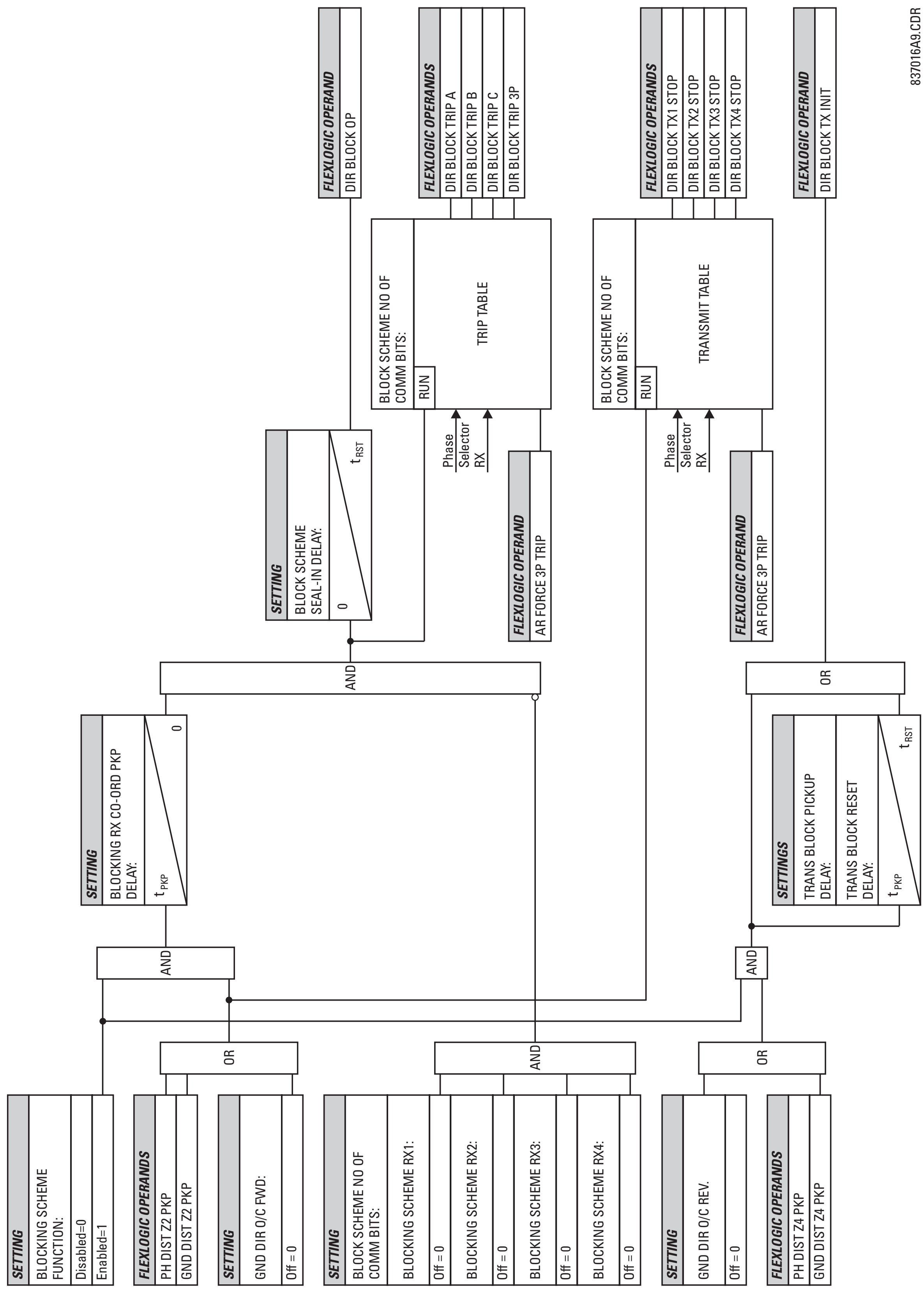

Figure 5–82: DIRECTIONAL COMPARISON BLOCKING SCHEME LOGIC

5.7.1 CONTACT INPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨ CONTACT INPUTS

```
■ CONTACT INPUTS
■
        ■ CONTACT INPUT H5a
        ■
MESSAGE     CONTACT INPUT H5a ID:       Range: up to 12 alphanumeric characters
            Cont Ip 1
MESSAGE     CONTACT INPUT H5a           Range: 0.0 to 16.0 ms in steps of 0.5
            DEBNCE TIME: 2.0 ms
MESSAGE     CONTACT INPUT H5a           Range: Disabled, Enabled
            EVENTS: Disabled
        ↓
        ■ CONTACT INPUT xxx
        ■
        ■ CONTACT INPUT
        ■ THRESHOLDS
MESSAGE     Ips H5a,H5c,H6a,H6c         Range: 17, 33, 84, 166 Vdc
            THRESHOLD: 33 Vdc
MESSAGE     Ips H7a,H7c,H8a,H8c         Range: 17, 33, 84, 166 Vdc
            THRESHOLD: 33 Vdc
            ↓
MESSAGE     Ips xxx,xxx,xxx,xxx         Range: 17, 33, 84, 166 Vdc
            THRESHOLD: 33 Vdc
```

The contact inputs menu contains configuration settings for each contact input as well as voltage thresholds for each group of four contact inputs. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then display settings for only those inputs.

An alphanumeric ID may be assigned to a contact input for diagnostic, setting, and event recording purposes. The "Contact Ip X On" (Logic 1) FlexLogic™ operand corresponds to contact input "X" being closed, while "Contact Input X Off" corresponds to contact input "X" being open. The **CONTACT INPUT DEBNCE TIME** defines the time required for the contact to overcome 'contact bouncing' conditions. As this time differs for different contact types and manufacturers, set it as a maximum contact debounce time (per manufacturer specifications) plus some margin to ensure proper operation. If **CONTACT INPUT EVENTS** is set to "Enabled", every change in the contact input state will trigger an event.

A raw status is scanned for all Contact Inputs synchronously at the constant rate of 0.5 ms as shown in the figure below. The DC input voltage is compared to a user-settable threshold. A new contact input state must be maintained for a user-settable debounce time in order for the D60 to validate the new contact state. In the figure below, the debounce time is set at 2.5 ms; thus the 6th sample in a row validates the change of state (mark no.1 in the diagram). Once validated (debounced), the contact input asserts a corresponding FlexLogic™ operand and logs an event as per user setting.

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 no. 2 in the diagram).

Protection and control elements, as well as FlexLogic™ equations and timers, are executed eight 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 (marks no. 3 and 4 on the figure below). The update is performed at the beginning of the protection pass so all protection and control functions, as well as FlexLogic™ equations, are fed with the updated states of the contact inputs.

5

The FlexLogic™ operand response time to the contact input change is equal to the debounce time setting plus up to one protection pass (variable and depending on system frequency if frequency tracking 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 0.5 ms scan rate, the time resolution for the input contact is below 1msec.

For example, 8 protection passes per cycle on a 60 Hz system correspond to a protection pass every 2.1 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 + 2.1 = 5.1 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 μs accuracy using the time of the first scan corresponding to the new state (mark no. 2 below). 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 LOW-HIGH (marks no.1, 2, 3, and 4 in the figure below) and HIGH-LOW (marks no.5, 6, 7, and 8 below) transitions.

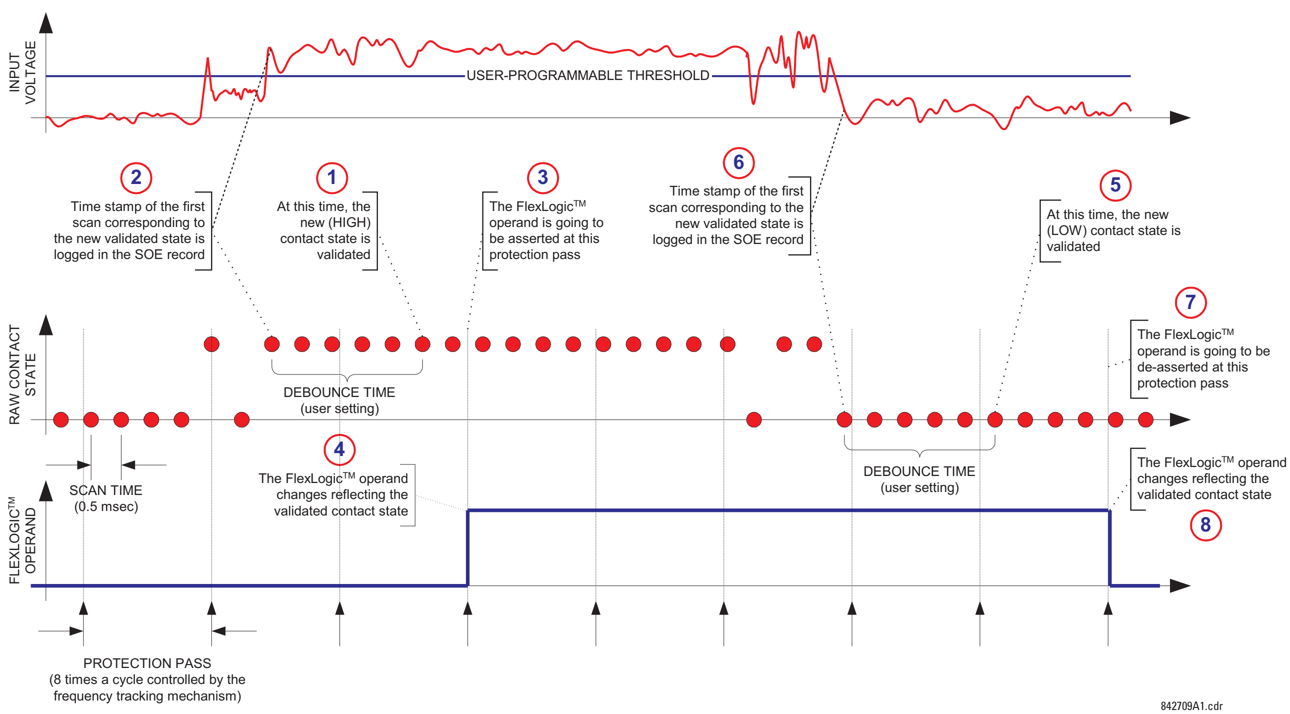

Figure 5–83: INPUT CONTACT DEBOUNCING MECHANISM AND TIME-STAMPING SAMPLE TIMING

Contact inputs are isolated in groups of four to allow connection of wet contacts from different voltage sources for each group. The **CONTACT INPUT THRESHOLDS** determine the minimum voltage required to detect a closed contact input. This value should be selected according to the following criteria: 16 for 24 V sources, 30 for 48 V sources, 80 for 110 to 125 V sources and 140 for 250 V sources.

For example, to use contact input H5a as a status input from the breaker 52b contact to seal-in the trip relay and record it in the Event Records menu, make the following settings changes:

CONTACT INPUT H5A ID: "Breaker Closed (52b)"
CONTACT INPUT H5A EVENTS: "Enabled"

Note that the 52b contact is closed when the breaker is open and open when the breaker is closed.

5.7.2 VIRTUAL INPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL INPUTS ⇨

```
■ VIRTUAL INPUT  1          VIRTUAL INPUT  1         Range:  Disabled, Enabled
■                           FUNCTION: Disabled

                 MESSAGE    VIRTUAL INPUT  1 ID:     Range:  Up to 12 alphanumeric characters
                            Virt Ip 1

                 MESSAGE    VIRTUAL INPUT  1         Range:  Self-Reset, Latched
                            TYPE: Latched

                 MESSAGE    VIRTUAL INPUT  1         Range:  Disabled, Enabled
                            EVENTS: Disabled

■ VIRTUAL INPUT  2          As above for Virtual Input 1
■
        ↓                              ↓
■ VIRTUAL INPUT  32         As above for Virtual Input 1
■

■ UCA SBO TIMER             UCA SBO TIMEOUT:         Range:  1 to 60 s in steps of 1
■                             30 s
```

There are 32 virtual inputs that can be individually programmed to respond to input signals from the keypad (COMMANDS menu) and non-UCA2 communications protocols only. All virtual input operands are defaulted to OFF = 0 unless the appropriate input signal is received. **Virtual input states are preserved through a control power loss**.

If the **VIRTUAL INPUT x FUNCTION** is to "Disabled", the input will be 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 FlexLogic™ operands in response to received input signals and the applied settings.

There are two types of operation: Self-Reset and Latched. If **VIRTUAL INPUT x TYPE** is "Self-Reset", when the input signal transits from OFF = 0 to ON = 1, the output operand will be set to ON = 1 for only one evaluation of the FlexLogic™ equations and then return to OFF = 0. If set to "Latched", the virtual input sets the state of the output operand to the same state as the most recent received input, ON =1 or OFF = 0.

NOTE: **The "Self-Reset" operating mode generates the output operand for a single evaluation of the FlexLogic™ equations. If the operand is to be used anywhere other than internally in a FlexLogic™ equation, it will likely have to be lengthened in time. A FlexLogic™ timer with a delayed reset can perform this function.**

The Select-Before-Operate timer sets the interval from the receipt of an Operate signal to the automatic de-selection of the virtual input, so that an input does not remain selected indefinitely (used only with the UCA Select-Before-Operate feature).

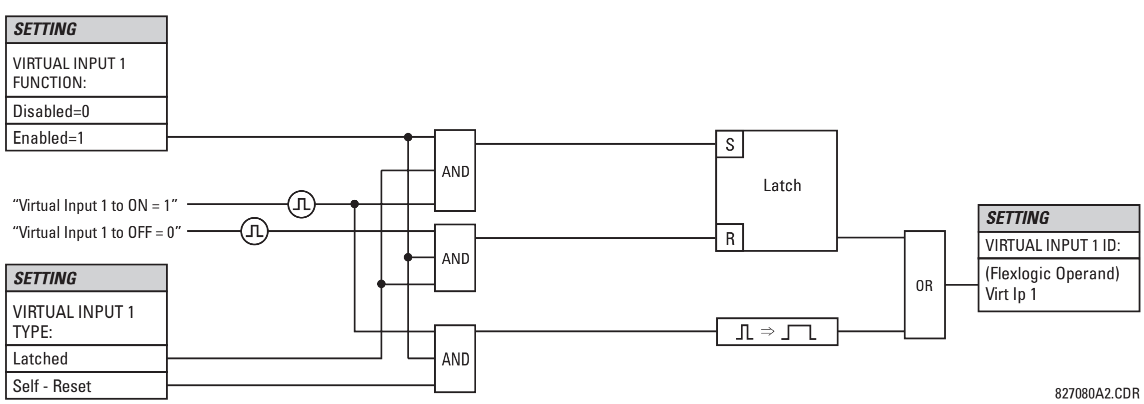

Figure 5–84: VIRTUAL INPUTS SCHEME LOGIC

5.7.3 CONTACT OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ CONTACT OUTPUTS ⇨ CONTACT OUTPUT H1

■ CONTACT OUTPUT H1 ■	◀▶	CONTACT OUTPUT H1 ID Cont Op 1	Range: Up to 12 alphanumeric characters
MESSAGE	▲▼	OUTPUT H1 OPERATE: Off	Range: FlexLogic™ operand
MESSAGE	▲▼	OUTPUT H1 SEAL-IN: Off	Range: FlexLogic™ operand
MESSAGE	▲	CONTACT OUTPUT H1 EVENTS: Enabled	Range: Disabled, Enabled

Upon startup of the relay, the main processor will determine from an assessment of the modules installed in the chassis which contact outputs are available and present the settings for only these outputs.

An ID may be assigned to each contact output. The signal that can OPERATE a contact output may be any FlexLogic™ operand (virtual output, element state, contact input, or virtual input). An additional FlexLogic™ operand may be used to SEAL-IN the relay. Any change of state of a contact output can be logged as an Event if programmed to do so.

EXAMPLE:

The trip circuit current is monitored by providing a current threshold detector in series with some Form-A contacts (see the TRIP CIRCUIT EXAMPLE in the DIGITAL ELEMENTS section). The monitor will set a flag (see the Specifications for Form-A). The name of the FlexLogic™ operand set by the monitor, consists of the output relay designation, followed by the name of the flag; e.g. 'Cont Op 1 IOn' or 'Cont Op 1 IOff'.

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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 which opens when the breaker has tripped, but 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 resetting of the initiating relay. This scheme is often called "trip seal-in".

This can be realized in the UR using the 'Cont Op 1 IOn' FlexLogic™ operand to seal-in the Contact Output as follows:

CONTACT OUTPUT H1 ID: "Cont Op 1"
OUTPUT H1 OPERATE: "Off"
OUTPUT H1 SEAL-IN: "Cont Op 1 IOn"
CONTACT OUTPUT H1 EVENTS: "Enabled"

5.7.4 VIRTUAL OUTPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ VIRTUAL OUTPUTS ⇨ VIRTUAL OUTPUT 1

■ VIRTUAL OUTPUT 1 ■	◀▶	VIRTUAL OUTPUT 1 ID Virt Op 1	Range: Up to 12 alphanumeric characters
MESSAGE	▲	VIRTUAL OUTPUT 1 EVENTS: Disabled	Range: Disabled, Enabled

There are 64 virtual outputs that may be assigned via FlexLogic™. If not assigned, the output will be forced to 'OFF' (Logic 0). An ID may be assigned to each virtual output. Virtual outputs are resolved in each pass through the evaluation of the FlexLogic™ equations. Any change of state of a virtual output can be logged as an event if programmed to do so.

For example, if Virtual Output 1 is the trip signal from FlexLogic™ and the trip relay is used to signal events, the settings would be programmed as follows:

VIRTUAL OUTPUT 1 ID: "Trip"
VIRTUAL OUTPUT 1 EVENTS: "Disabled"

5.7.5 REMOTE DEVICES

a) OVERVIEW

Remote inputs and outputs, which are a means of exchanging information regarding the state of digital points between remote devices, are provided in accordance with the Electric Power Research Institute's (EPRI) UCA2 "Generic Object Oriented Substation Event (GOOSE)" specifications.

NOTE **The UCA2 specification requires that communications between devices be implemented on Ethernet communications facilities. For UR relays, Ethernet communications is provided only on the type 9C and 9D versions of the CPU module.**

The sharing of digital point state information between GOOSE equipped relays is essentially an extension to FlexLogic™ to allow distributed FlexLogic™ by making operands available to/from devices on a common communications network. In addition to digital point states, 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 from only those messages that have originated in selected devices.

GOOSE messages are designed to be short, high priority and with a high level of reliability. The GOOSE message structure contains space for 128 bit pairs representing digital point state information. The UCA specification provides 32 "DNA" bit pairs, which are status bits representing pre-defined events. All remaining bit pairs are "UserSt" bit pairs, which are status bits representing user-definable events. The UR implementation provides 32 of the 96 available UserSt bit pairs.

The UCA2 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a GOOSE message upon a 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" which is set to three times the programmed default time, which is required by the receiving device.

Receiving devices are constantly monitoring the communications network for messages they require, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message "hold" time for the device. The receiving relay sets a timer assigned to the originating device to the "hold" 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 will use the programmed default state for all points from that specific remote device. This mechanism allows a receiving device to fail to detect a single transmission from a remote device which is sending messages at the slowest possible rate, as set by its "default update" timer, without reverting to use of the programmed default states. If a message is received from a remote device before the "hold" time expires, all points for that device are updated to the states contained in the message and the hold timer is restarted. The status of a remote device, where 'Offline' indicates 'non-communicating', can be displayed.

The GOOSE facility provides for 64 remote inputs and 32 remote outputs.

b) LOCAL DEVICES: ID of Device for Transmitting GOOSE Messages

In a UR relay, the device ID that identifies the originator of the message is programmed in the SETTINGS ⇨ PRODUCT SETUP ⇨⇩ INSTALLATION ⇨⇩ RELAY NAME setting.

c) REMOTE DEVICES: ID of Device for Receiving GOOSE Messages

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE DEVICES ⇨ REMOTE DEVICE 1(16)

■ REMOTE DEVICE 1 ■	REMOTE DEVICE 1 ID: Remote Device 1	*Range: up to 20 alphanumeric characters*

Sixteen Remote Devices, numbered from 1 to 16, can be selected for setting purposes. A receiving relay must be programmed to capture messages from only those originating remote devices of interest. This setting is used to select specific remote devices by entering (bottom row) the exact identification (ID) assigned to those devices.

5.7.6 REMOTE INPUTS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE INPUTS ⇨ REMOTE INPUT 1(32)

■ REMOTE INPUT 1 ■	◀▶	REMOTE IN 1 DEVICE: Remote Device 1	*Range: 1 to 16 inclusive*
MESSAGE	▲▼	REMOTE IN 1 BIT PAIR: None	*Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32*
MESSAGE	▲▼	REMOTE IN 1 DEFAULT STATE: Off	*Range: On, Off*
MESSAGE	▲	REMOTE IN 1 EVENTS: Disabled	*Range: Disabled, Enabled*

Remote Inputs which create FlexLogic™ operands at the receiving relay, are extracted from GOOSE messages originating in remote devices. The relay provides 32 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 UCA2 specifications and is presented in the UCA2 DNA ASSIGNMENTS table in the Remote Outputs section. The function of UserSt inputs is defined by the user selection of the FlexLogic™ operand whose state is represented in the GOOSE message. A user must program a DNA point from the appropriate operand.

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 shown above.

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REMOTE IN 1 DEVICE selects the number (1 to 16) of the Remote Device which originates the required signal, as previously assigned to the remote device via the setting **REMOTE DEVICE NN ID** (see REMOTE DEVICES section). **REMOTE IN 1 BIT PAIR** selects the specific bits of the GOOSE message required. **REMOTE IN 1 DEFAULT STATE** 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.

NOTE

For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS OVERVIEW in the REMOTE DEVICES section.

5.7.7 REMOTE OUTPUTS: DNA BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS DNA BIT PAIRS ⇨ REMOTE OUPUTS DNA- 1 BIT PAIR

```
■ REMOTE OUTPUTS          DNA- 1 OPERAND:      Range: FlexLogic™ Operand
■ DNA- 1 BIT PAIR         Off

                MESSAGE   DNA- 1 EVENTS:       Range: Disabled, Enabled
                          Disabled
```

Remote Outputs (1 to 32) are FlexLogic™ operands inserted into 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. The above operand setting represents a specific DNA function (as shown in the following table) to be transmitted.

Table 5–28: UCA DNA2 ASSIGNMENTS

DNA	DEFINITION	INTENDED FUNCTION	LOGIC 0	LOGIC 1
1	OperDev		Trip	Close
2	Lock Out		LockoutOff	LockoutOn
3	Initiate Reclosing	Initiate remote reclose sequence	InitRecloseOff	InitRecloseOn
4	Block Reclosing	Prevent/cancel remote reclose sequence	BlockOff	BlockOn
5	Breaker Failure Initiate	Initiate remote breaker failure scheme	BFIOff	BFIOn
6	Send Transfer Trip	Initiate remote trip operation	TxXfrTripOff	TxXfrTripOn
7	Receive Transfer Trip	Report receipt of remote transfer trip command	RxXfrTripOff	RxXfrTripOn
8	Send Perm	Report permissive affirmative	TxPermOff	TxPermOn
9	Receive Perm	Report receipt of permissive affirmative	RxPermOff	RxPermOn
10	Stop Perm	Override permissive affirmative	StopPermOff	StopPermOn
11	Send Block	Report block affirmative	TxBlockOff	TxBlockOn
12	Receive Block	Report receipt of block affirmative	RxBlockOff	RxBlockOn
13	Stop Block	Override block affirmative	StopBlockOff	StopBlockOn
14	BkrDS	Report breaker disconnect 3-phase state	Open	Closed
15	BkrPhsADS	Report breaker disconnect phase A state	Open	Closed
16	BkrPhsBDS	Report breaker disconnect phase B state	Open	Closed
17	BkrPhsCDS	Report breaker disconnect phase C state	Open	Closed
18	DiscSwDS		Open	Closed
19	Interlock DS		DSLockOff	DSLockOn
20	LineEndOpen	Report line open at local end	Open	Closed
21	Status	Report operating status of local GOOSE device	Offline	Available
22	Event		EventOff	EventOn
23	Fault Present		FaultOff	FaultOn
24	Sustained Arc	Report sustained arc	SustArcOff	SustArcOn
25	Downed Conductor	Report downed conductor	DownedOff	DownedOn
26	Sync Closing		SyncClsOff	SyncClsOn
27	Mode	Report mode status of local GOOSE device	Normal	Test
28→32	Reserved			

NOTE

For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS OVERVIEW in the REMOTE DEVICES section.

5.7.8 REMOTE OUTPUTS: UserSt BIT PAIRS

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ REMOTE OUTPUTS UserSt BIT PAIRS ⇨ REMOTE OUTPUTS UserSt- 1 BIT PAIR

■ REMOTE OUTPUTS ■ UserSt- 1 BIT PAIR	◀▶	UserSt- 1 OPERAND: Off	*Range: FlexLogic™ operand*
MESSAGE	▲	UserSt- 1 EVENTS: Disabled	*Range: Disabled, Enabled*

Remote Outputs 1 to 32 originate as 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. The setting above is used to select the operand which represents a specific UserSt function (as selected by the user) to be transmitted.

The following setting represents the time between sending GOOSE messages when there has been no change of state of any selected digital point. This setting is located in the PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ UCA/MMS PROTOCOL settings menu.

DEFAULT GOOSE UPDATE TIME: 60 s	*Range: 1 to 60 s in steps of 1*

NOTE

For more information on GOOSE specifications, see REMOTE INPUTS/OUTPUTS – OVERVIEW in the REMOTE DEVICES section.

5.7.9 RESETTING

5

PATH: SETTINGS ⇨⇩ INPUTS/OUTPUTS ⇨⇩ RESETTING

■ RESETTING ■	◀▶	RESET OPERAND: Off	*Range: FlexLogic™ operand*

Some events can be programmed to latch the faceplate LED event indicators and the target message on the display. Once set, the latching mechanism will hold all of the latched indicators or messages in the set state after the initiating condition has cleared until a RESET command is received to return these latches (not including FlexLogic™ latches) to the reset state. The RESET command can be sent from the faceplate RESET button, a remote device via a communications channel, or any programmed operand.

When the RESET command is received by the relay, two FlexLogic™ operands are created. These operands, which are stored as events, reset the latches if the initiating condition has cleared. The three sources of RESET commands each create the FlexLogic™ operand "RESET OP". Each individual source of a RESET command also creates its individual operand RESET OP (PUSHBUTTON), RESET OP (COMMS) or RESET OP (OPERAND) to identify the source of the command. The setting shown above selects the operand that will create the RESET OP (OPERAND) operand.

5.8.1 DCMA INPUTS

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ DCMA INPUTS

```
■ DCMA INPUTS        ◁▷    ■ DCMA INPUT H1
■                          ■
                              ↓
                              ↓
           MESSAGE   △     ■ DCMA INPUT U8
                           ■
```

Hardware and software is provided to receive signals from external transducers and convert these signals into a digital format for use as required. The relay will accept inputs in the range of –1 to +20 mA DC, suitable for use with most common transducer output ranges; all inputs are assumed to be linear over the complete range. Specific hardware details are contained in the HARDWARE chapter.

Before the DCMA input signal can be used, the value of the signal measured by the relay must be converted to the range and quantity of the external transducer primary input parameter, such as DC voltage or temperature. The relay simplifies this process by internally scaling the output from the external transducer and displaying the actual primary parameter.

DCMA input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown below for the first channel of a type 5F transducer module installed in slot M.

■ DCMA INPUT M1 ■	◁▷	DCMA INPUT M1 FUNCTION: Disabled	*Range: Disabled, Enabled*
MESSAGE	△▽	DCMA INPUT M1 ID: DCMA Ip 1	*Range: Up to 20 alphanumeric characters*
MESSAGE	△▽	DCMA INPUT M1 UNITS: μA	*Range: 6 alphanumeric characters*
MESSAGE	△▽	DCMA INPUT M1 RANGE: 0 to -1 mA	*Range: 0 to –1, 0 to +1, –1 to +1, 0 to 5, 0 to 10, 0 to 20*
MESSAGE	△▽	DCMA INPUT M1 MIN VALUE: 0.000	*Range: –9999.999 to +9999.999 in steps of 0.001*
MESSAGE	△	DCMA INPUT M1 MAX VALUE: 0.000	*Range: –9999.999 to +9999.999 in steps of 0.001*

The function of the channel may be either "Enabled" or "Disabled." If Disabled, there will not be an actual value created for the channel. An alphanumeric "ID" is assigned to the channel - this ID will be included in the display of the channel actual value, along with the programmed "UNITS" associated with the parameter measured by the transducer, such as Volt, °C, MegaWatts, etc. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. The RANGE setting is used to select the specific mA DC range of the transducer connected to the input channel.

The MIN VALUE and MAX VALUE settings are used to program the span of the transducer in primary units. For example, a temperature transducer might have a span from 0 to 250°C; in this case the MIN value would be 0 and the MAX value 250. Another example would be a Watt transducer with a span from –20 to +180 MW; in this case the MIN value would be –20 and the MAX value 180. Intermediate values between the MIN and MAX are scaled linearly.

5.8.2 RTD INPUTS

PATH: SETTINGS ⇨⇩ TRANSDUCER I/O ⇨⇩ RTD INPUTS

```
■ RTD INPUTS          ◀▶   ■ RTD INPUT H1
■                          ■
                               ↓
                               ↓
             MESSAGE  ▲    ■ RTD INPUT U8
                           ■
```

Hardware and software is provided to receive signals from external Resistance Temperature Detectors and convert these signals into a digital format for use as required. These channels are intended to be connected to any of the RTD types in common use. Specific hardware details are contained in the HARDWARE chapter.

RTD input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown below for the first channel of a type 5C transducer module installed in slot M.

5

```
■ RTD INPUT M5        ◀▶   RTD INPUT M5               Range: Disabled, Enabled
■                          FUNCTION: Disabled
             MESSAGE  ▲▼   RTD INPUT M5 ID:           Range: Up to 20 alphanumeric characters
                           RTD Ip 1
             MESSAGE  ▲    RTD INPUT M5 TYPE:         Range: 100Ω Nickel, 10Ω Copper, 100Ω Platinum,
                           100Ω Nickel                       120Ω Nickel
```

The function of the channel may be either "Enabled" or "Disabled." If Disabled, there will not be an actual value created for the channel. An alphanumeric "ID" is assigned to the channel - this ID will be included in the display of the channel actual value. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. Selecting the type of RTD connected to the channel configures the channel.

5.9.1 TEST MODE

PATH: SETTINGS ⇨⇩ TESTING ⇨ TEST MODE

■■ SETTINGS ■■ TESTING	◁▷	TEST MODE FUNCTION: Disabled	*Range: Disabled, Enabled*

The relay provides test settings to verify that the relay is functional using simulated conditions to test all contact inputs and outputs. While the relay is in Test Mode (**TEST MODE FUNCTION:** "Enabled"), the feature being tested overrides normal functioning of the relay. During this time the Test Mode LED will remain on. Once out of Test Mode (**TEST MODE FUNCTION:** "Disabled"), the normal functioning of the relay will be restored.

5.9.2 FORCE CONTACT INPUTS

PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT INPUTS

■ FORCE CONTACT ■ INPUTS	◁▷	FORCE Cont Ip 1 : Disabled	*Range: Disabled, Open, Closed*
MESSAGE	△▽	FORCE Cont Ip 2 : Disabled	*Range: Disabled, Open, Closed*
		↓	
MESSAGE	△	FORCE Cont Ip xx : Disabled	*Range: Disabled, Open, Closed*

The Force Contact Inputs feature provides a method of performing checks on the function of all contact inputs. Once enabled, the relay is placed into Test Mode, allowing this feature to override the normal function of contact inputs. The Test Mode LED will be ON indicating that the relay is in test mode. The state of each contact input may be programmed as Disabled, Open, or Closed. All contact input operations return to normal when all settings for this feature are disabled.

5

5.9.3 FORCE CONTACT OUTPUTS

PATH: SETTINGS ⇨⇩ TESTING ⇨⇩ FORCE CONTACT OUTPUTS

■ FORCE CONTACT ■ OUTPUTS	◁▷	FORCE Cont Op 1: Disabled	*Range: Disabled, Energized, De-energized, Freeze*
MESSAGE	△▽	FORCE Cont Op 2: Disabled	*Range: Disabled, Energized, De-energized, Freeze*
		↓	
MESSAGE	△	FORCE Cont Op xx: Disabled	*Range: Disabled, Energized, De-energized, Freeze*

The Force Contact Output feature provides a method of performing checks on all contact outputs. Once enabled, the relay is placed into Test Mode, allowing this feature to override the normal contact outputs functions. The TEST MODE LED will be ON. The state of each contact output may be programmed as Disabled, Energized, De-energized, or Freeze. The Freeze option maintains the output contact in the state at which it was frozen. All contact output operations return to normal when all the settings for this feature are disabled.

6.1.1 ACTUAL VALUES MAIN MENU

■■ ACTUAL VALUES ■■ STATUS	■ CONTACT INPUTS ■	See page 6-3.
	■ VIRTUAL INPUTS ■	See page 6-3.
	■ REMOTE INPUTS ■	See page 6-3.
	■ CONTACT OUTPUTS ■	See page 6-4.
	■ VIRTUAL OUTPUTS ■	See page 6-4.
	■ AUTORECLOSE ■	See page 6-4.
	■ REMOTE DEVICES ■ STATUS	See page 6-4.
	■ REMOTE DEVICES ■ STATISTICS	See page 6-5.
	■ DIGITAL COUNTERS ■	See page 6-5.
	■ FLEX STATES ■	See page 6-5.
	■ ETHERNET ■	See page 6-5.
■■ ACTUAL VALUES ■■ METERING	■ SOURCE SRC 1 ■	See page 6-9.
	■ SOURCE SRC 2 ■	
	↓ ↓	
	■ SOURCE SRC 6 ■	
	■ SYNCHROCHECK ■	See page 6-11.
	■ TRACKING FREQUENCY ■	See page 6-11.
	■ FLEXELEMENTS ■	See page 6–12.
	■ TRANSDUCER I/O ■ DCMA INPUTS	See page 6-12.
	■ TRANSDUCER I/O ■ RTD INPUTS	See page 6-12.

■■ ACTUAL VALUES ■■ RECORDS	■ FAULT REPORTS ■	See page 6-13.
	■ EVENT RECORDS ■	See page 6-15.
	■ OSCILLOGRAPHY ■	See page 6-15.
	■ DATA LOGGER ■	See page 6-15.
	■ MAINTENANCE ■	See page 6-16.
■■ ACTUAL VALUES ■■ PRODUCT INFO	■ MODEL INFORMATION ■	See page 6-17.
	■ FIRMWARE REVISIONS ■	See page 6-17.

6.2.1 NOTES

NOTE

For status reporting, 'On' represents Logic 1 and 'Off' represents Logic 0.

6.2.2 CONTACT INPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨ CONTACT INPUTS

```
■ CONTACT INPUTS        Cont Ip 1
■                       Off
                           ↓
                           ↓
MESSAGE                 Cont Ip xx
                        Off
```

The present status of the contact inputs is shown here. The first line of a message display indicates the ID of the contact input. For example, 'Cont Ip 1' refers to the contact input in terms of the default name-array index. The second line of the display indicates the logic state of the contact input.

6.2.3 VIRTUAL INPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL INPUTS

```
■ VIRTUAL INPUTS        Virt Ip 1
■                       Off
                           ↓
                           ↓
MESSAGE                 Virt Ip 32
                        Off
```

The present status of the 32 virtual inputs is shown here. The first line of a message display indicates the ID of the virtual input. For example, 'Virt Ip 1' refers to the virtual input in terms of the default name-array index. The second line of the display indicates the logic state of the virtual input.

6.2.4 REMOTE INPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE INPUTS

```
■ REMOTE INPUTS         REMOTE INPUT  1      Range: On, Off
■                       STATUS: Off
                           ↓
                           ↓
MESSAGE                 REMOTE INPUT 32      Range: On, Off
                        STATUS: Off
```

The present state of the 32 remote inputs is shown here.

The state displayed will be 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.

6

6.2.5 CONTACT OUTPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ CONTACT OUTPUTS

```
■ CONTACT OUTPUTS        Cont Op 1
■                        Off
                            ↓
          MESSAGE        Cont Op xx
                         Off
```

The present state of the contact outputs is shown here.

The first line of a message display indicates the ID of the contact output. For example, 'Cont Op 1' refers to the contact output in terms of the default name-array index. The second line of the display indicates the logic state of the contact output.

NOTE

For Form-A outputs, the state of the voltage(V) and/or current(I) detectors will show as: Off, VOff, IOff, On, VOn, and/or IOn. For Form-C outputs, the state will show as Off or On.

6.2.6 VIRTUAL OUTPUTS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ VIRTUAL OUTPUTS

```
■ VIRTUAL OUTPUTS        Virt Op 1
■                        Off
                            ↓
          MESSAGE        Virt Op 64
                         Off
```

The present state of up to 64 virtual outputs is shown here. The first line of a message display indicates the ID of the virtual output. For example, 'Virt Op 1' refers to the virtual output in terms of the default name-array index. The second line of the display indicates the logic state of the virtual output, as calculated by the FlexLogic™ equation for that output.

6

6.2.7 AUTORECLOSE

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ AUTORECLOSE ⇨ AUTORECLOSE 1

```
■ AUTORECLOSE 1          AUTORECLOSE 1            Range: 0, 1, 2, 3, 4
■                        SHOT COUNT:      0
```

The automatic reclosure shot count is shown here.

6.2.8 REMOTE DEVICES STATUS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATUS

```
■ REMOTE DEVICES         All REMOTE DEVICES       Range: Yes, No
■ STATUS                 ONLINE: No
          MESSAGE        REMOTE DEVICE  1         Range: Online, Offline
                         STATUS: Offline
                            ↓
          MESSAGE        REMOTE DEVICE 16         Range: Online, Offline
                         STATUS: Offline
```

The present state of up to 16 programmed Remote Devices is shown here. The **ALL REMOTE DEVICES ONLINE** message indicates whether or not all programmed Remote Devices are online. If the corresponding state is "No", then at least one required Remote Device is not online.

6.2.9 REMOTE DEVICES STATISTICS

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ REMOTE DEVICES STATISTICS ⇨ REMOTE DEVICE 1(16)

```
■ REMOTE DEVICE  1        REMOTE DEVICE  1
■                         StNum:          0

              MESSAGE     REMOTE DEVICE  1
                          SqNum:          0
```

Statistical data (2 types) for up to 16 programmed Remote Devices is shown here.

- The **StNum** number is obtained from the indicated Remote Device and is incremented whenever a change of state of at least one DNA or UserSt bit occurs.
- The **SqNum** number is obtained from the indicated Remote Device and is incremented whenever a GOOSE message is sent. This number will rollover to zero when a count of 4,294,967,295 is incremented.

6.2.10 DIGITAL COUNTERS

PATH: ACTUAL VALUES ⇨ DIGITAL COUNTERS ⇨⇩ DIGITAL COUNTERS ⇨ DIGITAL COUNTERS Counter 1(8)

```
■ DIGITAL COUNTERS        Counter 1      ACCUM:
■ Counter 1                        0

              MESSAGE     Counter 1     FROZEN:
                                   0

              MESSAGE     Counter 1     FROZEN:
                          YYYY/MM/DD HH:MM:SS

              MESSAGE     Counter 1     MICROS:
                                   0
```

The present status of the 8 digital counters is shown here. The status of each counter, with the user-defined counter name, includes the accumulated and frozen counts (the count units label will also appear). Also included, is the date/time stamp for the frozen count. The **Counter n MICROS** value refers to the microsecond portion of the time stamp.

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6.2.11 FLEX STATES

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ FLEX STATES

```
■ FLEX STATES             PARAM   1: Off       Range: Off, On
■                         Off
                                  ↓
              MESSAGE     PARAM 256: Off       Range: Off, On
                          Off
```

There are 256 FlexState bits available. The second line value indicates the state of the given FlexState bit.

6.2.12 ETHERNET

PATH: ACTUAL VALUES ⇨ STATUS ⇨⇩ ETHERNET

```
■ ETHERNET                ETHERNET PRI LINK    Range: Fail, OK
■                         STATUS: OK

              MESSAGE     ETHERNET SEC LINK    Range: Fail, OK
                          STATUS: OK
```

6.3.1 METERING CONVENTIONS

a) UR CONVENTION FOR MEASURING POWER AND ENERGY

The following figure illustrates the conventions established for use in UR relays.

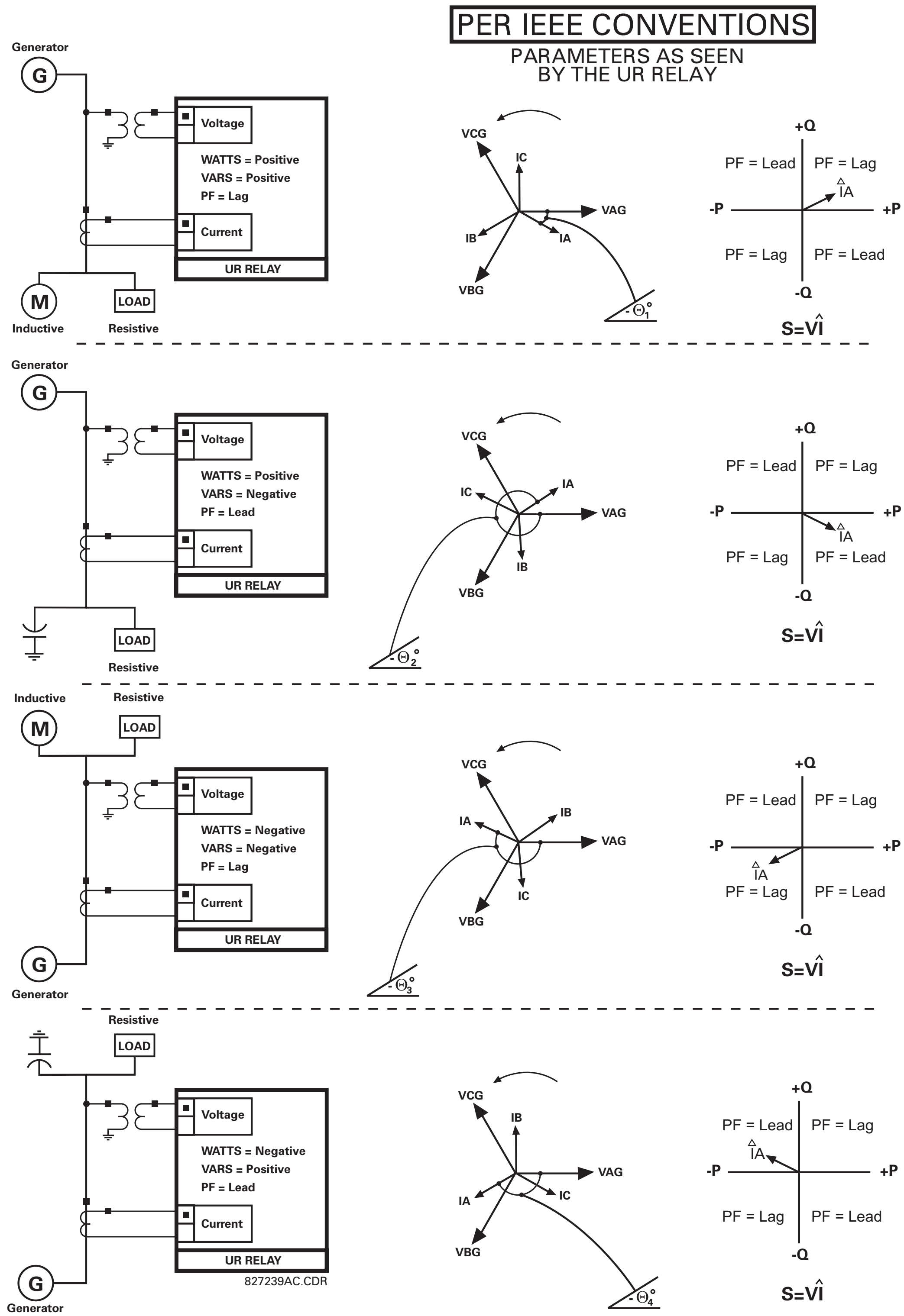

Figure 6–1: FLOW DIRECTION OF SIGNED VALUES FOR WATTS AND VARS

b) UR CONVENTION FOR MEASURING PHASE ANGLES

All phasors calculated by UR relays 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 relay are referred to an AC input channel pre-selected by the SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE setting. This setting defines a particular Source to be used as the reference.

The relay will first determine 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 relay determines if any "Aux VT" bank is indicated; if it is, the auxiliary voltage channel of that bank is used as the angle reference. If neither of the two conditions is satisfied, then two more steps of this hierarchical procedure to determine the reference signal include "Phase CT" bank and "Ground CT" bank.

If the AC signal pre-selected by the relay upon configuration is not measurable, the phase angles are not referenced. The phase angles are assigned as positive in the leading direction, and are presented as negative in the lagging direction, to more closely align with power system metering conventions. This is illustrated below.

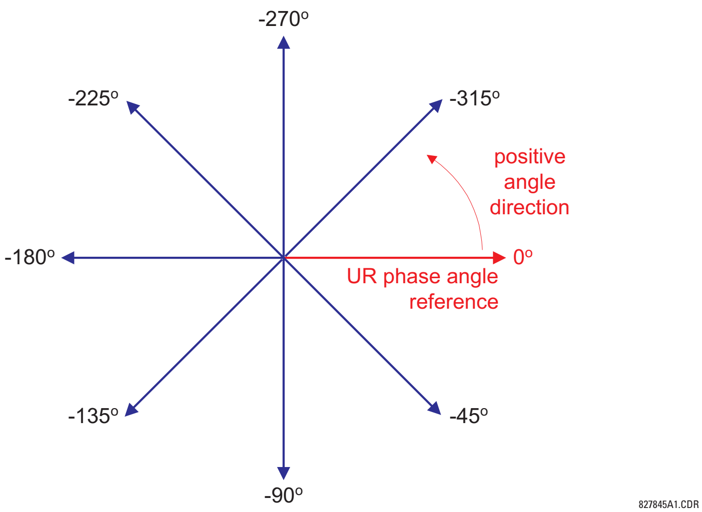

Figure 6–2: UR PHASE ANGLE MEASUREMENT CONVENTION

c) UR CONVENTION FOR MEASURING SYMMETRICAL COMPONENTS

UR relays calculate voltage symmetrical components for the power system phase A line-to-neutral voltage, and 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 reference as described in the previous sub-section.

WYE-Connected Instrument Transformers:

- ABC phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$
$$V\_1 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$
$$V\_2 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

- ACB phase rotation:

$$V\_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$
$$V\_1 = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$
$$V\_2 = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

The above equations apply to currents as well.

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DELTA-Connected Instrument Transformers:

- ABC phase rotation:

$$V\_0 = N/A$$

$$V\_1 = \frac{1\angle{-30°}}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

$$V\_2 = \frac{1\angle{30°}}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

- ACB phase rotation:

$$V\_0 = N/A$$

$$V\_1 = \frac{1\angle{30°}}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

$$V\_2 = \frac{1\angle{-30°}}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

The zero-sequence voltage is not measurable under the DELTA connection of instrument transformers and is defaulted to zero. The table below shows an example of symmetrical components calculations for the ABC phase rotation.

Table 6–1: CALCULATING VOLTAGE SYMMETRICAL COMPONENTS EXAMPLE

SYSTEM VOLTAGES, SEC. V *						VT CONN.	UR INPUTS, SEC. V			SYMM. COMP, SEC. V		
V_{AG}	V_{BG}	V_{CG}	V_{AB}	V_{BC}	V_{CA}		F5AC	F6AC	F7AC	V_0	V_1	V_2
13.9 ∠0°	76.2 ∠–125°	79.7 ∠–250°	84.9 ∠–313°	138.3 ∠–97°	85.4 ∠–241°	WYE	13.9 ∠0°	76.2 ∠–125°	79.7 ∠–250°	19.5 ∠–192°	56.5 ∠–7°	23.3 ∠–187°
UNKNOWN (only V_1 and V_2 can be determined)			84.9 ∠0°	138.3 ∠–144°	85.4 ∠–288°	DELTA	84.9 ∠0°	138.3 ∠–144°	85.4 ∠–288°	N/A	56.5 ∠–54°	23.3 ∠–234°

* The power system voltages are phase-referenced – for simplicity – to *VAG* and *VAB*, respectively. This, however, is a relative matter. It is important to remember that the UR displays are always referenced as specified under **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM ⇨⇩ FREQUENCY AND PHASE REFERENCE**.

The example above is illustrated in the following figure.

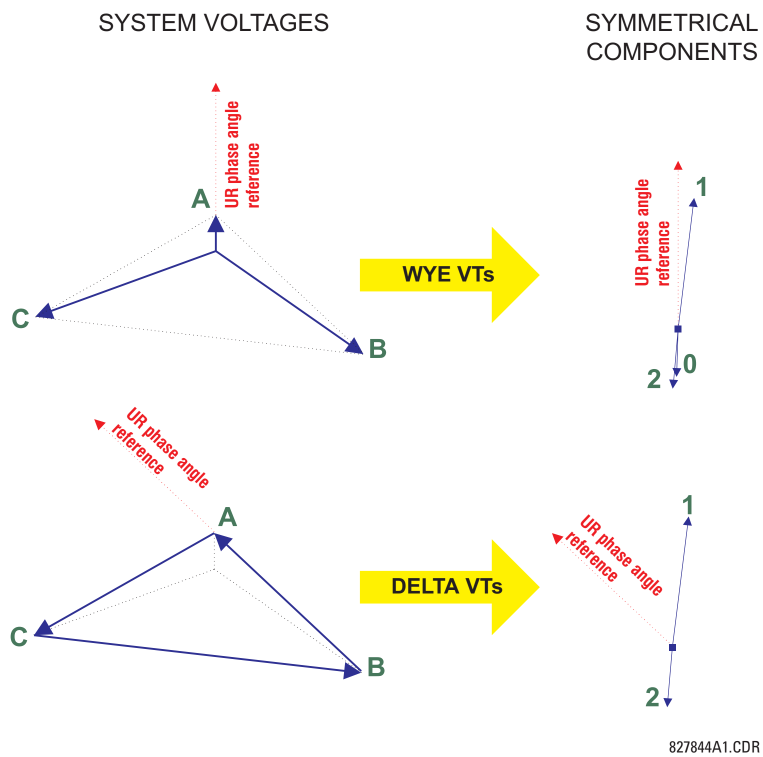

Figure 6–3: ILLUSTRATION OF THE UR CONVENTION FOR SYMMETRICAL COMPONENTS

6.3.2 SOURCES

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨ SOURCE SRC 1 ⇨

■ PHASE CURRENT ■ SRC 1		SRC 1 RMS Ia: 0.000 b: 0.000 c: 0.000 A
	MESSAGE	SRC 1 RMS Ia: 0.000 A
	MESSAGE	SRC 1 RMS Ib: 0.000 A
	MESSAGE	SRC 1 RMS Ic: 0.000 A
	MESSAGE	SRC 1 RMS In: 0.000 A
	MESSAGE	SRC 1 PHASOR Ia: 0.000 A 0.0°
	MESSAGE	SRC 1 PHASOR Ib: 0.000 A 0.0°
	MESSAGE	SRC 1 PHASOR Ic: 0.000 A 0.0°
	MESSAGE	SRC 1 PHASOR In: 0.000 A 0.0°
	MESSAGE	SRC 1 ZERO SEQ I0: 0.000 A 0.0°
	MESSAGE	SRC 1 POS SEQ I1: 0.000 A 0.0°
	MESSAGE	SRC 1 NEG SEQ I2: 0.000 A 0.0°
■ GROUND CURRENT ■ SRC 1		SRC 1 RMS Ig: 0.000 A
	MESSAGE	SRC 1 PHASOR Ig: 0.000 A 0.0°
	MESSAGE	SRC 1 PHASOR Igd: 0.000 A 0.0°
■ PHASE VOLTAGE ■ SRC 1		SRC 1 RMS Vag: 0.000 V
	MESSAGE	SRC 1 RMS Vbg: 0.000 V
	MESSAGE	SRC 1 RMS Vcg: 0.000 V
	MESSAGE	SRC 1 PHASOR Vag: 0.000 V 0.0°
	MESSAGE	SRC 1 PHASOR Vbg: 0.000 V 0.0°

MESSAGE		SRC 1 PHASOR Vcg: 0.000 V 0.0°
MESSAGE		SRC 1 RMS Vab: 0.000 V
MESSAGE		SRC 1 RMS Vbc: 0.000 V
MESSAGE		SRC 1 RMS Vca: 0.000 V
MESSAGE		SRC 1 PHASOR Vab: 0.000 V 0.0°
MESSAGE		SRC 1 PHASOR Vbc: 0.000 V 0.0°
MESSAGE		SRC 1 PHASOR Vca: 0.000 V 0.0°
MESSAGE		SRC 1 ZERO SEQ V0: 0.000 V 0.0°
MESSAGE		SRC 1 POS SEQ V1: 0.000 V 0.0°
MESSAGE		SRC 1 NEG SEQ V2: 0.000 V 0.0°
■ AUXILIARY VOLTAGE ■ SRC 1		SRC 1 RMS Vx: 0.000 V
MESSAGE		SRC 1 PHASOR Vx: 0.000 V 0.0°
■ POWER ■ SRC 1		SRC 1 REAL POWER 3ϕ: 0.000 W
MESSAGE		SRC 1 REAL POWER ϕa: 0.000 W
MESSAGE		SRC 1 REAL POWER ϕb: 0.000 W
MESSAGE		SRC 1 REAL POWER ϕc: 0.000 W
MESSAGE		SRC 1 REACTIVE PWR 3ϕ: 0.000 var
MESSAGE		SRC 1 REACTIVE PWR ϕa: 0.000 var
MESSAGE		SRC 1 REACTIVE PWR ϕb: 0.000 var
MESSAGE		SRC 1 REACTIVE PWR ϕc: 0.000 var
MESSAGE		SRC 1 APPARENT PWR 3ϕ: 0.000 VA

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MESSAGE		SRC 1 APPARENT PWR ϕa: 0.000 VA
MESSAGE		SRC 1 APPARENT PWR ϕb: 0.000 VA
MESSAGE		SRC 1 APPARENT PWR ϕc: 0.000 VA
MESSAGE		SRC 1 POWER FACTOR 3ϕ: 1.000
MESSAGE		SRC 1 POWER FACTOR ϕa: 1.000
MESSAGE		SRC 1 POWER FACTOR ϕb: 1.000
MESSAGE		SRC 1 POWER FACTOR ϕc: 1.000
■ FREQUENCY ■ SRC 1		SRC 1 FREQUENCY: 0.00 Hz

A maximum of 6 identical Source menus are available, numbered from SRC 1 to SRC 6. "SRC 1" will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ SIGNAL SOURCES**).

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 source configuration (see **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM**). 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.

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6.3.3 SYNCHROCHECK

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ SYNCHROCHECK ⇨ SYNCHROCHECK 1

■ SYNCHROCHECK1 ■		SYNCHROCHECK 1 DELTA VOLT: 0.000 V
MESSAGE		SYNCHROCHECK 1 DELTA PHASE: 0.0°
MESSAGE		SYNCHROCHECK 1 DELTA FREQ: 0.00 Hz

The Actual Values menu for SYNCHROCHECK2 is identical to that of SYNCHROCHECK1. If a Synchrocheck Function setting is set to "Disabled", the corresponding Actual Values menu item will not be displayed.

6.3.4 TRACKING FREQUENCY

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRACKING FREQUENCY

■ TRACKING FREQUENCY ■		TRACKING FREQUENCY: 60.00 Hz

The tracking frequency is displayed here. The frequency is tracked based on configuration of the reference source. See **SETTINGS ⇨⇩ SYSTEM SETUP ⇨⇩ POWER SYSTEM** for more details on frequency metering and tracking. With three-phase inputs configured the frequency is measured digitally using a Clarke combination of all three-phase signals for optimized performance during faults, open pole, and VT fuse fail conditions.

6.3.5 FLEXELEMENTS™

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ FLEXELEMENTS ⇨ FLEXELEMENT 1(8)

```
■ FLEXELEMENT 1          FLEXELEMENT 1 OpSig:
■                        0.000 pu
```

The operating signals for the FlexElements are displayed in pu values using the following definitions of the base units.

Table 6–2: FLEXELEMENT™ BASE UNITS

BREAKER ARCING AMPS (Brk X Arc Amp A, B, and C)	BASE = 2000 $kA^2 \times$ cycle
dcmA	BASE = maximum value of the **DCMA INPUT MAX** setting for the two transducers configured under the +IN and –IN inputs.
FREQUENCY	f_{BASE} = 1 Hz
PHASE ANGLE	φ_{BASE} = 360 degrees (see the UR angle referencing convention)
POWER FACTOR	PF_{BASE} = 1.00
RTDs	BASE = 100°C
SOURCE CURRENT	I_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SOURCE POWER	P_{BASE} = maximum value of $V_{BASE} \times I_{BASE}$ for the +IN and –IN inputs
SOURCE VOLTAGE	V_{BASE} = maximum nominal primary RMS value of the +IN and –IN inputs
SYNCHROCHECK (Max Delta Volts)	V_{BASE} = maximum primary RMS value of all the sources related to the +IN and –IN inputs

6.3.6 TRANSDUCER I/O

a) DCMA INPUTS

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O DCMA INPUTS ⇨ DCMA INPUT xx

```
■ DCMA INPUT xx          DCMA INPUT xx
■                        0.000 mA
```

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Actual values for each DCMA input channel that is Enabled are displayed with the top line as the programmed channel "ID" and the bottom line as the value followed by the programmed units.

b) RTD INPUTS

PATH: ACTUAL VALUES ⇨⇩ METERING ⇨⇩ TRANSDUCER I/O RTD INPUTS ⇨ RTD INPUT xx

```
■ RTD INPUT xx           RTD INPUT xx
■                        -50 °C
```

Actual values for each RTD input channel that is Enabled are displayed with the top line as the programmed channel "ID" and the bottom line as the value.

6.4.1 FAULT REPORTS

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨ FAULT REPORTS ⇨

```
NO FAULTS TO REPORT
```

or

■ FAULT REPORT # ■	◄►	FAULT # DATE: 2000/08/11	Range: YYYY/MM/DD
MESSAGE	▲▼	FAULT # TIME: 00:00:00.000000	Range: HH:MM:SS.ssssss
MESSAGE	▲▼	FAULT # TYPE: ABG	where applicable
MESSAGE	▲▼	FAULT # LOCATION 00.0 km	where applicable
MESSAGE	▲	FAULT # RECLOSE SHOT: 0	where applicable

The latest 10 fault reports can be stored. The most recent fault location calculation (when applicable) is displayed in this menu, along with the date and time stamp of the event which triggered the calculation. See the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ FAULT REPORT** menu for assigning the Source and Trigger for fault calculations. Refer to the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for clearing fault reports.

6.4.2 FAULT LOCATOR OPERATION

Fault Type determination is required for calculation of Fault Location – the algorithm uses the angle between the negative and positive sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used, i.e., 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 and zero sequence currents.

The single-ended fault location method assumes that the fault components of the currents supplied from the local (A) and remote (B) systems are in phase. The figure below shows an equivalent system for fault location.

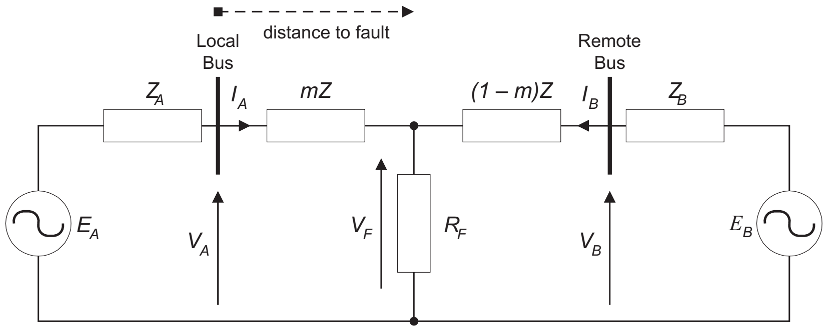

Figure 6–4: EQUIVALENT SYSTEM FOR FAULT LOCATION

The following equations hold true for this equivalent system.

$$V_A = m \cdot Z \cdot I_A + R_F \cdot (I_A + I_B) \quad \text{eqn. 1}$$

where: m = sought pu distance to fault, Z = positive sequence impedance of the line.

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components:

$$I_A = I_{AF} + I_{Apre} \quad \text{eqn. 2}$$

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and neglecting shunt parameters of the line:

$$I_B = I_{BF} - I_{Apre} \quad \text{eqn. 3}$$

Inserting equations 2 and 3 into equation 1 and solving for the fault resistance yields:

$$R_F = \frac{V_A - m \cdot Z \cdot I_A}{I_{AF} \cdot \left(1 + \frac{I_{BF}}{I_{AF}}\right)} \quad \text{eqn. 4}$$

Assuming the fault components of the currents, I_{AF} and I_{BF} are in phase, and observing that the fault resistance, as impedance, does not have any imaginary part gives:

$$\text{Im}\left(\frac{V_A - m \cdot Z \cdot I_A}{I_{AF}}\right) \quad \text{eqn. 5}$$

where: Im() represents the imaginary part of a complex number. Equation 5 solved for the unknown *m* creates the following fault location algorithm:

$$m = \frac{\text{Im}(V_A \cdot I_{AF}^*)}{\text{Im}(Z \cdot I_A \cdot I_{AF}^*)} \quad \text{eqn. 6}$$

where: ***** denotes the complex conjugate and: $I_{AF} = I_A - I_{Apre}$ eqn. 7

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying equations 6 and 7 (the superscripts denote phases, the subscripts denote stations):

- For AG faults: $V_A = V_A^A$, $I_A = I_A^A + K_0 \cdot I_{0A}$ eqn. 8a
- For BG faults: $V_A = V_A^B$, $I_A = I_A^B + K_0 \cdot I_{0A}$ eqn. 8b
- For CG faults: $V_A = V_A^C$, $I_A = I_A^{BC} + K_0 \cdot I_{0A}$ eqn. 8c
- For AB and ABG faults: $V_A = V_A^A - V_A^B$, $I_A = I_A^A - I_A^B$ eqn. 8d
- For BC and BCG faults: $V_A = V_A^B - V_A^C$, $I_A = I_A^B - I_A^C$ eqn. 8e
- For CA and CAG faults: $V_A = V_A^C - V_A^A$, $I_A = I_A^C - I_A^A$ eqn. 8f
  where K_0 is the zero sequence compensation factor (for equations 8a to 8f)
- 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 element calculates the distance to the fault (with *m* in miles or kilometers) and the phases involved in the fault.

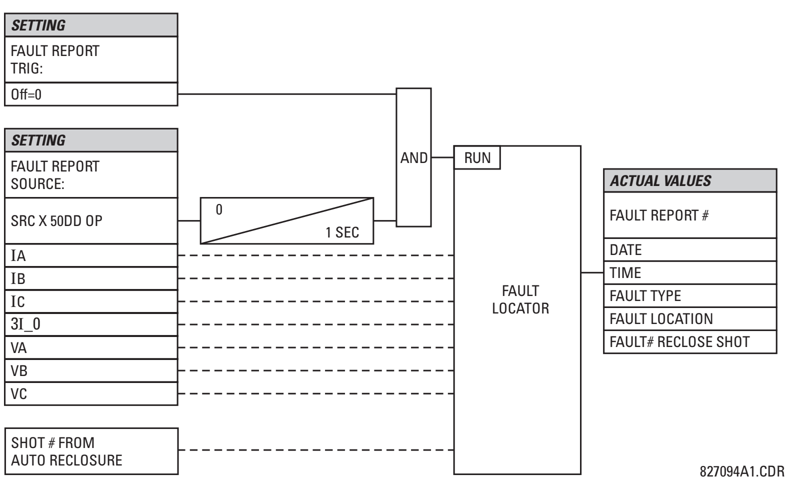

Figure 6–5: FAULT LOCATOR SCHEME

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6.4.3 EVENT RECORDS

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ EVENT RECORDS

```
■ EVENT RECORDS          ◄►   EVENT: XXXX
■                             RESET OP(PUSHBUTTON)
                                    ↓
        MESSAGE   ▲▼   EVENT: 3                 ◄►   ▼  EVENT 3
                       POWER ON                         DATE: 2000/07/14
        MESSAGE   ▲▼   EVENT: 2                      ▲  EVENT 3
                       POWER OFF                        TIME: 14:53:00.03405
        MESSAGE   ▲    EVENT: 1
                       EVENTS CLEARED                   Date and Time Stamps
```

The Event Records menu shows the contextual data associated with up to the last 1024 events, listed in chronological order from most recent to oldest. If all 1024 event records have been filled, the oldest record will be removed as a new record is added. Each event record shows the event identifier/sequence number, cause, and date/time stamp associated with the event trigger. Refer to the COMMANDS CLEAR RECORDS menu for clearing event records.

6.4.4 OSCILLOGRAPHY

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ OSCILLOGRAPHY

```
■ OSCILLOGRAPHY          ◄►   FORCE TRIGGER?            Range: No, Yes
■                             No
        MESSAGE   ▲▼   NUMBER OF TRIGGERS:
                            0
        MESSAGE   ▲▼   AVAILABLE RECORDS:
                            0
        MESSAGE   ▲▼   CYCLES PER RECORD:
                          0.0
        MESSAGE   ▲    LAST CLEARED DATE:
                       2000/07/14 015:40:16
```

This menu allows the user to view the number of triggers involved and number of oscillography traces available. The 'cycles per record' value is calculated to account for the fixed amount of data storage for oscillography. See the OSCILLOGRAPHY section of Chapter 5.

A trigger can be forced here at any time by setting "Yes" to the **FORCE TRIGGER?** command. Refer to the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for clearing the oscillography records.

6.4.5 DATA LOGGER

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ DATA LOGGER

```
■ DATA LOGGER            ◄►   OLDEST SAMPLE TIME:
■                             2000/01/14 13:45:51
        MESSAGE   ▲    NEWEST SAMPLE TIME:
                       2000/01/14 15:21:19
```

The **OLDEST SAMPLE TIME** is the time at which the oldest available samples were taken. It will be static until the log gets full, at which time it will start counting at the defined sampling rate. The **NEWEST SAMPLE TIME** is the time the most recent samples were taken. It counts up at the defined sampling rate. If Data Logger channels are defined, then both values are static.

Refer to the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for clearing data logger records.

6.4.6 MAINTENANCE

a) BREAKER 1(2)

PATH: ACTUAL VALUES ⇨⇩ RECORDS ⇨⇩ MAINTENANCE ⇨ BREAKER 1

```
■ BREAKER 1
■
```

```
BKR 1 ARCING AMP ϕA:
0.00 kA2-cyc
```

MESSAGE

```
BKR 1 ARCING AMP ϕB:
0.00 kA2-cyc
```

MESSAGE

```
BKR 1 ARCING AMP ϕC:
0.00 kA2-cyc
```

There is an identical Actual Value menu for each of the 2 Breakers. The **BKR 1 ARCING AMP** values are in units of kA^2-cycles. Refer to the **COMMANDS ⇨⇩ CLEAR RECORDS** menu for clearing breaker arcing current records.

6.5.1 MODEL INFORMATION

PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨ MODEL INFORMATION

■ MODEL INFORMATION ■	◁▷	ORDER CODE LINE 1: D60-A00-HCH-F8A-H6A	*Example code shown*
MESSAGE	△▽	ORDER CODE LINE 2:	
MESSAGE	△▽	ORDER CODE LINE 3:	
MESSAGE	△▽	ORDER CODE LINE 4:	
MESSAGE	△▽	SERIAL NUMBER:	
MESSAGE	△▽	ETHERNET MAC ADDRESS 000000000000	
MESSAGE	△▽	MANUFACTURING DATE: 0	*Range: YYYY/MM/DD HH:MM:SS*
MESSAGE	△	OPERATING TIME: 0:00:00	

The product order code, serial number, Ethernet MAC address, date/time of manufacture, and operating time are shown here.

6.5.2 FIRMWARE REVISIONS

PATH: ACTUAL VALUES ⇨⇩ PRODUCT INFO ⇨⇩ FIRMWARE REVISIONS

■ FIRMWARE REVISIONS ■	◁▷	D60 Distance Relay REVISION: 2.9X	*Range: 0.00 to 655.35* *Revision number of the application firmware.*
MESSAGE	△▽	MODIFICATION FILE NUMBER: 0	*Range: 0 to 65535 (ID of the MOD FILE)* *Value is 0 for each standard firmware release.*
MESSAGE	△▽	BOOT PROGRAM REVISION: 1.12	*Range: 0.00 to 655.35* *Revision number of the boot program firmware.*
MESSAGE	△▽	FRONT PANEL PROGRAM REVISION: 0.08	*Range: 0.00 to 655.35* *Revision number of faceplate program firmware.*
MESSAGE	△▽	COMPILE DATE: 2000/09/08 04:55:16	*Range: Any valid date and time.* *Date and time when product firmware was built.*
MESSAGE	△	BOOT DATE: 2000/05/11 16:41:32	*Range: Any valid date and time.* *Date and time when the boot program was built.*

The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.

7.1.1 COMMANDS MENU

```
                 MENU
          COMMANDS

             ⇩
MESSAGE ▼  ■■ COMMANDS
           ■■ VIRTUAL INPUTS
MESSAGE ▲▼ ■■ COMMANDS
           ■■ CLEAR RECORDS
MESSAGE ▲▼ ■■ COMMANDS
           ■■ SET DATE AND TIME
MESSAGE ▲  ■■ COMMANDS
           ■■ RELAY MAINTENANCE
```

The COMMANDS menu contains relay directives intended for operations personnel. All commands can be protected from unauthorized access via the Command Password; see the PASSWORD SECURITY menu description in the PRODUCT SETUP section of Chapter 5. The following flash message appears after successfully command entry:

```
COMMAND
EXECUTED
```

7.1.2 VIRTUAL INPUTS

PATH: COMMANDS ⇩ COMMANDS VIRTUAL INPUTS

```
■■ COMMANDS        ◄►  Virt Ip 1          Range: Off, On
■■ VIRTUAL INPUTS      Off
                          ↓
                          ↓
           MESSAGE ▲   Virt Ip 32         Range: Off, On
                       Off
```

The states of up to 32 virtual inputs are changed here. The first line of the display indicates the ID of the virtual input. The second line indicates the current or selected status of the virtual input. This status will be a logical state 'Off' (0) or 'On' (1).

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7.1.3 CLEAR RECORDS

PATH: COMMANDS ⇩ COMMANDS CLEAR RECORDS

```
■■ COMMANDS
■■ CLEAR RECORDS
```

CLEAR FAULT REPORTS? No	Range: No, Yes
CLEAR EVENT RECORDS? No	Range: No, Yes
CLEAR OSCILLOGRAPHY? No	Range: No, Yes
CLEAR DATA LOGGER? No	Range: No, Yes
CLEAR BREAKER 1 ARCING AMPS? No	Range: No, Yes
CLEAR BREAKER 2 ARCING AMPS? No	Range: No, Yes

This menu contains commands for clearing historical data such as the Event Records. Data is cleard by changing a command setting to "Yes" and pressing the ENTER key. After clearing data, the command setting automatically reverts to "No".

7.1.4 SET DATE AND TIME

PATH: COMMANDS ⇩ SET DATE AND TIME

```
■■ COMMANDS
■■ SET DATE AND TIME
```

SET DATE AND TIME: 2000/01/14 13:47:03	*(YYYY/MM/DD HH:MM:SS)*

The date and time can be entered here via the faceplate keypad, provided that the IRIG-B signal is not being used. The time setting is based on the 24-hour clock. The complete date, as a minimum, must be entered to allow execution of this command. The new time will take effect at the moment the ENTER key is clicked.

7.1.5 RELAY MAINTENANCE

PATH: COMMANDS ⇩ RELAY MAINTENANCE

7

```
■■ COMMANDS
■■ RELAY MAINTENANCE
```

PERFORM LAMPTEST? No	Range: No, Yes
UPDATE ORDER CODE? No	Range: No, Yes

This menu contains commands for relay maintenance purposes. Commands are activated by changing a command setting to "Yes" and pressing the ENTER key. The command setting will then automatically revert to "No".

The **PERFORM LAMPTEST** command turns on all faceplate LEDs and display pixels for a short duration. The **UPDATE ORDER CODE** command causes the relay to scan the backplane for the hardware modules and update the order code to match. If an update occurs, the following message is shown.

```
UPDATING...
PLEASE WAIT
```

There is no impact if there have been no changes to the hardware modules. When an update does not occur, the following message will be shown.

```
ORDER CODE
NOT UPDATED
```

7.2.1 TARGETS MENU

MENU

```
TARGETS
```

⇩

MESSAGE ▼	DIGITAL ELEMENT 1: LATCHED	*Displayed only if targets for this element are active. Example shown.*
MESSAGE ▲▼	DIGITAL ELEMENT 16: LATCHED	*Displayed only if targets for this element are active. Example shown.*
MESSAGE ▲	↓ ↓	

The status of any active targets will be displayed in the TARGETS menu. If no targets are active, the display will read:

```
No Active
Targets
```

a) TARGET MESSAGES

When there are no active targets, the first target to become active will cause the display to immediately default to that message. If there are active targets and the user is navigating through other messages, and when the default message timer times out (i.e. the keypad has not been used for a determined period of time), the display will again default back to the target message.

The range of variables for the target messages is described below. Phase information will be included if applicable. If a target message status changes, the status with the highest priority will be displayed.

Table 7–1: TARGET MESSAGE PRIORITY STATUS

PRIORITY	ACTIVE STATUS	DESCRIPTION
1	OP	element operated and still picked up
2	PKP	element picked up and timed out
3	LATCHED	element had operated but has dropped out

If a self test error is detected, a message appears indicating the cause of the error. For example:

```
UNIT NOT PROGRAMMED
:Self Test Error
```

7.2.2 RELAY SELF-TESTS

The relay performs a number of self-test diagnostic checks to ensure device integrity. The two types of self-tests (major and minor) are listed in the tables below. When either type of self-test error occurs, the TROUBLE indicator will turn on and a target message displayed. All errors record an event in the event recorder. Latched errors can be cleared by pressing the RESET key, providing the condition is no longer present.

Major self-test errors also result in the following:

- the critical fail relay on the power supply module is de-energized
- all other output relays are de-energized and are prevented from further operation
- the faceplate IN SERVICE indicator is turned off
- a RELAY OUT OF SERVICE event is recorded

Table 7–2: MAJOR SELF-TEST ERROR MESSAGES

SELF-TEST ERROR MESSAGE	LATCHED TARGET MSG?	DESCRIPTION OF PROBLEM	HOW OFTEN THE TEST IS PERFORMED	WHAT TO DO
UNIT NOT PROGRAMMED	No	**PRODUCT SETUP ⇨⇩ INSTALLATION** setting indicates relay is not in a programmed state.	On power up and whenever the **RELAY PROGRAMMED** setting is altered.	Program all settings (especially those under **PRODUCT SETUP ⇨⇩ INSTALLATION**).
EQUIPMENT MISMATCH with 2nd-line detail message	No	Configuration of modules does not match the order code stored in the CPU.	On power up; thereafter, the backplane is checked for missing cards every 5 seconds.	Check all module types against the order code, ensure they are inserted properly, and cycle control power (if problem persists, contact the factory).
UNIT NOT CALIBRATED	No	Settings indicate the unit is not calibrated.	On power up.	Contact the factory.
FLEXLOGIC ERR TOKEN with 2nd-line detail message	No	FlexLogic equations do not compile properly.	Event driven; whenever FlexLogic equations are modified.	Finish all equation editing and use self test to debug any errors.
DSP ERRORS: A/D RESET FAILURE A/D CAL FAILURE A/D INT. MISSING A/D VOLT REF. FAIL NO DSP INTERRUPTS DSP CHECKSUM FAILED DSP FAILED	Yes	CT/VT module with digital signal processor may have a problem.	Every 1/8th of a cycle.	Cycle the control power (if the problem recurs, contact the factory).
PROGRAM MEMORY Test Failed	Yes	Error was found while checking Flash memory.	Once flash is uploaded with new firmware.	Contact the factory.

Table 7–3: MINOR SELF-TEST ERROR MESSAGES

SELF-TEST ERROR MESSAGE	LATCHED TARGET MSG?	DESCRIPTION OF PROBLEM	HOW OFTEN THE TEST IS PERFORMED	WHAT TO DO
EEPROM CORRUPTED	Yes	The non-volatile memory has been corrupted.	On power up only.	Contact the factory.
IRIG-B FAILURE	No	Bad IRIG-B input signal.	Monitored whenever an IRIG-B signal is received.	• Ensure the IRIG-B cable is connected to the relay. • Check functionality of the cable (i.e. look for physical damage or perform a continuity test). • Ensure the IRIG-B receiver is functioning properly. • Check the input signal level; it may be lower than specification. If none of the above items apply, contact the factory.
PRIM ETHERNET FAIL	No	Primary Ethernet connection failed	Monitored every 2 seconds	Check connections.
SEC ETHERNET FAIL	No	Secondary Ethernet connection failed	Monitored every 2 seconds	Check connections.
BATTERY FAIL	No	Battery is not functioning.	Monitored every 5 seconds. Reported after 1 minute if problem persists.	Replace the battery.
PROTOTYPE FIRMWARE	Yes	A prototype version of the firmware is loaded.	On power up only.	Contact the factory.
SYSTEM EXCEPTION or ABNORMAL RESTART	Yes	Abnormal restart due to modules being removed/inserted when powered-up, abnormal DC supply, or internal relay failure.	Event driven.	Contact the factory.
LOW ON MEMORY	Yes	Memory is close to 100% capacity	Monitored every 5 seconds.	Contact the factory.
WATCHDOG ERROR	No	Some tasks are behind schedule	Event driven.	Contact the factory.
REMOTE DEVICE OFFLINE	Yes	One or more GOOSE devices are not responding	Event driven. Occurs when a device programmed to receive GOOSE messages stops receiving message. Time is 1 to 60 sec. depending on GOOSE protocol packets.	Check GOOSE setup

8.1.1 INTRODUCTION

The distance elements use memory voltage for polarization. Additional supervising functions – different for ground and phase distance zones – complement a classical mho characteristic in order to enhance the 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 – may have limited accuracy during double-line-to-ground faults. In order 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- 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 as described above. Right and left blinders adjustable as to both the resistive and angular positions complete the characteristic.

More information regarding the distance characteristics is found in the DISTANCE CHARACTERISTICS section. An example of analysis of the steady-state operation of the distance elements is found in the DISTANCE ELEMENTS ANALYSIS section.

The relay provides four zones of distance protection. All zones are identical in terms of settings. However, Zone 1 has extra adaptive mechanisms built-in to enhance the transient reach accuracy even when the voltage signals are supplied from poor quality voltage sources such as Capacitive Voltage Transformers (CVTs). Ground Zones 2 trough 4, in turn, 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 4 are recommended as overreaching elements and for time-delayed tripping.

The relay uses offset ground directional overcurrent functions as an optional supplement of the ground distance protection for pilot-aided schemes. The elements are described in more details in the GROUND DIRECTIONAL O/C section.

The relay provides for an adaptive distance reach control to cope with the overreaching and sub-synchronous oscillations when applied to, or in a near vicinity of series compensated lines. More details can be found in the APPLICATION ON SERIES COMPENSATED LINES section.

The distance elements use phase angle comparators to shape their characteristics as described in detail in the DISTANCE CHARACTERISTICS section. The voltage and current phasors are estimated using optimized techniques as explained in the next section.

8.1.2 PHASOR ESTIMATION

The relay samples its input AC signals at 64 samples per power system cycle. A fast and accurate frequency tracking mechanism ensures accurate filtering and phasor estimation during off-nominal frequency conditions.

The phasor estimation process for both currents and voltages is based on the commonly used Fourier algorithm. Due to a different nature of signal distortions in the current and voltage signals digital pre-filtering algorithms have been, however, 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 component (–s) guaranteeing transient overshoot below 2% regardless of the initial magnitude and time constant of the dc component (–s). The filter has significantly better frequency response for higher frequencies as compared with a classical MIMIC filter. This was possible without introducing any significant phase delay thanks to the high sampling rate used by the relay.

The voltage signals are pre-filtered using a special digital filter designed to cope with CVT transients. The 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.

8.1.3 DISTANCE CHARACTERISTICS

The relay shapes its distance characteristics using phase angle comparators and voltage and current phasors estimated as described in the previous section.

The following definitions pertain to all of the distance functions:

I_A	phase A current phasor
I_B	phase B current phasor
I_C	phase C current phasor
I_G	ground current from a parallel line
V_A	phase A to ground voltage phasor
V_B	phase B to ground voltage phasor
V_C	phase C to ground voltage phasor
()_1	positive-sequence phasor of () derived from the phase quantities
()_2	negative-sequence phasor of () derived from the phase quantities
()_0	zero-sequence phasor of () derived from the phase quantities
()M	memorized value of ()
Z	reach impedance (**REACH** ∠ **RCA**)
Z_D	directional characteristic impedance (1 ∠ **DIR RCA**)
Z_R	right blinder characteristic impedance: Z_R = **RGT BLD** × sin (**RGT BLD RCA** ∠ (**RGT BLD RCA** – 90°))
Z_L	left blinder characteristic impedance: Z_L = **LFT BLD** × sin (**LFT BLD RCA** ∠ (**LFT BLD RCA** + 90°))
K0	zero-sequence compensating factor: K0 = (**Z0/Z1 MAG** ∠ **Z0/Z1 ANG**) – 1
K0M	mutual zero-sequence compensating factor: K0M = 1/3 x **Z0M/Z1 MAG** ∠ **Z0M/Z1 ANG**

a) MHO CHARACTERISTIC

The dynamic 100% memory polarized mho characteristic is achieved by checking the angle between:

AB phase element:	$(I_A - I_B) \times Z - (V_A - V_B)$	**and**	$(V_A - V_B)$_1M
BC phase element:	$(I_B - I_C) \times Z - (V_B - V_C)$	**and**	$(V_B - V_C)$_1M
CA phase element:	$(I_C - I_A) \times Z - (V_C - V_A)$	**and**	$(V_C - V_A)$_1M
A ground element:	$I_A \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_A$	**and**	V_A_1M
B ground element:	$I_B \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_B$	**and**	V_B_1M
C ground element:	$I_C \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_C$	**and**	V_C_1M

8

The limit angle of the comparator is adjustable enabling the user to shape the characteristic as a mho or a lens as shown in the figures below.The memory-polarized mho characteristic has an excellent directional integrity built-in as explained in the MEMORY POLARIZATION section.

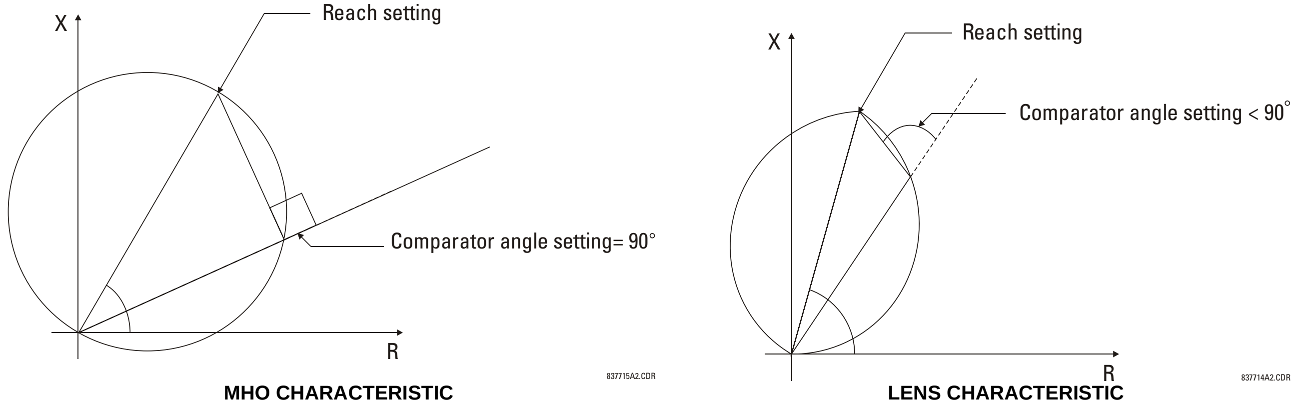

Figure 8–1: MHO AND LENS CHARACTERISTICS

b) REACTANCE CHARACTERISTIC

The reactance characteristic is achieved by checking the angle between:

AB phase element:	$(I_A - I_B) \times Z - (V_A - V_B)$ **and** $(I_A - I_B) \times Z$
BC phase element:	$(I_B - I_C) \times Z - (V_B - V_C)$ **and** $(I_B - I_C) \times Z$
CA phase element:	$(I_C - I_A) \times Z - (V_C - V_A)$ **and** $(I_C - I_A) \times Z$
A ground element:	$I_A \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_A$ **and** $I\_0 \times Z$
B ground element:	$I_B \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_B$ **and** $I\_0 \times Z$
C ground element:	$I_C \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_C$ **and** $I\_0 \times Z$

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. If the QUAD characteristic is selected, the reactance comparator constitutes the upper boundary of the operating region.

The reactance characteristic enables the relay to avoid overreaching on resistive faults during heavy load conditions.

c) DIRECTIONAL CHARACTERISTIC

The directional characteristic is achieved by checking the angle between:

AB phase element:	$(I_A - I_B) \times Z_D$ **and** $(V_A - V_B)\_1M$
BC phase element:	$(I_B - I_C) \times Z_D$ **and** $(V_B - V_C)\_1M$
CA phase element:	$(I_C - I_A) \times Z_D$ **and** $(V_C - V_A)\_1M$
A ground element:	$I\_0 \times Z_D$ **and** V_A_1M $I_A\_2 \times Z_D$ **and** V_A_1M
B ground element:	$I\_0 \times Z_D$ **and** V_B_1M $I_B\_2 \times Z_D$ **and** V_B_1M
C ground element:	$I\_0 \times Z_D$ **and** V_C_1M $I_C\_2 \times Z_D$ **and** V_C_1M

The characteristic and limit angles of the directional comparator are adjustable independently from the mho and reactance comparators. The directional characteristic improves directional integrity of the distance functions.

8

d) RIGHT BLINDER

The right blinder characteristic is achieved by checking the angle between the following signals:

AB phase element: $(I_A - I_B) \times Z_R - (V_A - V_B)$ **and** $(I_A - I_B) \times Z_R$

BC phase element: $(I_B - I_C) \times Z_R - (V_B - V_C)$ **and** $(I_B - I_C) \times Z_R$

CA phase element: $(I_C - I_A) \times Z_R - (V_C - V_A)$ **and** $(I_C - I_A) \times Z_R$

A ground element: $I_A \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R - V_A$ **and** $I_A \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R$

B ground element: $I_B \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R - V_B$ **and** $I_B \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R$

C ground element: $I_C \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R - V_C$ **and** $I_C \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R$

The blinders apply to the QUAD characteristic only.

e) LEFT BLINDER

The left blinder characteristic is achieved by checking the angle between the following signals:

AB phase element: $(I_A - I_B) \times Z_L - (V_A - V_B)$ **and** $(I_A - I_B) \times Z_L$

BC phase element: $(I_B - I_C) \times Z_L - (V_B - V_C)$ **and** $(I_B - I_C) \times Z_L$

CA phase element: $(I_C - I_A) \times Z_L - (V_C - V_A)$ **and** $(I_C - I_A) \times Z_L$

A ground element: $I_A \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L - V_A$ **and** $I_A \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L$

B ground element: $I_B \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L - V_B$ **and** $I_B \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L$

C ground element: $I_C \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L - V_C$ **and** $I_C \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L$

The blinders apply to the QUAD characteristic only.

f) FAULT-TYPE CHARCTERISTIC

The fault-type characteristic applies to ground elements only and is achieved by checking the angle between:

A ground element: I_0 **and** I_A_2

B ground element: I_0 **and** I_B_2

C ground element: I_0 **and** I_C_2

The limit angle of the comparator is not adjustable and equals 50°. The fault-type characteristic is intended to block the ground distance elements during double-line-to-ground faults.

g) ZERO-SEQUENCE DIRECTIONAL CHARACTERISTIC

The extra zero-sequence characteristic applies to ground Zones 2 through 4 only and is achieved by checking the angle between:

A ground element: $I\_0 \times Z_D$ **and** $-V\_0$

B ground element: $I\_0 \times Z_D$ **and** $-V\_0$

C ground element: $I\_0 \times Z_D$ **and** $-V\_0$

8

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.

h) OVERCURRENT SUPERVISION

The overcurrent supervision responds to the following currents:

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 ground element: $3 \times I\_0$

B ground element: $3 \times I\_0$

C ground element: $3 \times I\_0$

The following tables summarize the characteristics of the distance elements

Table 8–1: MHO PHASE DISTANCE FUNCTIONS

CHARACTERISTIC	COMPARATOR INPUTS		LIMIT ANGLE
Variable MHO	$I \times Z - V$	V_1M	COMP LIMIT
Reactance	$I \times Z - V$	$I \times Z$	COMP LIMIT
Directional	$I \times Z_D$	V_1M	DIR COMP LIMIT

Table 8–2: MHO GROUND DISTANCE FUNCTIONS

CHARACTERISTIC	COMPARATOR INPUTS		LIMIT ANGLE
Variable MHO	$I \times Z - V$	V_1M	COMP LIMIT
Reactance	$I \times Z - V$	$I\_0 \times Z$	COMP LIMIT
Directional	$I\_0 \times Z_D$	V_1M	DIR COMP LIMIT
Directional	$I\_2 \times Z_D$	V_1M	DIR COMP LIMIT
Fault-type	I_0	I_2	50°
Zero-sequence	$I\_0 \times Z_D$	–V_0	90° (Zones 2, 3 and 4 only)

Table 8–3: QUAD PHASE DISTANCE FUNCTIONS

CHARACTERISTIC	COMPARATOR INPUTS		LIMIT ANGLE
Reactance	$I \times Z - V$	$I \times Z$	COMP LIMIT
Directional	$I \times Z_D$	V_1M	DIR COMP 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 8–4: QUAD GROUND DISTANCE FUNCTIONS

CHARACTERISTIC	COMPARATOR INPUTS		LIMIT ANGLE
Reactance	$I \times Z - V$	V_1M	COMP LIMIT
Directional	$I\_0 \times Z_D$	V_1M	DIR COMP LIMIT
Directional	$I\_2 \times Z_D$	V_1M	DIR COMP 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_0	I_2	50°
Zero-sequence	$I\_0 \times Z_D$	–V_0	90° (Zones 2, 3, and 4 only)

8.1.4 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 three-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. After the memory expires, the relay checks the magnitude of the actual positive-sequence voltage. If it is higher than 10% of nominal, the actual voltage is used; if lower, the memory voltage continues to be used.

The memory-polarized mho has an extra directional integrity built-in as illustrated below. 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.

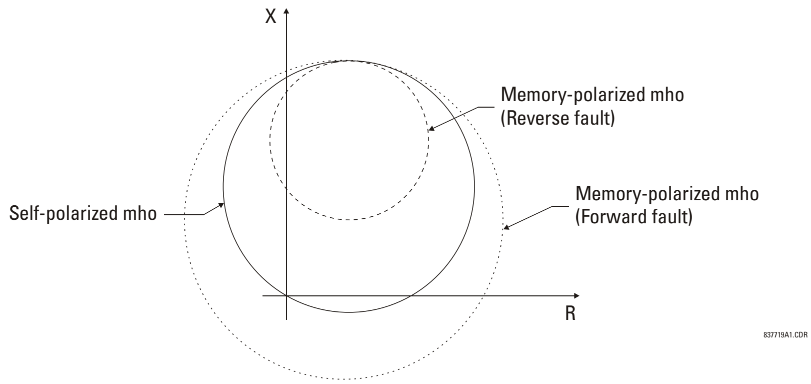

Figure 8–2: DYNAMIC SHIFT OF THE MHO CHARACTERISTIC

The same desirable effect of memory polarization applies to the directional comparator of the QUAD characteristic

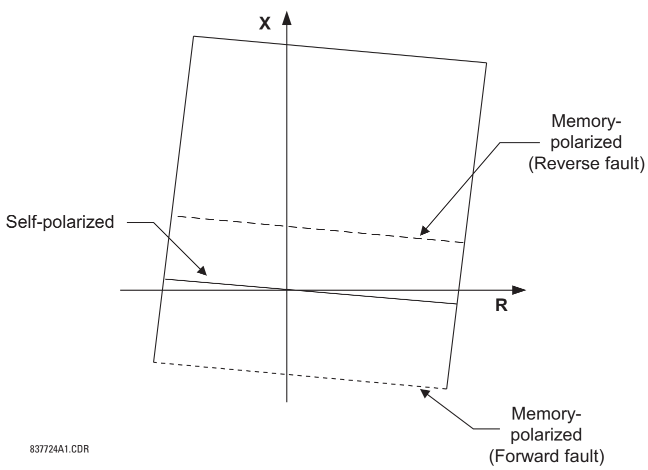

Figure 8–3: DYNAMIC SHIFT OF THE MEMORY-POLARIZED DIRECTIONAL CHARACTERISTIC

Mutual zero-sequence compensation may raise concerns regarding directional integrity on reverse faults in the situation when the relay gets "overcompensated". This problem does not affect the D60 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.

8.1.5 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:

Phase Rotation:	ABC	Right Blinder Reach:	10 Ω
Nominal Secondary Voltage:	69.28 V	Right Blinder RCA:	88°
Distance Reach:	14 Ω	Left Blinder Reach:	5 Ω
Distance RCA:	88°	Left Blinder RCA:	88°
Directional RCA:	88°	Z0/Z1 Magnitude:	4.55
Overcurrent supervision:	3 A	Z0/Z1 Angle:	–12°
Distance Comparator limit angle:	75°	Z0M/Z1 Magnitude:	0
Directional Comparator limit angle:	75°		

Assume the following signals are injected to the relay:

V_A = 64.71 V ∠0.0° (pre-fault)	I_A = 4.47 A ∠–107.8°
V_A = 25.43 V ∠–19.9°	I_B = 2.92 A ∠68.9°
V_B = 80.22 V ∠–133.5°	I_C = 2.93 A ∠–51.1°
V_C = 77.33 V ∠135.7°	

Based on the entered setting the relay calculates:

K0 = 3.58 ∠–15.2°	Z_D = 1 Ω ∠88°
K0M= 0	Z_R = 9.99 Ω ∠2°
Z = 14.00 Ω ∠88°	Z_L = 4.99 Ω ∠178°

For the assumed steady-state injection the relay calculates:

V_A_1	= 58.83 V ∠–2.1°	–V_0	= 29.18 V ∠8.4°
V_A_1M	= 64.71 V ∠0.0°	(V_A–V_B)_1	= 93.35 V ∠32.0°
I_0	= 1.37 A ∠–68.2°	(V_A–V_B)_1M	= 112.08 V ∠30.0°
I_A_2	= 1.37 A ∠–68.1°	I_A–I_B	= 7.39 A ∠–109.1°

a) MHO PHASE A GROUND ELEMENT (BEFORE MEMORY EXPIRES)

I_A × Z + I_0 × K0 × Z + I_A × K0M × Z – V_A = 103.33 V ∠–3.9°

V_A_1M = 64.71 V ∠0.0°

I_A_2 × Z_D = 1.37 V ∠19.8°

I_0 × Z = 19.11 V ∠19.8°

I_0 × Z_D = 1.37 V ∠19.8°

- Overcurrent supervision: | 3 × I_0 | = 4.09 A > 3 A
- Mho difference angle = | –3.9° – 0° | = 3.9° < 75°
- Reactance difference angle = | –3.9° – 19.8° | = 23.7° < 75°
- Zero-sequence directional difference angle = | 19.8° – 0.0° | = 19.8° < 75°
- Negative-sequence directional difference angle = | 19.8° – 0.0° | = 19.8° < 75°
- Fault-type comparator difference angle = | 19.8° – 19.8° | = 0.0° < 50°

All four comparators and the overcurrent supervision are satisfied.

The MHO phase A ground element will operate for this fault.

8

b) MHO PHASE A GROUND ELEMENT (AFTER MEMORY EXPIRES)

After the memory expires the relay checks the actual positive-sequence voltage and compares it with 10% of the nominal voltage:

$| V_{A}\_1 | = 58.83 \text{ V} > 0.1 \times 69.28 \text{ V}$

After the memory expires the relay will use the actual voltage for polarization.

$I_A \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_A = 103.33 \text{ V} \angle{-3.9°}$

$V_{A}\_1 = 58.83 \text{ V} \angle{-2.1°}$

$I_{A}\_2 \times Z_D = 1.37 \text{ V} \angle 19.8°$

$I\_0 \times Z = 19.11 \text{ V} \angle 19.8°$

$I\_0 \times Z_D = 1.37 \text{ V} \angle 19.8°$

- Overcurrent supervision: $| 3 \times I\_0 | = 4.09 \text{ A} > 3 \text{ A}$
- Mho difference angle = $| -3.9° - (-2.1°) | = 1.8° < 75°$
- Reactance difference angle = $| -3.9° - 19.8° | = 23.7° < 75°$
- Zero-sequence directional difference angle = $| 19.8° - (-2.1°) | = 21.9° < 75°$
- Negative-sequence directional difference angle = $| 19.8° - (-2.1°) | = 21.9° < 75°$
- Fault-type comparator difference angle = $| 19.8° - 19.8° | = 0.0° < 50°$

All four comparators and the overcurrent supervision are satisfied.

The Zone 1 MHO phase A ground element will operate for this fault.

- Zero-sequence directional difference angle for Zones 2 through 4 (phase A) = $| 19.8° - 8.4° | = 11.4° < 90°$.

Zones 2 through 4 phase A ground elements will pick-up, time-out and operate.

c) MHO AB PHASE ELEMENT

$(I_A - I_B) \times Z - (V_A - V_B) = 88.65 \text{ V} \angle{-78.7°}$

$(V_A - V_B)\_1M = 112.08 \text{ V} \angle 30.0°$

$(I_A - I_B) \times Z = 103.50 \text{ V} \angle{-21.2°}$

$(I_A - I_B) \times Z_D = 7.39 \text{ V} \angle{-21.2°}$

- Overcurrent supervision: $| (I_A - I_B) / \sqrt{3} | = 4.27 \text{ A} > 3 \text{ A}$
- Mho difference angle = $| -78.7° - 30.0° | = 108.7° > 75°$
- Reactance difference angle = $| -78.7° - (-21.2°) | = 57.5° < 75°$
- Directional difference angle = $| -21.2° - 30.0° | = 51.2° < 75°$

The mho comparator is not satisfied.

The MHO AB phase element will not operate for this fault.

Repeating the above analysis one concludes that out of the six distance elements only the ground element in phase A will operate for this fault.

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d) QUAD PHASE A TO GROUND ELEMENT (BEFORE MEMORY EXPIRES)

$I_A \times Z + I\_0 \times K0 \times Z + I_G \times K0M \times Z - V_A = 103.33\ V\ \angle -3.9°$

$V_{A}\_1M = 64.71\ V\ \angle 0.0°$

$I\_0 \times Z = 19.11\ V\ \angle 19.8°$

$I_{A}\_2 \times Z_D = 1.37\ V\ \angle 19.8°$

$I\_0 \times Z_D = 1.37\ V\ \angle 19.8°$

$I_A \times Z_R + I\_0 \times K0 \times Z_R + I_G \times K0M \times Z_R - V_A = 87.6\ V\ \angle -109.2°$

$I_A \times Z_R + I\_0 \times K0 \times Z_R = 91.5\ V\ \angle -93.0°$

$I_A \times Z_L + I\_0 \times K0 \times Z_L + I_G \times K0M \times Z_L - V_A = 57.0\ V\ \angle 108.7°$

$I_A \times Z_L + I\_0 \times K0 \times Z_L = 45.8\ V\ \angle 82.9°$

- Overcurrent supervision: $| 3 \times I\_0 | = 4.09\ A > 3\ A$
- Reactance difference angle = $| -3.9° - 19.8° | = 23.7° < 75°$
- Zero-sequence difference angle = $| -19.8° - 0.0° | = 19.8° < 75°$
- Negative-sequence directional difference angle = $| -19.8° - 0.0° | = 19.8° < 75°$
- Right blinder difference angle = $| -93.0° - (-109.2°) | = 16.2° < 90°$
- Left blinder difference angle = $| 82.9° - 108.7° | = 25.8° < 90°$
- Fault-type comparator difference angle = $| 19.8° - 19.8° | = 0.0° < 50°$

All six comparators and the overcurrent supervision are satisfied.

The QUAD phase A ground element will operate for this fault.

8

8.2.1 DESCRIPTION

Consider the negative-sequence directional overcurrent element. As illustrated below, the negative-sequence voltage could be low during internal fault conditions.

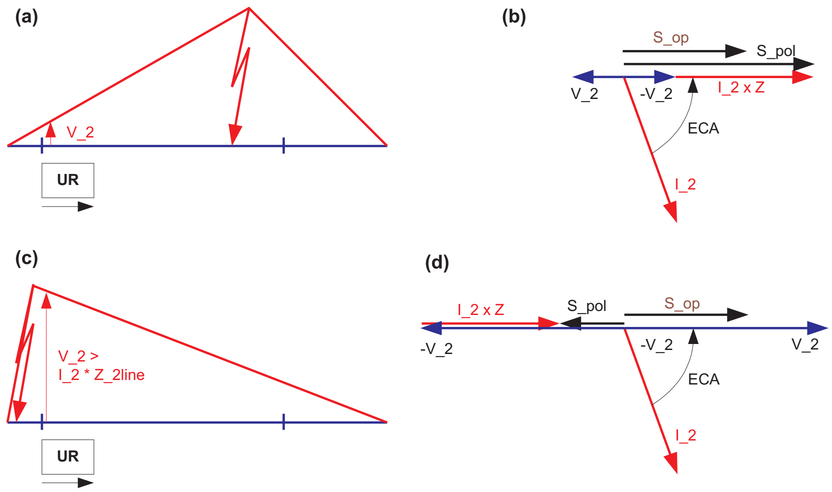

Figure 8–4: OFFSET IMPEDANCE AUGMENTATION

In order to ensure operation of the element under such circumstances the angle comparator uses a polarizing voltage augmented by the negative-sequence current as per following equations:

- Forward-looking element: $S\_pol = -V\_2 + I\_2 \times Z\_offset \times 1\angle ECA$
  $S\_op = I\_2 \times 1\angle ECA$
- Reverse-looking element: $S\_pol = -V\_2 + I\_2 \times Z\_offset \times 1\angle ECA$
  $S\_op = -I\_2 \times 1\angle ECA$

where: ECA = forward ECA angle (maximum torque angle); Z_offset = offset impedance

The effect of the augmentation for forward and reverse fault is shown in the figures above. As long as the offset impedance is not higher than the negative-sequence line impedance the element will ensure correct and fast fault direction identification for both forward and reverse faults. The same principle applies to the neutral directional overcurrent element.

8.2.2 EXAMPLE

Consider relay input signals as in the DISTANCE ELEMENTS ANALYSIS section and assume an offset impedance of 4 Ω and ECA and limit angles of 88° and 90°, respectively. The relay calculates the following negative-sequence quantities:

$V\_2 = 6.39\ V\ \angle{-159.6°}$; $I\_2 = 1.37\ A\ \angle{-68.1°}$; $I\_1 = 2.94\ A\ \angle{-144.2°}$

and the following signals for the directional unit of the negative-sequence directional overcurrent element:

- Forward-looking element: $S\_pol = 11.87\ V\angle 20.2°$
  $S\_op = 1.37\ V\angle 20.2°$
- Reverse-looking element: $S\_pol = 11.87\ V\angle 20.2°$
  $S\_op = 1.37\ V\angle{-160.0°}$

After comparing the angles, a solid forward indication is given.

Assume further the pickup setting of 0.25 A for both forward and reverse directions, and the "Negative-sequence" mode setting entered for the overcurrent unit of the element. The relay calculates the operating signal using the positive-sequence restraint:

$I\_op = |I\_2| - |I\_1| / 8 = 1.003\ A > 0.25\ A.$

The overcurrent unit will pickup and the element will operate in the forward direction.

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8.3.1 DESCRIPTION

Faults on or in a close vicinity of series compensated lines may create problems for distance protection:

- Voltage and/or current inversion may lead to false direction discrimination by directional elements. This may 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 may appear much closer to the relay as compared with the actual fault location. The apparent impedance may 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 the above steady-state overreach effect; sub-synchronous oscillations in both currents and voltages may cause significant transient overreach.

Distance protection elements of the D60 deal with the problem of voltage inversion by using 100% memory polarized directional comparators. As the memory duration is set longer that the slowest fault clearing time for reverse faults, it is guaranteed that the distance element would not pick-up on reverse faults should the voltage inversion happen.

At the same time, it is guaranteed that the distance elements would pick-up for all forward faults regardless of any voltage inversion as long as the memory voltage is used. Before the memory expires the relay would respond 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 D60 deal with the problem of current inversion by using a multi-input-comparator approach as described in the DISTANCE CHARACTERITICS subsection. Should the current inversion happen, 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 may take place for a short period of time. The condition cannot sustain for a long time as very high fault currents would occur causing large voltage drops across the series capacitors and prompting the overvoltage protection of the capacitors to operate quickly. This would effectively remove the series compensation and eliminate the current inversion. However, when the currents used by distance comparator (fault-loop current for ground and phase distance protection, and the negative- and zero-sequence currents for ground elements) stay shifted by more than 90 degrees from their natural fault position determined by the user as the element characteristic angle, the distance elements may 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 D60 relay.

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.

The problem of steady-state overreaching due to the negative reactance of the series capacitors may be addressed in the D60 in a traditional way by shortening the reach of an underreaching distance elements to the net inductive reactance of the line between the potential source and the far end busbar (-s). This generic approach has two major drawbacks. First, it leaves 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.

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Therefore, the D60 offers a unique option for dynamic reach control that is effectively based on the magnitude of the current flowing through the series capacitor bank (-s). The underreaching distance functions can be set as for plain uncompensated line, i.e. using the impedance of the line alone, and the relay would control an effective reach accordingly using the current magnitude as illustrated in the figure below.

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 may be as high as 100%. This means that fast distance protection is not achievable. The adaptive D60's mechanism would guarantee security on external faults. Overreaching ground fault directional overcurrent functions (such as negative-sequence, ground or neutral) shall be used for dependability.

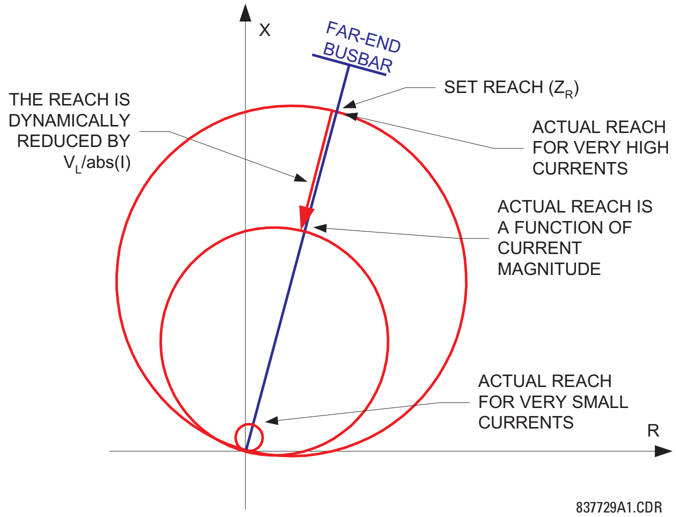

Figure 8–5: DYNAMIC REACH CONTROL

Section (a) of the figure below 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. Section (b) shows a high-current external fault. The air gaps or MOVs conduct majority of the fault current and neither steady-state nor transient overreach takes place. The relay does not reduce its reach as it is not necessary. Section (c) shows a high-current internal fault. Because of the large current, the reach is not reduced and the element responds to this internal fault. Traditional approach would leave this fault out of the relay reach.

The neutral and negative-sequence directional protection functions of the relay cope with the voltage and/or current inversions by adding appropriate offset to their polarizing signals as explained in the GROUND DIRECTIONAL OVERCURRENT subsection. The offset impedance can always be successfully selected to guarantee correct fault direction discrimination regardless of the degree of compensation and location of the series capacitors and the potential source.

Refer to the APPLICATION OF SETTINGS chapter for detailed recommendations on settings for series compensation applications.

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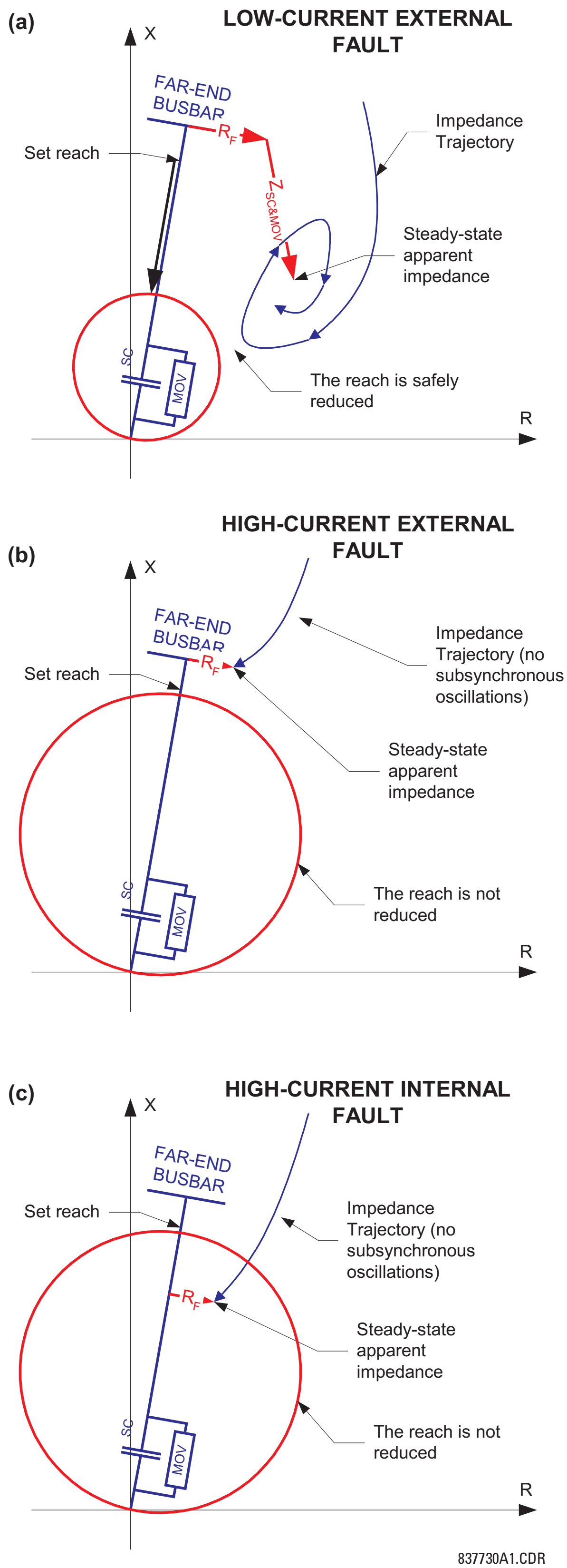

Figure 8–6: DYNAMIC REACH FOR EXTERNAL AND INTERNAL FAULTS

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8.4.1 OVERVIEW

See the SINGLE POLE OPERATION diagram in this section for an overview of trip and reclose operations.

Single pole operations make use of many features of the relay. At the 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 is also designed to make use of the advantages provided by communications channels with multiple-bit capacities for fault identification.

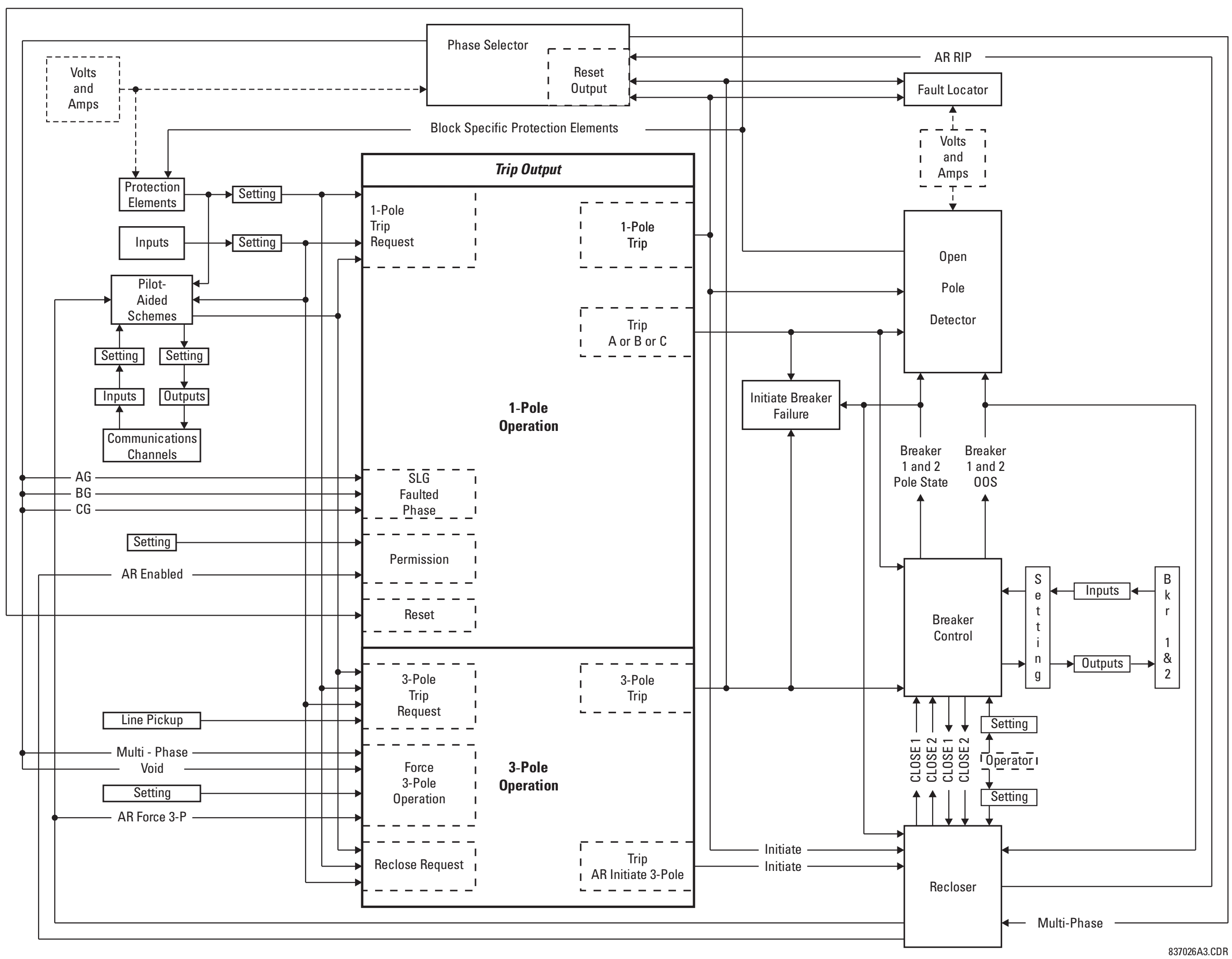

Figure 8–7: SINGLE-POLE OPERATION

The Trip Output element receives requests for single and three pole trips and three pole reclose initiation, which it then processes to generate outputs that are used to:

- determine whether a single or three pole operation should 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 or three pole reclosing
- notify the Phase Selector when a trip operation is imminent

When notified that a single pole operation has been initiated Open Pole Detector will:

- initiate blocking of protection elements that could potentially mis-operate when a breaker pole is open
- instruct the Phase Selector to de-assert all outputs, as an Open Pole invalidates calculations.

The operation of the scheme on a line in a single breaker arrangement will be described. The line is protected by a D60 relay using the Line Pickup, Z1 Phase and Ground Distance elements, and a Permissive Overreaching Transfer Trip scheme (using Z2 Phase and Ground distance elements as well as Negative-Sequence Directional Overcurrent elements, **GND DIR O/C FWD:** "NEG SEQ OC1 FWD", **GND DIR O/C REV:** "NEG SEQ OC1 REV"). Z1 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 will issue a single-pole trip. It is assumed that when tripping three-poles both the Z1 and the POTT shall initiate three-pole reclosing. This is achieved by setting **TRIP RECLOSE INPUT-1:** "POTT TRIP 3P", **TRIP RECLOSE INPUT-2:** "GND DIST Z1 OP", and **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 figure 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.

Because the line is de-energized the Line Pickup element is armed. The Recloser is presently 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 RECLOSER, the AR1 BLK TIME @ MAN 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 RECLOSER, TRIP OUTPUT, BREAKER FAILURE and OPEN POLE Detector. Because a fault is not detected the AR1 BLK TIME @ MAN CLOSE times out and the RECLOSER is enabled, which asserts the ENABLED output, informing TRIP OUTPUT that single pole trip operations are now 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 below.

a) SLG FAULT

An AG fault occurs close to the considered relay. Immediately after the fault, the Disturbance Detector (50DD) picks-up and activates the PHASE SELECTOR. The PHASE SELECTOR recognizes an AG fault by asserting its PHASE SELECT AG operand. Ground distance Z1 (AG element) responds to the fault. As the fault is close to the relay the phase distance Z1 (AB, CA elements) may respond to this fault as well. In any case, a single-pole operation is requested by Z1 via the GND DIST Z1 OP and/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 OPEN POLE OP FA (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 neutral and negative-sequence overcurrent elements (OPEN POLE BLK N), and distance elements (OPEN POLE BLK AB, OPEN POLE BLK CA). The two latter operands block phase distance AB and CA elements, respectively (all zones); the OPEN POLE FA OP blocks the ground distance AG elements (all zones). As a result, the Z1 OP and Z2 PKP operands that were picked-up reset immediately. The following distance elements remain operational guarding the line against evolving faults: BG, CG and BC.

As Z2 and/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 the RX1, the POTT decides to trip. The scheme will check the PHASE SELECTOR for phase type identification and will issue 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 Z1.

Depending on response times, the actual trip is initiated either by the Z1 or by the POTT. At the moment TRIP 1-POLE operand is asserted, the PHASE SELECTOR resets and no other trip action could 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 AR is started and asserts its 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 could respond to a single-line-to-ground fault during OPEN POLE conditions.

8 msec after the AR is initiated, the AR FORCE 3-P TRIP operand is asserted. 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 BREAKER CONTROL to close the breaker. BREAKER CONTROL operates output relays to close the breaker.

When pole A of the breaker closes this new status is reported to BREAKER CONTROL, which transfers this data to BREAKER FAILURE, RECLOSER, OPEN POLE detector and TRIP OUTPUT. The response at BREAKER FAILURE is dependent on the programming of that element. The response at RECLOSER is not relevant to this discussion. At OPEN POLE Detector the blocking signals to protection elements are de-asserted.

If the fault was transient the reset time would expire at RECLOSER and the AR FORCE 3-P TRIP and RIP outputs would be de-asserted, returning all features to the state described at the beginning of this description.

If the fault was permanent appropriate protection elements would detect it and place a trip request for the TRIP OUTPUT. 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 above for the second trip, except the RECLOSER will go to lockout upon the next initiation (depending on the number of shots programmed).

b) SLG FAULT EVOLVING INTO LLG

When an AG fault occurs the events unfold initially as in the previous example. If the fault evolves quickly, the PHASE SELECTOR will change its initial assessment from AG to ABG fault and when the trip request is placed either by the Z1 or the POTT, a trip-pole trip will be initiated. If this is the case, all three TRIP PHASE A, B and C operands will be 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 Z1 and Z2 AG, AB, CA and negative-sequence overcurrent elements to reset. If the Z1 BG element picks up, or Z2 BG element picks up resulting in operation of the POTT scheme, no trip command will be issued until the AR FORCE 3-P TRIP is asserted. This happens 8 msec 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 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 will pickup the fault and issue 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 the RECLOSER will go to lockout upon the next initiation (depending on the number of shots programmed).

8.4.2 PHASE SELECTION

The D60 uses phase relations between current symmetrical components for phase selection. First, the algorithm validates if there is enough zero-, positive-, and negative-sequence currents 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 and positive-sequence currents and negative and zero-sequence currents (when applicable) as illustrated below.

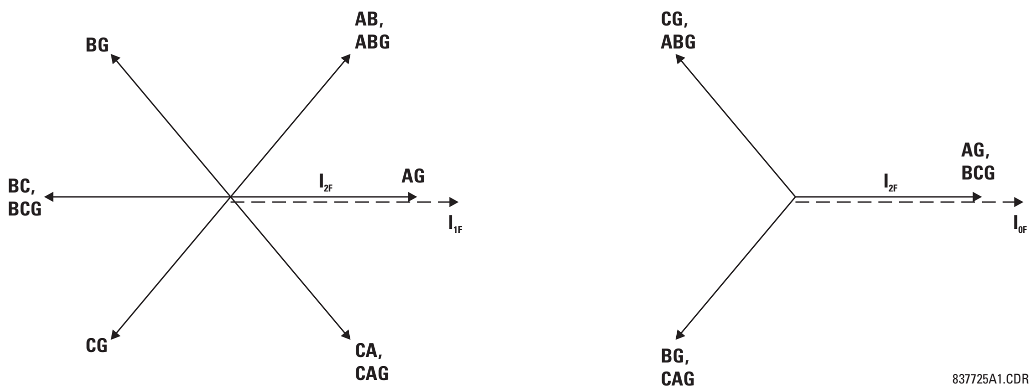

Figure 8–8: PHASE SELECTION PRINCIPLE (ABC PHASE ROTATION)

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 operates.

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 may not 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, e.g. phase angles between the zero-, negative-, 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 (50DD) operates.

When the trip command is issued by the TRIP OUTPUT logic (TRIP 1-POLE or TRIP 3-POLE) and during autoreclosure cycle (AR RIP), the phase selector resets all its output operands and ignores any subsequent operations of the DISTURBANCE DETECTOR.

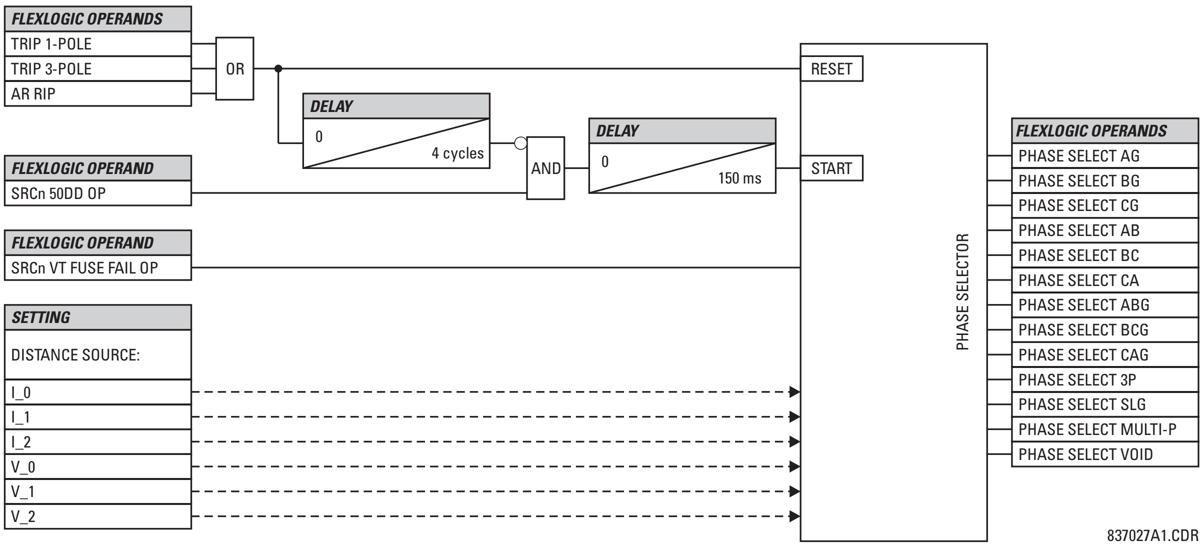

Figure 8–9: PHASE SELECTOR LOGIC

8.4.3 COMMUNICATIONS CHANNELS FOR PILOT-AIDED SCHEMES

In the D60 relay 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 is 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 (RX1, RX2, RX3, RX4) and output (TX1, TX2, TX3, TX4 for communications and [SCHEME ABBREVIATION] TRIP A, TRIP B, TRIP C, TRIP 3P for action) operands 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.

a) SINGLE-BIT CHANNELS

The TX1 and RX1 operands are used, and fault data is coded per the following tables.

Table 8–5: PERMISSIVE SCHEME TRANSIT CODES FOR 1-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED
	TX1
AG, BC, BCG, BG, CA, CAG, CG, AB, ABG, 3P	1
Unrecognized or AR FORCE 3P TRIP	1
None of the above	0

Table 8–6: BLOCKING SCHEME TRANSIT CODES FOR 1-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED
	TX1
AG, BC, BCG, BG, CA, CAG, CG, AB, ABG, 3P	0
Unrecognized or AR FORCE 3P TRIP	0
None of the above	1

8

The action output is generated per the following tables.

Table 8–7: PERMISSIVE SCHEME TRIP TABLE FOR 1-BIT CHANNELS

REMOTE DATA		LOCAL DATA	
BIT PATTERN RECEIVED	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	MULTI-P, Unrecognized, or AR FORCE 3P TRIP	Trip Three Phases

Table 8–8: BLOCKING SCHEME TRIP TABLE FOR 1-BIT CHANNELS

REMOTE DATA		LOCAL DATA	
BIT PATTERN RECEIVED	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	MULTI-P, Unrecognized, or AR FORCE 3P TRIP	Trip Three Phases

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.

b) TWO-BIT CHANNELS

The TX1, TX2, RX1 and RX2 operands are used and fault data is coded per the following tables.

Table 8–9: PERMISSIVE SCHEME TRANSMIT CODES FOR TWO-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED	
	TX1	TX2
AG, BC, BCG	1	0
BG, CA, CAG	0	1
CG, AB, ABG, 3P	1	1
Unrecognized or AR FORCE 3P TRIP	1	1
None of the above	0	0

Table 8–10: BLOCKING SCHEME TRANSMIT CODES FOR TWO-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED		FLEXLOGIC™ OPERANDS ASSERTED	
	TX1	TX2	TX1 STOP	TX2 STOP
AG, BC, BCG	0	1	1	0
BG, CA, CAG	1	0	0	1
CG, AB, ABG, 3P	0	0	1	1
Unrecognized or AR FORCE 3P TRIP	0	0	1	1
None of the above	1	1	0	0

The action output is generated per the following tables.

Table 8–11: PERMISSIVE SCHEME TRIP TABLE FOR TWO-BIT CHANNELS

REMOTE DATA			LOCAL DATA	
BIT PATTERN RECEIVED		REMOTE DETERMINATION OF FAULT TYPE	LOCAL DETERMINATION OF FAULT TYPE	TRIP OUTPUT
RX1	RX2			
1	0	AG, BC, BCG	AG, AB, ABG CA, CAG, 3P	Trip Phase A
0	1	BG, CA, CAG	AG	
1	1	CG, AB, ABG, 3P	AG	
0	1	BG, CA, CAG	BG, AB, ABG, BC, BCG, 3P	Trip Phase B
1	1	CG, AB, ABG, 3P	BG	
1	0	AG, BC, BCG	BG	
1	1	CG, AB, ABG, 3P	CG, BC, BCG, CA, CAG	Trip Phase C
1	0	AG, BC, BCG	CG	
0	1	BG, CA, CAG	CG	
1	1	CG, AB, ABG, 3P	AB, ABG, 3P	Trip Three Phases
1	0	AG, BC, BCG	BC, BCG	
0	1	BG, CA, CAG	CA, CAG	

Table 8–12: BLOCKING SCHEME TRIP TABLE FOR TWO-BIT CHANNELS

REMOTE DATA			LOCAL DATA	
BIT PATTERN RECEIVED		REMOTE DETERMINATION OF FAULT TYPE	LOCAL DETERMINATION OF FAULT TYPE	TRIP OUTPUT
RX1	RX2			
0	1	AG, BC, BCG	AG, AB, ABG CA, CAG, 3P	Trip Phase A
1	0	BG, CA, CAG	AG	
0	0	CG, AB, ABG, 3P	AG	
1	0	BG, CA, CAG	BG, AB, ABG, BC, BCG, 3P	Trip Phase B
0	0	CG, AB, ABG, 3P	BG	
0	1	AG, BC, BCG	BG	
0	0	CG, AB, ABG, 3P	CG, BC, BCG, CA, CAG	Trip Phase C
0	1	AG, BC, BCG	CG	
1	0	BG, CA, CAG	CG	
0	0	CG, AB, ABG, 3P	AB, ABG, 3P, Unrecognized, or AR FORCE 3P TRIP	Trip Three Phases
0	1	AG, BC, BCG	BC, BCG Unrecognized, or AR FORCE 3P TRIP	
1	0	BG, CA, CAG	CA, CAG Unrecognized, or AR FORCE 3P TRIP	

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c) FOUR-BIT CHANNELS

The TX1, TX2, TX3, TX4, RX1, RX2, RX3 and RX4 operands are used.

Table 8–13: PERMISSIVE SCHEME TRANSMIT CODES FOR 4-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED			
	TX1	TX2	TX3	TX4
AG	1	0	0	0
BG	0	1	0	0
CG	0	0	1	0
MULTI-P	0	0	0	1
Unrecognized or AR FORCE 3P TRIP	0	0	0	1
None of the above	0	0	0	0

Table 8–14: BLOCKING SCHEME TRANSMIT CODES FOR 4-BIT CHANNELS

PHASE SELECTOR DETERMINATION OF FAULT TYPE	BIT PATTERN TRANSMITTED				FLEXLOGIC™ OPRERANDS 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
MULTI-P, Unrecognized, or AR FORCE 3P TRIP	1	1	1	0	0	0	0	1
None of the above	1	1	1	1	0	0	0	0

The action output is generated per the following tables.

Table 8–15: PERMISSIVE SCHEME TRIP TABLE FOR 4-BIT CHANNELS

REMOTE DATA					LOCAL DATA	
BIT PATTERN RECEIVED				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
1	0	0	0	AG	AG, AB, ABG, CA, CAG, 3P	
0	1	0	0	BG	BG, AB, ABG, BC, BCG, 3P	Trip Phase B
0	0	0	1	MULTI-P	BG	
0	0	1	0	CG	CG, BC, BCG, CA, CAG, 3P	Trip Phase C
0	0	0	1	MULTI-P	CG	
1	0	0	0	AG	BG, CG, BC, BCG	Trip Three Phases
0	1	0	0	BG	AG, CG, CA, CAG	
0	0	1	0	CG	AG, BG, AB, ABG	
0	0	0	1	MULTI-P	MULTI-P	
Any valid combination				Any	Unrecognized or AR FORCE 3P TRIP	
Any other combination						None

Table 8–16: BLOCKING SCHEME TRIP TABLE FOR FOUR-BIT CHANNELS

REMOTE DATA					LOCAL DATA	
BIT PATTERN RECEIVED				REMOTE DETERMINATION OF FAULT TYPE	LOCAL DETERMINATION OF FAULT TYPE	TRIP OUTPUT
RX1	RX2	RX3	RX4			
1	1	1	0	MULTI-P	AG	Trip Phase A
0	1	1	1	AG	AG, AB, ABG, CA, CAG, 3P	
1	1	1	0	MULTI-P	BG	Trip Phase B
1	0	1	1	BG	BG, AB, ABG, BC, BCG, 3P	
1	1	1	0	MULTI-P	CG	Trip Phase C
1	1	0	1	CG	CG, BC, BCG, CA, CAG, 3P	
0	1	1	1	AG	BG, CG, BC, BCG	Trip Three Phases
1	0	1	1	BG	AG, CG, CA, CAG	
1	1	0	1	CG	AG, BG, AB, ABG	
1	1	1	0	MULTI-P	MULTI-P	
0	0	0	0	Any – blockng channel was not initiated	Trip as in a single-bit scheme	
Any valid combination				Any	Unrecognized or AR FORCE 3P TRIP	
Any other combination						None

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8.4.4 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.

Permissive Over-Reaching Transfer Trip Scheme:

When used this feature will "echo" 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 settable period. The duration of the echo pulse does not depend on the duration or shape of the received RX signals but is settable.

The echo is sent back only if none of the overreaching protection elements operates.

Hybrid Permissive Over-Reaching Transfer Trip Permissive Echo:

When used this feature will "echo" 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 settable period. The duration of the echo pulse does not depend on the duration or shape of the received RX signal but is settable as ECHO DURATION.

The echo is sent back only if none of the overreaching protection elements operates.

Permissive Echo Operands And Transmit Codes:

In single-pole tripping, single-bit channel applications the signal received on bit no. 1 (RX1) is echoed back on bit no. 1 (TX1). In two- and four-bit applications the following Echo Tables apply.

Table 8–17: ECHO TABLE FOR 2-BIT CHANNELS

LOCAL DETERMINATION OF FAULT TYPE	ECHOED BITS	
	TX1	TX2
AG	1	0
BG	0	1
CG	1	1
MULTI-P, Unrecognized, or AR FORCE 3P TRIP	Repeat as received	

Table 8–18: ECHO TABLE FOR 4-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
MULTI-P, Unrecognized, or AR FORCE 3P TRIP	Repeat as received			

8.4.5 COORDINATION BETWEEN PILOT SCHEMES AND PHASE SELECTOR

For local fault type identification the pilot schemes use the Phase Selector. The latter may fail to respond to certain fault scenarios. Examples are: simultaneous forward and reverse fault, simultaneous SLG and LL fault involving different phases (e.g. AG and BC) or two simultaneous faults in the same direction but at very different locations. The Phase Selector is optimized to either 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 - it is two different simultaneous faults and as such cannot be described by any single fault pattern, therefore, the Phase Selector would assert the VOID flag.

The VOID phase selection combined with a local trip request (such as high-set directional overcurrent) will result in three-pole trip as per TRIP OUTPUT logic.

The Pilot Schemes, however, try to recover more 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 Z1; all the other schemes use Z2. The schemes analyze all six fault loops of the zone to determine the fault type.

For example, simultaneous forward AG and reverse BG faults may result in the VOID indication. The POTT scheme would analyze the Z2 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 will be further improved as illustrated in the next subsection.

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 will force 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 more than one-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.

8.4.6 CROSS COUNTRY FAULT EXAMPLE

Assume a single pole operation application where D60 relays 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 over-reaching transfer trip scheme. The performance of the system with one- two and four-bit communications channels is outlined for a mid-line phase A-to-ground fault and a co-incident phase B-to-ground fault just behind terminal T2. Assume also that the reclosers are enabled and reset.

At T1 the following protection elements will pickup:

- 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

At T1 the phase selector will determine the fault is type ABG. This response is independent from the distance elements – the Phase Selector sees two forward faults.

At T2 the following protection elements will pickup:

- Ground Distance Zone 1, 2, and 3 for an AG fault

At T2 the phase selector will determine the fault is type AG. The reverse BG fault is likely to be ignored.

If a one-bit channel is used, terminal T1 will trip three poles but terminal T2 will trip phase A only, (see the Tables below) which is undesirable.

TERMINAL	REMOTE DATA		LOCAL DATA	
	BIT PATTERN RECEIVED	REMOTE DETERMINATION OF FAULT TYPE	LOCAL DETERMINATION OF FAULT TYPE	TRIP OUTPUT
	RX1			
T1	1	Any	MULTI-P (ABG)	Trip Three Phases
T2	1	Any	AG	Trip Phase A

If a two-bit channel is used both terminals will trip phase A only, (see the Tables below) which is the desired outcome.

TERMINAL	REMOTE DATA			LOCAL DATA	
	BIT PATTERN RECEIVED		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 terminals will trip phase A only, (see the Tables below) which is the desired outcome.

TERMINAL	REMOTE DATA					LOCAL DATA	
	BIT PATTERN RECEIVED				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

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9.1.1 INTRODUCTION

This chapter provides general application guidelines for stepped distance, overcurrent and pilot protection. Where relevant, design details and performance characteristics of the D60 are given to facilitate the process of setting the relay for a given application.

9.1.2 IMPACT OF THE USE OF MEMORY POLARIZATION

As explained in THEORY OF OPERATION chapter, the D60 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 the zone 4 so that a time delayed backup function may be obtained. As mentioned earlier, it may 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.

9.1.3 HIGH SET OVERCURRENT ELEMENTS

Especially at low SIR values, fast fault clearance times may be seen as extremely important, both from system stability, and from equipment damage viewpoints. The high-set overcurrent element, when set appropriately, can be extremely useful in achieving these goals. It helps the setting calculations if the system impedances are reasonably well known.

The overcurrent pick up should be set to the greater of the following values:

1. The maximum infeed seen by the relay, for a close in reverse fault.
2. The maximum fault level seen by the relay for a fault at 100% of the protected line.

The maximum error of the phase overcurrent elements is below 2%. A safety factor of 1.25 should be used 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, it should be noted that the IOC elements require 1.33 cycle 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 power cycle is required by the phase IOC to operate. The above information should not be confused with the operating time, which includes some inherent delays such as a trip rated output contact.

9.2.1 PHASE DISTANCE

a) PHASE CURRENT SUPERVISION AND USAGE OF THE FUSE FAILURE ELEMENT

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 will not be picked up due to noise or induced voltages, on the line.

However, this supervision feature may 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 may be avoided by the use of a separate fuse fail function, which means that the phase current supervision can be set much lower, typically 2 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 would not prevent maloperation in such circumstances.

It must be kept in mind that the Fuse Failure element provided on the D60 needs some time to detect fuse fail conditions. This may create a race between the instantaneous Zone 1 and the Fuse Failure element. Therefore, for maximum security, it is recommended to both set the current supervision above the maximum load current and use the Fuse Failure function. The current supervision prevents maloperation 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 a secondary importance for time-delayed Zones 2 through 4 as the Fuse Failure element has some extra time for guaranteed operation. The current supervision may be set below the maximum load current for the time delayed zones.

Blocking distance elements during fuse fail conditions may not be acceptable in some applications and/or under some protection philosophies. Applied solutions may vary from not using the Fuse Failure element for blocking at all; through using it and modifying – through FlexLogic™ and multiple setting groups mechanisms – other protection functions or other relays to provide some protection after detecting fuse fail conditions and blocking the distance elements; to using it and accepting the fact that the distance protection will not respond to subsequent internal faults until the problem is addressed.

NOTE

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 square root of 3 factor.

b) PHASE DISTANCE ZONE 1

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. The 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 may minimize this latter concern. The total relay inaccuracy including both steady state and transient overreach even when supplied from CVTs under the Source Impedance Ratios of up to 30, is below 5%.

c) PHASE DISTANCE ZONE 2

The 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. Typically the reach is set 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.

Typically the Zone 2 time delay would be 0.2 to 0.6 sec., although this may have to be reviewed more carefully if a short line terminates on the remote bus because the two Zone 2 elements may overlap and therefore not coordinate satisfactorily.

d) PHASE DISTANCE ZONE 3

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 which 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 may be overcome by using lens or quadrilateral characteristics and/or a load encroachment supervising characteristic. Consideration should also be given to a situation where the load impedance may enter into the relay characteristic for a time longer than the chosen time delay, which could occur transiently during a system power swing. For this reason the Power Swing Blocking function should be used.

e) PHASE DISTANCE ZONE 4

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 protections on the next line. The use of a lens characteristic or the load encroachment element may be advantageous if load limits are a problem.

To avoid extremely large reach settings, the D60 has the ability to implement any element so that it is reverse looking, which then can provide a back up for the longest line terminated on the local bus. This strategy can be beneficial if the reduced reach helps discrimination between the load and fault conditions, but must be implemented at both ends of the protected line.

9.2.2 GROUND DISTANCE

a) NEUTRAL CURRENT SUPERVISION

The current supervision for the ground distance elements responds to an internally calculated neutral current (3 x I_0). The setting for this element should be based on twice the zero-sequence line capacitance current or the maximum zero-sequence unbalance under maximum load conditions. This element should not be used to prevent an output when the load impedance is inside the distance characteristic on a steady state basis.

b) GROUND DISTANCE ZONE 1

The Zone 1 reach must be set so that nominally instantaneous operation does not extend beyond the end of the protected line. However this may 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 out of service and grounded at multiple points. A fault beyond 100% of the protected line may 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 may 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 may vary significantly due to weather and other conditions.

c) GROUND DISTANCE ZONE 2

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 may occur on double circuit lines, when both lines may carry the same current. An analytical study should be carried out 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.

d) GROUND DISTANCE ZONE 3

This remote back up function must have a reach which is set to account for any infeed at the remote bus, plus the impedance of the longest line which 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.

e) GROUND DISTANCE ZONE 4

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 may be advantageous if load limits are a problem. To avoid extremely large reach settings the D60 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. It should be recognized however that, if adopted, this approach must be implemented at both ends of the protected line.

9.3.1 DESCRIPTION

The D60 includes five common pilot-aided schemes:

- direct under-reaching transfer trip (DUTT)
- permissive under-reaching transfer trip (PUTT)
- permissive over-reaching transfer trip (POTT)
- hybrid permissive over-reaching transfer trip (HYB-POTT)
- directional comparison blocking

9.3.2 DIRECT UNDER-REACHING TRANSFER TRIP (DUTT)

This scheme uses an under-reaching Zone 1 distance element to key a transfer trip signal to the remote end(s), 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, configured and set per rules of distance relaying.

The 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/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface.

Note that the same protection signaling may be used by a breaker failure scheme, in which case the signal can be sealed in by breaker fail for a time longer than the auto-reclose “reclaim” time which then prevents auto-reclose when not required.

A provision for an optional seal-in of the send signal is made to cover those situations where PLC (Power Line Carrier) 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 relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.3.3 PERMISSIVE UNDER-REACHING TRANSFER TRIP (PUTT)

This scheme uses an under-reaching Zone 1 distance element to key a transfer trip signal to the remote end where it is supervised by the over-reaching Zone 2 distance elements.

For proper operation of the scheme the Zone 1 and 2 phase and ground distance elements must be enabled, configured and set per 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/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface.

The PUTT RX PICKUP DELAY timer can be used to ride through spurious PLC receive signals.

The scheme output operand (PUTT OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.3.4 PERMISSIVE OVERREACHING TRANSFER TRIP (POTT)

This scheme is intended for two-terminal line applications only.

This scheme uses an over-reaching Zone 2 distance element to essentially compare the direction to a fault at both the ends 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.

Good directional integrity is the key requirement for an over-reaching forward-looking protection element used to supplement Zone 2. Even though any FlexLogic™ operand could be used for this purpose allowing 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 IOC or Neutral Directional IOC. Both of these elements have separate forward (FWD) and reverse (REV) output operands. The forward indication should be used (NEG SEQ DIR OC1 FWD or NEUTRAL DIR OC1 FWD).

An important consideration is when one of the line terminals is open. It is then necessary to identify this 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, which is producing the fault infeed. With any echo scheme however, a means must be provided to avoid a permanent lock up of the transmit/receive loop. The echo co-ordination (ECHO DURATION) and lock-out (ECHO LOCKOUT) timers 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 settable period of time.

It should be recognized that in ring bus or breaker and a half situations, it may be the line disconnect or a combination of the disconnect and/or the breaker(s) status that is the indication that the terminal is open.

The POTT RX PICKUP DELAY timer is included in the permissive receive path to ride through spurious receive outputs that may 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. A situation can occur however, where the ground distance element will have an extended reach. This situation is encountered when it is desired to account for the zero sequence inter-circuit mutual coupling. This is not a problem for the ground distance elements in the D60 which do have a 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 their reach well defined, therefore 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 a settable time TRANS BLOCK PICKUP DELAY for the local forward looking directional element to pick up.

The 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/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should 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 since the PLC signal can be interrupted by a fault.

For proper operation of the scheme the Zone 2 phase and ground distance elements must be enabled, configured and set per rules of distance relaying. The LINE PICKUP element should be enabled, configured and set properly to detect line-end-open/weak-infeed conditions.

If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set accordingly The output operand from the scheme (POTT OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.3.5 HYBRID POTT SCHEME (HYB-POTT)

Generally, this scheme uses an over-reaching 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 relay 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 three-terminal applications and for weak-infeed conditions. As a long reach of the overreaching distance element may be required for three-terminal applications, transient blocking logic is provided for both distance and ground directional overcurrent elements. In order to cope with weak-infeed conditions an echo feature is made available.

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 4 phase and ground distance elements must be enabled, configured and set per rules of distance relaying. The LINE PICKUP element should be enabled, configured and set properly to detect line-end-open/weak-infeed and undervoltage conditions.

If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set accordingly.

The 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/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface.

For more application recommendation refer to the POTT scheme.

The output operand from the scheme (HYBRID POTT OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.3.6 DIRECTIONAL COMPARISON BLOCKING SCHEME

Generally, the scheme 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 this scheme uses only a forward-looking over-reaching 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.

By default the scheme uses only a reverse-looking Zone 4 distance element to identify reverse faults. Ground directional overcurrent functions available in the relay can be used in conjunction with the Zone 4 distance element for better time and sensitivity coordination.

For proper operation of the scheme the Zone 2 and 4 phase and ground distance elements must be enabled, configured and set per rules of distance relaying.

If used by this scheme, the selected ground directional overcurrent function(s) must be enabled, configured and set accordingly.

The scheme generates output operands (BLOCKING SCHEME TX INIT and BLOCKING SCHEME TX STOP) that are used control the transmission of signals to the remote end. Choices of communications channel include Remote Inputs/Outputs and telecommunications interfaces. When used with telecommunications facilities the output operand should be assigned to operate an output contact connected to key the transmitter at the interface.

A blocking scheme may 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. A blocking scheme on the other hand, 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 BLOCK RX CO-ORD PKP DELAY, 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 timer TRANS BLOCK, which continues to send a blocking signal for a settable time TRANS BLOCK RESET DELAY, if it was being sent for at least 30 ms during the initial reverse fault set via TRANS BLOCK PICKUP DELAY.

The output operand from the scheme (BLOCKING SCHEME OP) must be configured to interface with other relay functions, output contacts in particular, in order to make the scheme fully operational. Typically, the output operand should be programmed to initiate a trip, breaker fail, and auto-reclose, and drive a user-programmable LED as per user application.

9.4.1 INTRODUCTION

For reasons described in the THEORY OF OPERATION chapter 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 below must take into account variety of system configurations, particularly a status of series capacitors (in-service, by-passed). Either the worst-case topology shall be considered or - if possible - adaptive settings shall be applied though the MULTIPLE SETTING GROUPS mechanism.

A line compensating capacitor is a bank of three physical capacitors and their overvoltage protecting devices (air gaps and/ or MOVs). If none of the MOV/gaps conducts any significant current, the positive-, negative- and zero-sequence reactance of the three-phase bank equal the reactance of the actual (phase) capacitors. Under asymmetrical conditions, however, such as a single line to ground fault, when only one MOV/gap may operate, the series capacitor bank would create extra (series) asymmetry in addition to the fault (shunt) asymmetry. The positive-, negative- and zero-sequence impedances will differ from each other and will not equal the impedance of the phase capacitors. Moreover, there may 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 the zero-, positive- 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.

9.4.2 DISTANCE

Traditionally, the reach setting of an underreaching distance function shall be set 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 below is considered.

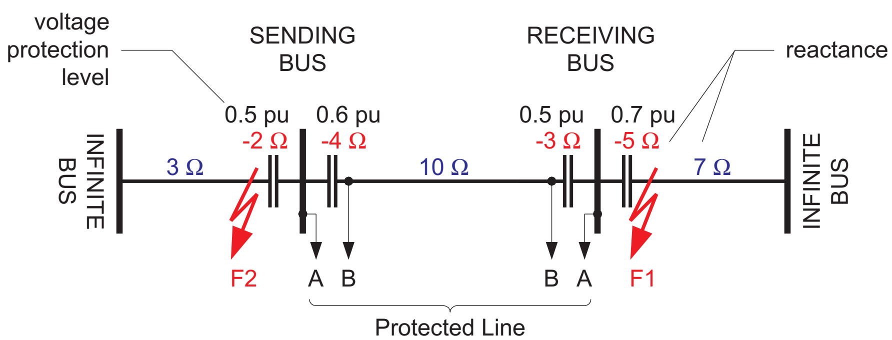

Figure 9–1: SAMPLE SERIES COMPENSATED SYSTEM

Assuming 20% security margin, the underreaching zone shall be set as follows.

At the SENDING BUS one must consider an external fault at F1 as the 5 Ω capacitor would contribute to the overreaching effect. Any fault behind F1 is less severe as extra inductive line impedance increases the apparent impedance:

Reach Setting: 0.8 x (10 – 3 – 5) = 1.6 Ω if the line-side (B) VTs are used
Reach Setting: 0.8 x (10 – 4 – 3 – 5) = –1.6 Ω 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 pick-up, is overcompensated, i.e. capacitive.

At the RECEIVING BUS, one must consider a fault at F2:

Reach Setting: 0.8 x (10 – 4 – 2) = 3.2 Ω if the line-side (B) VTs are used
Reach Setting: 0.8 x (10 – 4 – 3 – 2) = 0.8 Ω if the bus-side (A) VTs are used

Practically, however, to cope with the effect of sub-synchronous oscillations, one may need to reduce the reach even more. As the characteristics of sub-synchronous oscillations are in complex relations with fault and system parameters, no solid 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 D60 feature for dynamic reach control.

If the adaptive reach control feature is used, the PHS DIST Z1 VOLT LEVEL setting shall be set accordingly.

This setting is a sum of the overvoltage protection levels for all the series capacitors located between the relay potential source and the far-end busbar, or location for which the zone must not overreach. The setting is entered in pu of the phase VT nominal voltage (RMS, not peak value).

If a minimum fault current level (phase current) is causing a voltage drop across a given capacitor that prompts its air gap to flash over or its MOV to carry practically all the current, then the series capacitor shall be excluded from the calculations (the capacitor is immediately by-passed by its overvoltage protection system and does not cause any overreach problems).

If a minimum fault current does not guarantee an immediate capacitor by-pass, then the capacitor must be included in the calculation: its overvoltage protection level, either air gap flash-over voltage or MOV knee-point voltage, shall be used (RMS, not peak value).

Assuming none of the series capacitors in the sample system is guaranteed to get by-passed, the following calculations apply:

For the SENDING BUS: 0.5 + 0.7 = 1.2 pu if the line-side (B) VTs are used
0.6 + 0.5 + 0.7 = 1.8 pu if the bus-side (A) VTs are used

For the RECEIVING BUS: 0.6 + 0.5 = 1.1 pu if the line-side (B) VTs are used
0.6 + 0.5 + 0.5 = 1.6 pu if the bus-side (A) VTs are used

9.4.3 GROUND DIRECTIONAL OVERCURRENT

Ground directional overcurrent function (negative-sequence or neutral) uses an offset impedance to guarantee correct fault direction discrimination. The following setting rules apply.

1. 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.
2. 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 may 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.

SENDING BUS relay, bus-side VTs:

- Net inductive reactance from the relay into the local system = –2 + 3 = 1 Ω > 0; there is no need for offset.
- Net inductive reactance from relay through far-end busbar = –4 + 10 – 3 = 3 Ω; the offset cannot be higher than 3 Ω.
- It is recommended to use 1.5 Ω offset impedance.

SENDING BUS relay, line-side VTs:

- Net inductive reactance from relay into local system = –2 + 3 – 4 = –3 Ω < 0; an offset impedance ≥3 Ω must be used.
- Net inductive reactance from relay through far-end busbar = 10 – 3 = 7 Ω; the offset cannot be higher than 7 Ω.
- It is recommended to use 5 Ω offset impedance.

RECEIVING BUS relay, bus-side VTs:

- Net inductive reactance from relay into local system = –5 + 7 = 2 Ω > 0; there is no need for offset.
- Net inductive reactance from relay through far-end busbar = –3 + 10 – 4 = 3 Ω; the offset cannot be higher than 3 Ω.
- It is recommended to use 1.5 Ω offset impedance.

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RECEIVING BUS relay, line-side VTs:

- Net inductive reactance from relay into local system = –3 – 5 + 7 = –1 Ω < 0; an offset impedance ≥1 Ω must be used.
- Net inductive reactance from relay through far-end busbar = 10 – 4 = 6 Ω; the offset cannot be higher than 6 Ω.
- It is recommended to use 3.5 Ω offset impedance.

9.4.4 HIGH-SET PHASE OVERCURRENT

The setting rules for high-set overcurrent protection are explained in the HIGH-SET OVERCURRENT ELEMENTS section.

The following tables are provided to keep a record of settings to be used on a relay.

10.1.1 PRODUCT SETUP

Table 10–1: PRODUCT SETUP (Sheet 1 of 14)

SETTING	VALUE
PASSWORD SECURITY	
Access Level	
Command Password	
Setting Password	
Encrypted Command Password	
Encrypted Setting Password	
DISPLAY PROPERTIES	
Flash Message Time	
Default Message Timeout	
Default Message Intensity	
REAL TIME CLOCK	
IRIG-B Signal Type	
COMMUNICATIONS > SERIAL PORTS	
RS485 COM1 Baud Rate	
RS485 COM1 Parity	
RS485 COM2 Baud Rate	
RS485 COM2 Parity	
COMMUNICATIONS > NETWORK	
IP Address	
Subnet IP Mask	
Gateway IP Address	
OSI Network Address (NSAP)	
Ethernet Operation Mode	
Ethernet Primary Link Monitor	
Ethernet Secondary Link Monitor	
COMMUNICATIONS > MODBUS PROTOCOL	
Modbus Slave Address	
Modbus TCP Port Number	
COMMUNICATIONS > DNP PROTOCOL	
DNP Port	
DNP Address	
DNP Network Client Address 1	
DNP Network Client Address 2	
DNP TCP/UDP Port Number	
DNP Unsol Response Function	
DNP Unsol Response Timeout	
DNP Unsol Response Max Retries	
Unsol Response Dest Address	
User Map for DNP Analogs	
Number of Sources in Analog List	

Table 10–1: PRODUCT SETUP (Sheet 2 of 14)

SETTING	VALUE
DNP Current Scale Factor	
DNP Voltage Scale Factor	
DNP Power Scale Factor	
DNP Energy Scale Factor	
DNP Other Scale Factor	
DNP Current Default Deadband	
DNP Voltage Default Deadband	
DNP Power Default Deadband	
DNP Energy Default Deadband	
DNP Other Default Deadband	
DNP Time Sync In IIN Period	
DNP Message Fragment Size	
COMMUNICATIONS > UCA/MMS PROTOCOL	
Default GOOSE Update Time	
UCA Logical Device	
UCA/MMS TCP Port Number	
COMMUNICATIONS > WEB SERVER HTTP PROT.	
HTTP TCP Port Number	
COMMUNICATIONS > TFTP PROTOCOL	
TFTP Main UDP Port Number	
TFTP Data UDP Port 1 Number	
TFTP Data UDP Port 2 Number	
COMMUNICATIONS > IEC 60870-5-104 PROTOCOL	
IEC 60870-5-104 Function	
IEC TCP Port Number	
IEC Common Address of ASDU	
IEC Cyclic Data Period	
Number of Sources in MMENC1 List	
IEC Current Default Threshold	
IEC Voltage Default Threshold	
IEC Power Default Threshold	
IEC Energy Default Threshold	
IEC Other Default Threshold	
OSCILLOGRAPHY	
Number of Records	
Trigger Mode	
Trigger Position	
Trigger Source	
AC Input Waveforms	
FAULT REPORT	
Fault Report Source	

Table 10–1: PRODUCT SETUP (Sheet 3 of 14)

SETTING	VALUE
Fault Report Trigger	
OSCILLOGRAPHY > DIGITAL CHANNELS	
Digital Channel 1	
Digital Channel 2	
Digital Channel 3	
Digital Channel 4	
Digital Channel 5	
Digital Channel 6	
Digital Channel 7	
Digital Channel 8	
Digital Channel 9	
Digital Channel 10	
Digital Channel 11	
Digital Channel 12	
Digital Channel 13	
Digital Channel 14	
Digital Channel 15	
Digital Channel 16	
Digital Channel 17	
Digital Channel 18	
Digital Channel 19	
Digital Channel 20	
Digital Channel 21	
Digital Channel 22	
Digital Channel 23	
Digital Channel 24	
Digital Channel 25	
Digital Channel 26	
Digital Channel 27	
Digital Channel 28	
Digital Channel 29	
Digital Channel 30	
Digital Channel 31	
Digital Channel 32	
Digital Channel 33	
Digital Channel 34	
Digital Channel 35	
Digital Channel 36	
Digital Channel 37	
Digital Channel 38	
Digital Channel 39	
Digital Channel 40	
Digital Channel 41	
Digital Channel 42	
Digital Channel 43	
Digital Channel 44	
Digital Channel 45	

Table 10–1: PRODUCT SETUP (Sheet 4 of 14)

SETTING	VALUE
Digital Channel 46	
Digital Channel 47	
Digital Channel 48	
Digital Channel 49	
Digital Channel 50	
Digital Channel 51	
Digital Channel 52	
Digital Channel 53	
Digital Channel 54	
Digital Channel 55	
Digital Channel 56	
Digital Channel 57	
Digital Channel 58	
Digital Channel 59	
Digital Channel 60	
Digital Channel 61	
Digital Channel 62	
Digital Channel 63	
Digital Channel 64	
OSCILLOGRAPHY > ANALOG CHANNELS	
Analog Channel 1	
Analog Channel 2	
Analog Channel 3	
Analog Channel 4	
Analog Channel 5	
Analog Channel 6	
Analog Channel 7	
Analog Channel 8	
Analog Channel 9	
Analog Channel 10	
Analog Channel 11	
Analog Channel 12	
Analog Channel 13	
Analog Channel 14	
Analog Channel 15	
Analog Channel 16	
DATA LOGGER	
Rate	
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	
Channel 9	

Table 10–1: PRODUCT SETUP (Sheet 5 of 14)

SETTING	VALUE
Channel 10	
Channel 11	
Channel 12	
Channel 13	
Channel 14	
Channel 15	
Channel 16	
USER PROGRAMMABLE LEDS	
Trip LED Input	
Alarm LED Input	
LED 1 Operand	
LED 1 Type	
LED 2 Operand	
LED 2 Type	
LED 3 Operand	
LED 3 Type	
LED 4 Operand	
LED 4 Type	
LED 5 Operand	
LED 5 Type	
LED 6 Operand	
LED 6 Type	
LED 7 Operand	
LED 7 Type	
LED 8 Operand	
LED 8 Type	
LED 9 Operand	
LED 9 Type	
LED 10 Operand	
LED 10 Type	
LED 11 Operand	
LED 11 Type	
LED 12 Operand	
LED 12 Type	
LED 13 Operand	
LED 13 Type	
LED 14 Operand	
LED 14 Type	
LED 15 Operand	
LED 15 Type	
LED 16 Operand	
LED 16 Type	
LED 17 Operand	
LED 17 Type	
LED 18 Operand	
LED 18 Type	
LED 19 Operand	

Table 10–1: PRODUCT SETUP (Sheet 6 of 14)

SETTING	VALUE
LED 19 Type	
LED 20 Operand	
LED 20 Type	
LED 21 Operand	
LED 21 Type	
LED 22 Operand	
LED 22 Type	
LED 23 Operand	
LED 23 Type	
LED 24 Operand	
LED 24 Type	
LED 25 Operand	
LED 25 Type	
LED 26 Operand	
LED 26 Type	
LED 27 Operand	
LED 27 Type	
LED 28 Operand	
LED 28 Type	
LED 29 Operand	
LED 29 Type	
LED 30 Operand	
LED 30 Type	
LED 31 Operand	
LED 31 Type	
LED 32 Operand	
LED 32 Type	
LED 33 Operand	
LED 33 Type	
LED 34 Operand	
LED 34 Type	
LED 35 Operand	
LED 35 Type	
LED 36 Operand	
LED 36 Type	
LED 37 Operand	
LED 37 Type	
LED 38 Operand	
LED 38 Type	
LED 39 Operand	
LED 39 Type	
LED 40 Operand	
LED 40 Type	
LED 41 Operand	
LED 41 Type	
LED 42 Operand	
LED 42 Type	

Table 10–1: PRODUCT SETUP (Sheet 7 of 14)

SETTING	VALUE
LED 43 Operand	
LED 43 Type	
LED 44 Operand	
LED 44 Type	
LED 45 Operand	
LED 45 Type	
LED 46 Operand	
LED 46 Type	
LED 47 Operand	
LED 47 Type	
LED 48 Operand	
LED 48 Type	
FLEX STATE PARAMETERS	
Flex State Parameter 1	
Flex State Parameter 2	
Flex State Parameter 3	
Flex State Parameter 4	
Flex State Parameter 5	
Flex State Parameter 6	
Flex State Parameter 7	
Flex State Parameter 8	
Flex State Parameter 9	
Flex State Parameter 10	
Flex State Parameter 11	
Flex State Parameter 12	
Flex State Parameter 13	
Flex State Parameter 14	
Flex State Parameter 15	
Flex State Parameter 16	
Flex State Parameter 17	
Flex State Parameter 18	
Flex State Parameter 19	
Flex State Parameter 20	
Flex State Parameter 21	
Flex State Parameter 22	
Flex State Parameter 23	
Flex State Parameter 24	
Flex State Parameter 25	
Flex State Parameter 26	
Flex State Parameter 27	
Flex State Parameter 28	
Flex State Parameter 29	
Flex State Parameter 30	
Flex State Parameter 31	
Flex State Parameter 32	
Flex State Parameter 33	
Flex State Parameter 34	

Table 10–1: PRODUCT SETUP (Sheet 8 of 14)

SETTING	VALUE
Flex State Parameter 35	
Flex State Parameter 36	
Flex State Parameter 37	
Flex State Parameter 38	
Flex State Parameter 39	
Flex State Parameter 40	
Flex State Parameter 41	
Flex State Parameter 42	
Flex State Parameter 43	
Flex State Parameter 44	
Flex State Parameter 45	
Flex State Parameter 46	
Flex State Parameter 47	
Flex State Parameter 48	
Flex State Parameter 49	
Flex State Parameter 50	
Flex State Parameter 51	
Flex State Parameter 52	
Flex State Parameter 53	
Flex State Parameter 54	
Flex State Parameter 55	
Flex State Parameter 56	
Flex State Parameter 57	
Flex State Parameter 58	
Flex State Parameter 59	
Flex State Parameter 60	
Flex State Parameter 61	
Flex State Parameter 62	
Flex State Parameter 63	
Flex State Parameter 64	
Flex State Parameter 65	
Flex State Parameter 66	
Flex State Parameter 67	
Flex State Parameter 68	
Flex State Parameter 69	
Flex State Parameter 70	
Flex State Parameter 71	
Flex State Parameter 72	
Flex State Parameter 73	
Flex State Parameter 74	
Flex State Parameter 75	
Flex State Parameter 76	
Flex State Parameter 77	
Flex State Parameter 78	
Flex State Parameter 79	
Flex State Parameter 80	
Flex State Parameter 81	

Table 10–1: PRODUCT SETUP (Sheet 9 of 14)

SETTING	VALUE
Flex State Parameter 82	
Flex State Parameter 83	
Flex State Parameter 84	
Flex State Parameter 85	
Flex State Parameter 86	
Flex State Parameter 87	
Flex State Parameter 88	
Flex State Parameter 89	
Flex State Parameter 90	
Flex State Parameter 91	
Flex State Parameter 92	
Flex State Parameter 93	
Flex State Parameter 94	
Flex State Parameter 95	
Flex State Parameter 96	
Flex State Parameter 97	
Flex State Parameter 98	
Flex State Parameter 99	
Flex State Parameter 100	
Flex State Parameter 101	
Flex State Parameter 102	
Flex State Parameter 103	
Flex State Parameter 104	
Flex State Parameter 105	
Flex State Parameter 106	
Flex State Parameter 107	
Flex State Parameter 108	
Flex State Parameter 109	
Flex State Parameter 110	
Flex State Parameter 111	
Flex State Parameter 112	
Flex State Parameter 113	
Flex State Parameter 114	
Flex State Parameter 115	
Flex State Parameter 116	
Flex State Parameter 117	
Flex State Parameter 118	
Flex State Parameter 119	
Flex State Parameter 120	
Flex State Parameter 121	
Flex State Parameter 122	
Flex State Parameter 123	
Flex State Parameter 124	
Flex State Parameter 125	
Flex State Parameter 126	
Flex State Parameter 127	
Flex State Parameter 128	

Table 10–1: PRODUCT SETUP (Sheet 10 of 14)

SETTING	VALUE
Flex State Parameter 129	
Flex State Parameter 130	
Flex State Parameter 131	
Flex State Parameter 132	
Flex State Parameter 133	
Flex State Parameter 134	
Flex State Parameter 135	
Flex State Parameter 136	
Flex State Parameter 137	
Flex State Parameter 138	
Flex State Parameter 139	
Flex State Parameter 140	
Flex State Parameter 141	
Flex State Parameter 142	
Flex State Parameter 143	
Flex State Parameter 144	
Flex State Parameter 145	
Flex State Parameter 146	
Flex State Parameter 147	
Flex State Parameter 148	
Flex State Parameter 149	
Flex State Parameter 150	
Flex State Parameter 151	
Flex State Parameter 152	
Flex State Parameter 153	
Flex State Parameter 154	
Flex State Parameter 155	
Flex State Parameter 156	
Flex State Parameter 157	
Flex State Parameter 158	
Flex State Parameter 159	
Flex State Parameter 160	
Flex State Parameter 161	
Flex State Parameter 162	
Flex State Parameter 163	
Flex State Parameter 164	
Flex State Parameter 165	
Flex State Parameter 166	
Flex State Parameter 167	
Flex State Parameter 168	
Flex State Parameter 169	
Flex State Parameter 170	
Flex State Parameter 171	
Flex State Parameter 172	
Flex State Parameter 173	
Flex State Parameter 174	
Flex State Parameter 175	

Table 10–1: PRODUCT SETUP (Sheet 11 of 14)

SETTING	VALUE
Flex State Parameter 176	
Flex State Parameter 177	
Flex State Parameter 178	
Flex State Parameter 179	
Flex State Parameter 180	
Flex State Parameter 181	
Flex State Parameter 182	
Flex State Parameter 183	
Flex State Parameter 184	
Flex State Parameter 185	
Flex State Parameter 186	
Flex State Parameter 187	
Flex State Parameter 188	
Flex State Parameter 189	
Flex State Parameter 190	
Flex State Parameter 191	
Flex State Parameter 192	
Flex State Parameter 193	
Flex State Parameter 194	
Flex State Parameter 195	
Flex State Parameter 196	
Flex State Parameter 197	
Flex State Parameter 198	
Flex State Parameter 199	
Flex State Parameter 200	
Flex State Parameter 201	
Flex State Parameter 202	
Flex State Parameter 203	
Flex State Parameter 204	
Flex State Parameter 205	
Flex State Parameter 206	
Flex State Parameter 207	
Flex State Parameter 208	
Flex State Parameter 209	
Flex State Parameter 210	
Flex State Parameter 211	
Flex State Parameter 212	
Flex State Parameter 213	
Flex State Parameter 214	
Flex State Parameter 215	
Flex State Parameter 216	
Flex State Parameter 217	
Flex State Parameter 218	
Flex State Parameter 219	
Flex State Parameter 220	
Flex State Parameter 221	
Flex State Parameter 222	

Table 10–1: PRODUCT SETUP (Sheet 12 of 14)

SETTING	VALUE
Flex State Parameter 223	
Flex State Parameter 224	
Flex State Parameter 225	
Flex State Parameter 226	
Flex State Parameter 227	
Flex State Parameter 228	
Flex State Parameter 229	
Flex State Parameter 230	
Flex State Parameter 231	
Flex State Parameter 232	
Flex State Parameter 233	
Flex State Parameter 234	
Flex State Parameter 235	
Flex State Parameter 236	
Flex State Parameter 237	
Flex State Parameter 238	
Flex State Parameter 239	
Flex State Parameter 240	
Flex State Parameter 241	
Flex State Parameter 242	
Flex State Parameter 243	
Flex State Parameter 244	
Flex State Parameter 245	
Flex State Parameter 246	
Flex State Parameter 247	
Flex State Parameter 248	
Flex State Parameter 249	
Flex State Parameter 250	
Flex State Parameter 251	
Flex State Parameter 252	
Flex State Parameter 253	
Flex State Parameter 254	
Flex State Parameter 255	
Flex State Parameter 256	
USER DISPLAY 1	
Disp 1 Top Line	
Disp 1 Bottom Line	
Disp 1 Item 1	
Disp 1 Item 2	
Disp 1 Item 3	
Disp 1 Item 4	
Disp 1 Item 5	
USER DISPLAY 2	
Disp 2 Top Line	
Disp 2 Bottom Line	
Disp 2 Item 1	
Disp 2 Item 2	

Table 10–1: PRODUCT SETUP (Sheet 13 of 14)

SETTING	VALUE
Disp 2 Item 3	
Disp 2 Item 4	
Disp 2 Item 5	
USER DISPLAY 3	
Disp 3 Top Line	
Disp 3 Bottom Line	
Disp 3 Item 1	
Disp 3 Item 2	
Disp 3 Item 3	
Disp 3 Item 4	
Disp 3 Item 5	
USER DISPLAY 4	
Disp 4 Top Line	
Disp 4 Bottom Line	
Disp 4 Item 1	
Disp 4 Item 2	
Disp 4 Item 3	
Disp 4 Item 4	
Disp 4 Item 5	
USER DISPLAY 5	
Disp 5 Top Line	
Disp 5 Bottom Line	
Disp 5 Item 1	
Disp 5 Item 2	
Disp 5 Item 3	
Disp 5 Item 4	
Disp 5 Item 5	
USER DISPLAY 6	
Disp 6 Top Line	
Disp 6 Bottom Line	
Disp 6 Item 1	
Disp 6 Item 2	
Disp 6 Item 3	
Disp 6 Item 4	
Disp 6 Item 5	
USER DISPLAY 7	
Disp 7 Top Line	
Disp 7 Bottom Line	
Disp 7 Item 1	
Disp 7 Item 2	
Disp 7 Item 3	
Disp 7 Item 4	
Disp 7 Item 5	
USER DISPLAY 8	
Disp 8 Top Line	
Disp 8 Bottom Line	
Disp 8 Item 1	

Table 10–1: PRODUCT SETUP (Sheet 14 of 14)

SETTING	VALUE
Disp 8 Item 2	
Disp 8 Item 3	
Disp 8 Item 4	
Disp 8 Item 5	
INSTALLATION	
Relay Settings	
Relay Name	

10.2.1 SETTINGS

Table 10–2: SYSTEM SETUP (Sheet 1 of 3)

SETTING	VALUE
CURRENT BANK 1	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
CURRENT BANK 2	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
CURRENT BANK 3	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
CURRENT BANK 4	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
CURRENT BANK 5	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
CURRENT BANK 6	
Phase CT ______ Primary	
Phase CT ______ Secondary	
Ground CT ______ Primary	
Ground CT ______ Secondary	
VOLTAGE BANK 1	
Phase VT ______ Connection	
Phase VT ______ Secondary	
Phase VT ______ Ratio	
Auxiliary VT ______ Connection	
Auxiliary VT ______ Secondary	
Auxiliary VT ______ Ratio	
VOLTAGE BANK 2	
Phase VT ______ Connection	
Phase VT ______ Secondary	
Phase VT ______ Ratio	
Auxiliary VT ______ Connection	
Auxiliary VT ______ Secondary	
Auxiliary VT ______ Ratio	

Table 10–2: SYSTEM SETUP (Sheet 2 of 3)

SETTING	VALUE
VOLTAGE BANK 3	
Phase VT ______ Connection	
Phase VT ______ Secondary	
Phase VT ______ Ratio	
Auxiliary VT ______ Connection	
Auxiliary VT ______ Secondary	
Auxiliary VT ______ Ratio	
POWER SYSTEM	
Nominal Frequency	
Phase Rotation	
Frequency and Phase Reference	
Frequency Tracking	
SIGNAL SOURCE 1	
Source 1 Name	
Source 1 Phase CT	
Source 1 Ground CT	
Source 1 Phase VT	
Source 1 Auxiliary VT	
SIGNAL SOURCE 2	
Source 2 Name	
Source 2 Phase CT	
Source 2 Ground CT	
Source 2 Phase VT	
Source 2 Auxiliary VT	
SIGNAL SOURCE 3	
Source 3 Name	
Source 3 Phase CT	
Source 3 Ground CT	
Source 3 Phase VT	
Source 3 Auxiliary VT	
SIGNAL SOURCE 4	
Source 4 Name	
Source 4 Phase CT	
Source 4 Ground CT	
Source 4 Phase VT	
Source 4 Auxiliary VT	
SIGNAL SOURCE 5	
Source 5 Name	
Source 5 Phase CT	
GSource 5 round CT	
Source 5 Phase VT	
Source 5 Auxiliary VT	
SIGNAL SOURCE 6	
Source 6 Name	

Table 10–2: SYSTEM SETUP (Sheet 3 of 3)

SETTING	VALUE
Source 6 Phase CT	
Source 6 Ground CT	
Source 6 Phase VT	
Source 6 Auxiliary VT	
LINE	
Pos. Seq. Impedance Magnitude	
Pos. Seq. Impedance Angle	
Zero Seq. Impedance Magnitude	
Zero Seq. Impedance Angle	
Line Length Units	
Line Length	
BREAKER 1	
Breaker 1 Function	
Breaker 1 Pushbutton Control	
Breaker 1 Name	
Breaker 1 Mode	
Breaker 1 Open	
Breaker 1 Close	
Breaker 1 ΦA/3-Pole	
Breaker 1 ΦB	
Breaker 1 ΦC	
Breaker 1 Ext Alarm	
Breaker 1 Alarm Delay	
Breaker 1 Out of Sv	
Breaker 1 Manual Close Recall Time	
BREAKER 2	
Breaker 2 Function	
Breaker 2 Pushbutton Control	
Breaker 2 Name	
Breaker 2 Mode	
Breaker 2 Open	
Breaker 2 Close	
Breaker 2 ΦA/3-Pole	
Breaker 2 ΦB	
Breaker 2 ΦC	
Breaker 2 Ext Alarm	
Breaker 2 Alarm Delay	
Breaker 2 Out of Sv	
Breaker 2 Manual Close Recall Time	
UCA SBO TIMER (FOR BREAKERS 1/2)	
UCA SBO Timeout	

10.2.2 FLEXCURVE™ A

Table 10–3: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
0.00		0.68		1.03		2.9		4.9		10.5	
0.05		0.70		1.05		3.0		5.0		11.0	
0.10		0.72		1.1		3.1		5.1		11.5	
0.15		0.74		1.2		3.2		5.2		12.0	
0.20		0.76		1.3		3.3		5.3		12.5	
0.25		0.78		1.4		3.4		5.4		13.0	
0.30		0.80		1.5		3.5		5.5		13.5	
0.35		0.82		1.6		3.6		5.6		14.0	
0.40		0.84		1.7		3.7		5.7		14.5	
0.45		0.86		1.8		3.8		5.8		15.0	
0.48		0.88		1.9		3.9		5.9		15.5	
0.50		0.90		2.0		4.0		6.0		16.0	
0.52		0.91		2.1		4.1		6.5		16.5	
0.54		0.92		2.2		4.2		7.0		17.0	
0.56		0.93		2.3		4.3		7.5		17.5	
0.58		0.94		2.4		4.4		8.0		18.0	
0.60		0.95		2.5		4.5		8.5		18.5	
0.62		0.96		2.6		4.6		9.0		19.0	
0.64		0.97		2.7		4.7		9.5		19.5	
0.66		0.98		2.8		4.8		10.0		20.0	

10.2.3 FLEXCURVE™ B

Table 10–4: FLEXCURVE™ TABLE

RESET	TIME MS	RESET	TIME MS
0.00		0.68	
0.05		0.70	
0.10		0.72	
0.15		0.74	
0.20		0.76	
0.25		0.78	
0.30		0.80	
0.35		0.82	
0.40		0.84	
0.45		0.86	
0.48		0.88	
0.50		0.90	
0.52		0.91	
0.54		0.92	
0.56		0.93	
0.58		0.94	
0.60		0.95	
0.62		0.96	
0.64		0.97	
0.66		0.98	

OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS	OPERATE	TIME MS
1.03		2.9		4.9		10.5	
1.05		3.0		5.0		11.0	
1.1		3.1		5.1		11.5	
1.2		3.2		5.2		12.0	
1.3		3.3		5.3		12.5	
1.4		3.4		5.4		13.0	
1.5		3.5		5.5		13.5	
1.6		3.6		5.6		14.0	
1.7		3.7		5.7		14.5	
1.8		3.8		5.8		15.0	
1.9		3.9		5.9		15.5	
2.0		4.0		6.0		16.0	
2.1		4.1		6.5		16.5	
2.2		4.2		7.0		17.0	
2.3		4.3		7.5		17.5	
2.4		4.4		8.0		18.0	
2.5		4.5		8.5		18.5	
2.6		4.6		9.0		19.0	
2.7		4.7		9.5		19.5	
2.8		4.8		10.0		20.0	

10.3.1 SETTINGS

Table 10–5: FLEXLOGIC™ (Sheet 1 of 17)

SETTING	VALUE
FLEXLOGIC EQUATION EDITOR	
FlexLogic Entry 1	
FlexLogic Entry 2	
FlexLogic Entry 3	
FlexLogic Entry 4	
FlexLogic Entry 5	
FlexLogic Entry 6	
FlexLogic Entry 7	
FlexLogic Entry 8	
FlexLogic Entry 9	
FlexLogic Entry 10	
FlexLogic Entry 11	
FlexLogic Entry 12	
FlexLogic Entry 13	
FlexLogic Entry 14	
FlexLogic Entry 15	
FlexLogic Entry 16	
FlexLogic Entry 17	
FlexLogic Entry 18	
FlexLogic Entry 19	
FlexLogic Entry 20	
FlexLogic Entry 21	
FlexLogic Entry 22	
FlexLogic Entry 23	
FlexLogic Entry 24	
FlexLogic Entry 25	
FlexLogic Entry 26	
FlexLogic Entry 27	
FlexLogic Entry 28	
FlexLogic Entry 29	
FlexLogic Entry 30	
FlexLogic Entry 31	
FlexLogic Entry 32	
FlexLogic Entry 33	
FlexLogic Entry 34	
FlexLogic Entry 35	
FlexLogic Entry 36	
FlexLogic Entry 37	
FlexLogic Entry 38	
FlexLogic Entry 39	
FlexLogic Entry 40	
FlexLogic Entry 41	
FlexLogic Entry 42	
FlexLogic Entry 43	

Table 10–5: FLEXLOGIC™ (Sheet 2 of 17)

SETTING	VALUE
FlexLogic Entry 44	
FlexLogic Entry 45	
FlexLogic Entry 46	
FlexLogic Entry 47	
FlexLogic Entry 48	
FlexLogic Entry 49	
FlexLogic Entry 50	
FlexLogic Entry 51	
FlexLogic Entry 52	
FlexLogic Entry 53	
FlexLogic Entry 54	
FlexLogic Entry 55	
FlexLogic Entry 56	
FlexLogic Entry 57	
FlexLogic Entry 58	
FlexLogic Entry 59	
FlexLogic Entry 60	
FlexLogic Entry 61	
FlexLogic Entry 62	
FlexLogic Entry 63	
FlexLogic Entry 64	
FlexLogic Entry 65	
FlexLogic Entry 66	
FlexLogic Entry 67	
FlexLogic Entry 68	
FlexLogic Entry 69	
FlexLogic Entry 70	
FlexLogic Entry 71	
FlexLogic Entry 72	
FlexLogic Entry 73	
FlexLogic Entry 74	
FlexLogic Entry 75	
FlexLogic Entry 76	
FlexLogic Entry 77	
FlexLogic Entry 78	
FlexLogic Entry 79	
FlexLogic Entry 80	
FlexLogic Entry 81	
FlexLogic Entry 82	
FlexLogic Entry 83	
FlexLogic Entry 84	
FlexLogic Entry 85	
FlexLogic Entry 86	
FlexLogic Entry 87	

Table 10–5: FLEXLOGIC™ (Sheet 3 of 17)

SETTING	VALUE
FlexLogic Entry 88	
FlexLogic Entry 89	
FlexLogic Entry 90	
FlexLogic Entry 91	
FlexLogic Entry 92	
FlexLogic Entry 93	
FlexLogic Entry 94	
FlexLogic Entry 95	
FlexLogic Entry 96	
FlexLogic Entry 97	
FlexLogic Entry 98	
FlexLogic Entry 99	
FlexLogic Entry 100	
FlexLogic Entry 101	
FlexLogic Entry 102	
FlexLogic Entry 103	
FlexLogic Entry 104	
FlexLogic Entry 105	
FlexLogic Entry 106	
FlexLogic Entry 107	
FlexLogic Entry 108	
FlexLogic Entry 109	
FlexLogic Entry 110	
FlexLogic Entry 111	
FlexLogic Entry 112	
FlexLogic Entry 113	
FlexLogic Entry 114	
FlexLogic Entry 115	
FlexLogic Entry 116	
FlexLogic Entry 117	
FlexLogic Entry 118	
FlexLogic Entry 119	
FlexLogic Entry 120	
FlexLogic Entry 121	
FlexLogic Entry 122	
FlexLogic Entry 123	
FlexLogic Entry 124	
FlexLogic Entry 125	
FlexLogic Entry 126	
FlexLogic Entry 127	
FlexLogic Entry 128	
FlexLogic Entry 129	
FlexLogic Entry 130	
FlexLogic Entry 131	
FlexLogic Entry 132	
FlexLogic Entry 133	
FlexLogic Entry 134	

Table 10–5: FLEXLOGIC™ (Sheet 4 of 17)

SETTING	VALUE
FlexLogic Entry 135	
FlexLogic Entry 136	
FlexLogic Entry 137	
FlexLogic Entry 138	
FlexLogic Entry 139	
FlexLogic Entry 140	
FlexLogic Entry 141	
FlexLogic Entry 142	
FlexLogic Entry 143	
FlexLogic Entry 144	
FlexLogic Entry 145	
FlexLogic Entry 146	
FlexLogic Entry 147	
FlexLogic Entry 148	
FlexLogic Entry 149	
FlexLogic Entry 150	
FlexLogic Entry 151	
FlexLogic Entry 152	
FlexLogic Entry 153	
FlexLogic Entry 154	
FlexLogic Entry 155	
FlexLogic Entry 156	
FlexLogic Entry 157	
FlexLogic Entry 158	
FlexLogic Entry 159	
FlexLogic Entry 160	
FlexLogic Entry 161	
FlexLogic Entry 162	
FlexLogic Entry 163	
FlexLogic Entry 164	
FlexLogic Entry 165	
FlexLogic Entry 166	
FlexLogic Entry 167	
FlexLogic Entry 168	
FlexLogic Entry 169	
FlexLogic Entry 170	
FlexLogic Entry 171	
FlexLogic Entry 172	
FlexLogic Entry 173	
FlexLogic Entry 174	
FlexLogic Entry 175	
FlexLogic Entry 176	
FlexLogic Entry 177	
FlexLogic Entry 178	
FlexLogic Entry 179	
FlexLogic Entry 180	
FlexLogic Entry 181	

Table 10–5: FLEXLOGIC™ (Sheet 5 of 17)

SETTING	VALUE
FlexLogic Entry 182	
FlexLogic Entry 183	
FlexLogic Entry 184	
FlexLogic Entry 185	
FlexLogic Entry 186	
FlexLogic Entry 187	
FlexLogic Entry 188	
FlexLogic Entry 189	
FlexLogic Entry 190	
FlexLogic Entry 191	
FlexLogic Entry 192	
FlexLogic Entry 193	
FlexLogic Entry 194	
FlexLogic Entry 195	
FlexLogic Entry 196	
FlexLogic Entry 197	
FlexLogic Entry 198	
FlexLogic Entry 199	
FlexLogic Entry 200	
FlexLogic Entry 201	
FlexLogic Entry 202	
FlexLogic Entry 203	
FlexLogic Entry 204	
FlexLogic Entry 205	
FlexLogic Entry 206	
FlexLogic Entry 207	
FlexLogic Entry 208	
FlexLogic Entry 209	
FlexLogic Entry 210	
FlexLogic Entry 211	
FlexLogic Entry 212	
FlexLogic Entry 213	
FlexLogic Entry 214	
FlexLogic Entry 215	
FlexLogic Entry 216	
FlexLogic Entry 217	
FlexLogic Entry 218	
FlexLogic Entry 219	
FlexLogic Entry 220	
FlexLogic Entry 221	
FlexLogic Entry 222	
FlexLogic Entry 223	
FlexLogic Entry 224	
FlexLogic Entry 225	
FlexLogic Entry 226	
FlexLogic Entry 227	
FlexLogic Entry 228	

Table 10–5: FLEXLOGIC™ (Sheet 6 of 17)

SETTING	VALUE
FlexLogic Entry 229	
FlexLogic Entry 230	
FlexLogic Entry 231	
FlexLogic Entry 232	
FlexLogic Entry 233	
FlexLogic Entry 234	
FlexLogic Entry 235	
FlexLogic Entry 236	
FlexLogic Entry 237	
FlexLogic Entry 238	
FlexLogic Entry 239	
FlexLogic Entry 240	
FlexLogic Entry 241	
FlexLogic Entry 242	
FlexLogic Entry 243	
FlexLogic Entry 244	
FlexLogic Entry 245	
FlexLogic Entry 246	
FlexLogic Entry 247	
FlexLogic Entry 248	
FlexLogic Entry 249	
FlexLogic Entry 250	
FlexLogic Entry 251	
FlexLogic Entry 252	
FlexLogic Entry 253	
FlexLogic Entry 254	
FlexLogic Entry 255	
FlexLogic Entry 256	
FlexLogic Entry 257	
FlexLogic Entry 258	
FlexLogic Entry 259	
FlexLogic Entry 260	
FlexLogic Entry 261	
FlexLogic Entry 262	
FlexLogic Entry 263	
FlexLogic Entry 264	
FlexLogic Entry 265	
FlexLogic Entry 266	
FlexLogic Entry 267	
FlexLogic Entry 268	
FlexLogic Entry 269	
FlexLogic Entry 270	
FlexLogic Entry 271	
FlexLogic Entry 272	
FlexLogic Entry 273	
FlexLogic Entry 274	
FlexLogic Entry 275	

Table 10–5: FLEXLOGIC™ (Sheet 7 of 17)

SETTING	VALUE
FlexLogic Entry 276	
FlexLogic Entry 277	
FlexLogic Entry 278	
FlexLogic Entry 279	
FlexLogic Entry 280	
FlexLogic Entry 281	
FlexLogic Entry 282	
FlexLogic Entry 283	
FlexLogic Entry 284	
FlexLogic Entry 285	
FlexLogic Entry 286	
FlexLogic Entry 287	
FlexLogic Entry 288	
FlexLogic Entry 289	
FlexLogic Entry 290	
FlexLogic Entry 291	
FlexLogic Entry 292	
FlexLogic Entry 293	
FlexLogic Entry 294	
FlexLogic Entry 295	
FlexLogic Entry 296	
FlexLogic Entry 297	
FlexLogic Entry 298	
FlexLogic Entry 299	
FlexLogic Entry 300	
FlexLogic Entry 301	
FlexLogic Entry 302	
FlexLogic Entry 303	
FlexLogic Entry 304	
FlexLogic Entry 305	
FlexLogic Entry 306	
FlexLogic Entry 307	
FlexLogic Entry 308	
FlexLogic Entry 309	
FlexLogic Entry 310	
FlexLogic Entry 311	
FlexLogic Entry 312	
FlexLogic Entry 313	
FlexLogic Entry 314	
FlexLogic Entry 315	
FlexLogic Entry 316	
FlexLogic Entry 317	
FlexLogic Entry 318	
FlexLogic Entry 319	
FlexLogic Entry 320	
FlexLogic Entry 321	
FlexLogic Entry 322	

Table 10–5: FLEXLOGIC™ (Sheet 8 of 17)

SETTING	VALUE
FlexLogic Entry 323	
FlexLogic Entry 324	
FlexLogic Entry 325	
FlexLogic Entry 326	
FlexLogic Entry 327	
FlexLogic Entry 328	
FlexLogic Entry 329	
FlexLogic Entry 330	
FlexLogic Entry 331	
FlexLogic Entry 332	
FlexLogic Entry 333	
FlexLogic Entry 334	
FlexLogic Entry 335	
FlexLogic Entry 336	
FlexLogic Entry 337	
FlexLogic Entry 338	
FlexLogic Entry 339	
FlexLogic Entry 340	
FlexLogic Entry 341	
FlexLogic Entry 342	
FlexLogic Entry 343	
FlexLogic Entry 344	
FlexLogic Entry 345	
FlexLogic Entry 346	
FlexLogic Entry 347	
FlexLogic Entry 348	
FlexLogic Entry 349	
FlexLogic Entry 350	
FlexLogic Entry 351	
FlexLogic Entry 352	
FlexLogic Entry 353	
FlexLogic Entry 354	
FlexLogic Entry 355	
FlexLogic Entry 356	
FlexLogic Entry 357	
FlexLogic Entry 358	
FlexLogic Entry 359	
FlexLogic Entry 360	
FlexLogic Entry 361	
FlexLogic Entry 362	
FlexLogic Entry 363	
FlexLogic Entry 364	
FlexLogic Entry 365	
FlexLogic Entry 366	
FlexLogic Entry 367	
FlexLogic Entry 368	
FlexLogic Entry 369	

Table 10–5: FLEXLOGIC™ (Sheet 9 of 17)

SETTING	VALUE
FlexLogic Entry 370	
FlexLogic Entry 371	
FlexLogic Entry 372	
FlexLogic Entry 373	
FlexLogic Entry 374	
FlexLogic Entry 375	
FlexLogic Entry 376	
FlexLogic Entry 377	
FlexLogic Entry 378	
FlexLogic Entry 379	
FlexLogic Entry 380	
FlexLogic Entry 381	
FlexLogic Entry 382	
FlexLogic Entry 383	
FlexLogic Entry 384	
FlexLogic Entry 385	
FlexLogic Entry 386	
FlexLogic Entry 387	
FlexLogic Entry 388	
FlexLogic Entry 389	
FlexLogic Entry 390	
FlexLogic Entry 391	
FlexLogic Entry 392	
FlexLogic Entry 393	
FlexLogic Entry 394	
FlexLogic Entry 395	
FlexLogic Entry 396	
FlexLogic Entry 397	
FlexLogic Entry 398	
FlexLogic Entry 399	
FlexLogic Entry 400	
FlexLogic Entry 401	
FlexLogic Entry 402	
FlexLogic Entry 403	
FlexLogic Entry 404	
FlexLogic Entry 405	
FlexLogic Entry 406	
FlexLogic Entry 407	
FlexLogic Entry 408	
FlexLogic Entry 409	
FlexLogic Entry 410	
FlexLogic Entry 411	
FlexLogic Entry 412	
FlexLogic Entry 413	
FlexLogic Entry 414	
FlexLogic Entry 415	
FlexLogic Entry 416	

Table 10–5: FLEXLOGIC™ (Sheet 10 of 17)

SETTING	VALUE
FlexLogic Entry 417	
FlexLogic Entry 418	
FlexLogic Entry 419	
FlexLogic Entry 420	
FlexLogic Entry 421	
FlexLogic Entry 422	
FlexLogic Entry 423	
FlexLogic Entry 424	
FlexLogic Entry 425	
FlexLogic Entry 426	
FlexLogic Entry 427	
FlexLogic Entry 428	
FlexLogic Entry 429	
FlexLogic Entry 430	
FlexLogic Entry 431	
FlexLogic Entry 432	
FlexLogic Entry 433	
FlexLogic Entry 434	
FlexLogic Entry 435	
FlexLogic Entry 436	
FlexLogic Entry 437	
FlexLogic Entry 438	
FlexLogic Entry 439	
FlexLogic Entry 440	
FlexLogic Entry 441	
FlexLogic Entry 442	
FlexLogic Entry 443	
FlexLogic Entry 444	
FlexLogic Entry 445	
FlexLogic Entry 446	
FlexLogic Entry 447	
FlexLogic Entry 448	
FlexLogic Entry 449	
FlexLogic Entry 450	
FlexLogic Entry 451	
FlexLogic Entry 452	
FlexLogic Entry 453	
FlexLogic Entry 454	
FlexLogic Entry 455	
FlexLogic Entry 456	
FlexLogic Entry 457	
FlexLogic Entry 458	
FlexLogic Entry 459	
FlexLogic Entry 460	
FlexLogic Entry 461	
FlexLogic Entry 462	
FlexLogic Entry 463	

Table 10–5: FLEXLOGIC™ (Sheet 11 of 17)

SETTING	VALUE
FlexLogic Entry 464	
FlexLogic Entry 465	
FlexLogic Entry 466	
FlexLogic Entry 467	
FlexLogic Entry 468	
FlexLogic Entry 469	
FlexLogic Entry 470	
FlexLogic Entry 471	
FlexLogic Entry 472	
FlexLogic Entry 473	
FlexLogic Entry 474	
FlexLogic Entry 475	
FlexLogic Entry 476	
FlexLogic Entry 477	
FlexLogic Entry 478	
FlexLogic Entry 479	
FlexLogic Entry 480	
FlexLogic Entry 481	
FlexLogic Entry 482	
FlexLogic Entry 483	
FlexLogic Entry 484	
FlexLogic Entry 485	
FlexLogic Entry 486	
FlexLogic Entry 487	
FlexLogic Entry 488	
FlexLogic Entry 489	
FlexLogic Entry 490	
FlexLogic Entry 491	
FlexLogic Entry 492	
FlexLogic Entry 493	
FlexLogic Entry 494	
FlexLogic Entry 495	
FlexLogic Entry 496	
FlexLogic Entry 497	
FlexLogic Entry 498	
FlexLogic Entry 499	
FlexLogic Entry 500	
FlexLogic Entry 501	
FlexLogic Entry 502	
FlexLogic Entry 503	
FlexLogic Entry 504	
FlexLogic Entry 505	
FlexLogic Entry 506	
FlexLogic Entry 507	
FlexLogic Entry 508	
FlexLogic Entry 509	
FlexLogic Entry 510	

Table 10–5: FLEXLOGIC™ (Sheet 12 of 17)

SETTING	VALUE
FlexLogic Entry 511	
FlexLogic Entry 512	
FLEXLOGIC TIMER 1	
FlexLogic Timer 1 Type	
FlexLogic Timer 1 Pickup Delay	
FlexLogic Timer 1 Dropout Delay	
FLEXLOGIC TIMER 2	
FlexLogic Timer 2 Type	
FlexLogic Timer 2 Pickup Delay	
FlexLogic Timer 2 Dropout Delay	
FLEXLOGIC TIMER 3	
FlexLogic Timer 3 Type	
FlexLogic Timer 3 Pickup Delay	
FlexLogic Timer 3 Dropout Delay	
FLEXLOGIC TIMER 4	
FlexLogic Timer 4 Type	
FlexLogic Timer 4 Pickup Delay	
FlexLogic Timer 4 Dropout Delay	
FLEXLOGIC TIMER 5	
FlexLogic Timer 5 Type	
FlexLogic Timer 5 Pickup Delay	
FlexLogic Timer 5 Dropout Delay	
FLEXLOGIC TIMER 6	
FlexLogic Timer 6 Type	
FlexLogic Timer 6 Pickup Delay	
FlexLogic Timer 6 Dropout Delay	
FLEXLOGIC TIMER 7	
FlexLogic Timer 7 Type	
FlexLogic Timer 7 Pickup Delay	
FlexLogic Timer 7 Dropout Delay	
FLEXLOGIC TIMER 8	
FlexLogic Timer 8 Type	
FlexLogic Timer 8 Pickup Delay	
FlexLogic Timer 8 Dropout Delay	
FLEXLOGIC TIMER 9	
FlexLogic Timer 9 Type	
FlexLogic Timer 9 Pickup Delay	
FlexLogic Timer 9 Dropout Delay	
FLEXLOGIC TIMER 10	
FlexLogic Timer 10 Type	
FlexLogic Timer 10 Pickup Delay	
FlexLogic Timer 10 Dropout Delay	
FLEXLOGIC TIMER 11	
FlexLogic Timer 11 Type	
FlexLogic Timer 11 Pickup Delay	
FlexLogic Timer 11 Dropout Delay	

Table 10–5: FLEXLOGIC™ (Sheet 13 of 17)

SETTING	VALUE
FLEXLOGIC TIMER 12	
FlexLogic Timer 12 Type	
FlexLogic Timer 12 Pickup Delay	
FlexLogic Timer 12 Dropout Delay	
FLEXLOGIC TIMER 13	
FlexLogic Timer 13 Type	
FlexLogic Timer 13 Pickup Delay	
FlexLogic Timer 13 Dropout Delay	
FLEXLOGIC TIMER 14	
FlexLogic Timer 14 Type	
FlexLogic Timer 14 Pickup Delay	
FlexLogic Timer 14 Dropout Delay	
FLEXLOGIC TIMER 15	
FlexLogic Timer 15 Type	
FlexLogic Timer 15 Pickup Delay	
FlexLogic Timer 15 Dropout Delay	
FLEXLOGIC TIMER 16	
FlexLogic Timer 16 Type	
FlexLogic Timer 16 Pickup Delay	
FlexLogic Timer 16 Dropout Delay	
FLEXLOGIC TIMER 17	
FlexLogic Timer 17 Type	
FlexLogic Timer 17 Pickup Delay	
FlexLogic Timer 17 Dropout Delay	
FLEXLOGIC TIMER 18	
FlexLogic Timer 18 Type	
FlexLogic Timer 18 Pickup Delay	
FlexLogic Timer 18 Dropout Delay	
FLEXLOGIC TIMER 19	
FlexLogic Timer 19 Type	
FlexLogic Timer 19 Pickup Delay	
FlexLogic Timer 19 Dropout Delay	
FLEXLOGIC TIMER 20	
FlexLogic Timer 20 Type	
FlexLogic Timer 20 Pickup Delay	
FlexLogic Timer 20 Dropout Delay	
FLEXLOGIC TIMER 21	
FlexLogic Timer 21 Type	
FlexLogic Timer 21 Pickup Delay	
FlexLogic Timer 21 Dropout Delay	
FLEXLOGIC TIMER 22	
FlexLogic Timer 22 Type	
FlexLogic Timer 22 Pickup Delay	
FlexLogic Timer 22 Dropout Delay	
FLEXLOGIC TIMER 23	
FlexLogic Timer 23 Type	
FlexLogic Timer 23 Pickup Delay	

Table 10–5: FLEXLOGIC™ (Sheet 14 of 17)

SETTING	VALUE
FlexLogic Timer 23 Dropout Delay	
FLEXLOGIC TIMER 24	
FlexLogic Timer 24 Type	
FlexLogic Timer 24 Pickup Delay	
FlexLogic Timer 24 Dropout Delay	
FLEXLOGIC TIMER 25	
FlexLogic Timer 25 Type	
FlexLogic Timer 25 Pickup Delay	
FlexLogic Timer 25 Dropout Delay	
FLEXLOGIC TIMER 26	
FlexLogic Timer 26 Type	
FlexLogic Timer 26 Pickup Delay	
FlexLogic Timer 26 Dropout Delay	
FLEXLOGIC TIMER 27	
FlexLogic Timer 27 Type	
FlexLogic Timer 27 Pickup Delay	
FlexLogic Timer 27 Dropout Delay	
FLEXLOGIC TIMER 28	
FlexLogic Timer 28 Type	
FlexLogic Timer 28 Pickup Delay	
FlexLogic Timer 28 Dropout Delay	
FLEXLOGIC TIMER 29	
FlexLogic Timer 29 Type	
FlexLogic Timer 29 Pickup Delay	
FlexLogic Timer 29 Dropout Delay	
FLEXLOGIC TIMER 30	
FlexLogic Timer 30 Type	
FlexLogic Timer 30 Pickup Delay	
FlexLogic Timer 30 Dropout Delay	
FLEXLOGIC TIMER 31	
FlexLogic Timer 31 Type	
FlexLogic Timer 31 Pickup Delay	
FlexLogic Timer 31 Dropout Delay	
FLEXLOGIC TIMER 32	
FlexLogic Timer 32 Type	
FlexLogic Timer 32 Pickup Delay	
FlexLogic Timer 32 Dropout Delay	
FLEXELEMENT 1	
FlexElement 1 Function	
FlexElement 1 Name	
FlexElement 1 +IN	
FlexElement 1 –IN	
FlexElement 1 Input Mode	
FlexElement 1 Comp Mode	
FlexElement 1 Direction	
FlexElement 1 Pickup	
FlexElement 1 Hysteresis	

Table 10–5: FLEXLOGIC™ (Sheet 15 of 17)

SETTING	VALUE
FlexElement 1 dt Unit	
FlexElement 1 dt	
FlexElement 1 Pkp Delay	
FlexElement 1 Rst Delay	
FlexElement 1 Blk	
FlexElement 1 Target	
FlexElement 1 Events	
FLEXLELEMENT 2	
FlexElement 2 Function	
FlexElement 2 Name	
FlexElement 2 +IN	
FlexElement 2 –IN	
FlexElement 2 Input Mode	
FlexElement 2 Comp Mode	
FlexElement 2 Direction	
FlexElement 2 Pickup	
FlexElement 2 Hysteresis	
FlexElement 2 dt Unit	
FlexElement 2 dt	
FlexElement 2 Pkp Delay	
FlexElement 2 Rst Delay	
FlexElement 2 Blk	
FlexElement 2 Target	
FlexElement 2 Events	
FLEXLELEMENT 3	
FlexElement 3 Function	
FlexElement 3 Name	
FlexElement 3 +IN	
FlexElement 3 –IN	
FlexElement 3 Input Mode	
FlexElement 3 Comp Mode	
FlexElement 3 Direction	
FlexElement 3 Pickup	
FlexElement 3 Hysteresis	
FlexElement 3 dt Unit	
FlexElement 3 dt	
FlexElement 3 Pkp Delay	
FlexElement 3 Rst Delay	
FlexElement 3 Blk	
FlexElement 3 Target	
FlexElement 3 Events	
FLEXLELEMENT 4	
FlexElement 4 Function	
FlexElement 4 Name	
FlexElement 4 +IN	
FlexElement 4 –IN	
FlexElement 4 Input Mode	

Table 10–5: FLEXLOGIC™ (Sheet 16 of 17)

SETTING	VALUE
FlexElement 4 Comp Mode	
FlexElement 4 Direction	
FlexElement 4 Pickup	
FlexElement 4 Hysteresis	
FlexElement 4 dt Unit	
FlexElement 4 dt	
FlexElement 4 Pkp Delay	
FlexElement 4 Rst Delay	
FlexElement 4 Blk	
FlexElement 4 Target	
FlexElement 4 Events	
FLEXLELEMENT 5	
FlexElement 5 Function	
FlexElement 5 Name	
FlexElement 5 +IN	
FlexElement 5 –IN	
FlexElement 5 Input Mode	
FlexElement 5 Comp Mode	
FlexElement 5 Direction	
FlexElement 5 Pickup	
FlexElement 5 Hysteresis	
FlexElement 5 dt Unit	
FlexElement 5 dt	
FlexElement 5 Pkp Delay	
FlexElement 5 Rst Delay	
FlexElement 5 Blk	
FlexElement 5 Target	
FlexElement 5 Events	
FLEXLELEMENT 6	
FlexElement 6 Function	
FlexElement 6 Name	
FlexElement 6 +IN	
FlexElement 6 –IN	
FlexElement 6 Input Mode	
FlexElement 6 Comp Mode	
FlexElement 6 Direction	
FlexElement 6 Pickup	
FlexElement 6 Hysteresis	
FlexElement 6 dt Unit	
FlexElement 6 dt	
FlexElement 6 Pkp Delay	
FlexElement 6 Rst Delay	
FlexElement 6 Blk	
FlexElement 6 Target	
FlexElement 6 Events	
FLEXLELEMENT 7	
FlexElement 7 Function	

Table 10–5: FLEXLOGIC™ (Sheet 17 of 17)

SETTING	VALUE
FlexElement 7 Name	
FlexElement 7 +IN	
FlexElement 7 –IN	
FlexElement 7 Input Mode	
FlexElement 7 Comp Mode	
FlexElement 7 Direction	
FlexElement 7 Pickup	
FlexElement 7 Hysteresis	
FlexElement 7 dt Unit	
FlexElement 7 dt	
FlexElement 7 Pkp Delay	
FlexElement 7 Rst Delay	
FlexElement 7 Blk	
FlexElement 7 Target	
FlexElement 7 Events	
FLEXLELEMENT 8	
FlexElement 8 Function	
FlexElement 8 Name	
FlexElement 8 +IN	
FlexElement 8 –IN	
FlexElement 8 Input Mode	
FlexElement 8 Comp Mode	
FlexElement 8 Direction	
FlexElement 8 Pickup	
FlexElement 8 Hysteresis	
FlexElement 8 dt Unit	
FlexElement 8 dt	
FlexElement 8 Pkp Delay	
FlexElement 8 Rst Delay	
FlexElement 8 Blk	
FlexElement 8 Target	
FlexElement 8 Events	

10.4.1 SETTINGS

Table 10–6: GROUPED ELEMENTS (Sheet 1 of 13)

SETTING	VALUE
LINE ELEMENTS	
LINE PICKUP	
Line Pickup Function	
Line Pickup Signal Source	
Phase IOC Line Pickup	
Positive Seq. UV Pickup	
Line End Open Pickup Delay	
Line End Open Reset Delay	
Positive Seq. OV Pickup Delay	
AR CO-ORD Bypass	
AR CO-ORD Pickup Delay	
AR CO-ORD Reset Delay	
Line Pickup Block	
Line Pickup Target	
Line Pickup Events	
DISTANCE ELEMENTS	
DISTANCE	
Distance Source	
Memory Duration	
PHASE DISTANCE Z1	
Phs Dist Z1 Function	
Phs Dist Z1 Direction	
Phs Dist Z1 Shape	
Phs Dist Z1 Reach	
Phs Dist Z1 RCA	
Phs Dist Z1 Comp. Limit	
Phs Dist Z1 Dir RCA	
Phs Dist Z1 Dir Comp. Limit	
Phs Dist Z1 Quad Rgt Bld	
Phs Dist Z1 Quad Rgt Bld RCA	
Phs Dist Z1 Quad Lft Bld	
Phs Dist Z1 Quad Lft Bld RCA	
Phs Dist Z1 Supv	
Phs Dist Z1 Volt Level	
Phs Dist Z1 Delay	
Phs Dist Z1 Blk	
Phs Dist Z1 Target	
Phs Dist Z1 Events	
PHASE DISTANCE Z2	
Phs Dist Z2 Function	
Phs Dist Z2 Direction	
Phs Dist Z2 Shape	
Phs Dist Z2 Reach	
Phs Dist Z2 RCA	

Table 10–6: GROUPED ELEMENTS (Sheet 2 of 13)

SETTING	VALUE
Phs Dist Z2 Comp. Limit	
Phs Dist Z2 Dir RCA	
Phs Dist Z2 Dir Comp. Limit	
Phs Dist Z2 Quad Rgt Bld	
Phs Dist Z2 Quad Rgt Bld RCA	
Phs Dist Z2 Quad Lft Bld	
Phs Dist Z2 Quad Lft Bld RCA	
Phs Dist Z2 Supv	
Phs Dist Z2 Volt Level	
Phs Dist Z2 Delay	
Phs Dist Z2 Blk	
Phs Dist Z2 Target	
Phs Dist Z2 Events	
PHASE DISTANCE Z3	
Phs Dist Z3 Function	
Phs Dist Z3 Direction	
Phs Dist Z3 Shape	
Phs Dist Z3 Reach	
Phs Dist Z3 RCA	
Phs Dist Z3 Comp. Limit	
Phs Dist Z3 Dir RCA	
Phs Dist Z3 Dir Comp. Limit	
Phs Dist Z3 Quad Rgt Bld	
Phs Dist Z3 Quad Rgt Bld RCA	
Phs Dist Z3 Quad Lft Bld	
Phs Dist Z3 Quad Lft Bld RCA	
Phs Dist Z3 Supv	
Phs Dist Z3 Volt Level	
Phs Dist Z3 Delay	
Phs Dist Z3 Blk	
Phs Dist Z3 Target	
Phs Dist Z3 Events	
PHASE DISTANCE Z4	
Phs Dist Z4 Function	
Phs Dist Z4 Direction	
Phs Dist Z4 Shape	
Phs Dist Z4 Reach	
Phs Dist Z4 RCA	
Phs Dist Z4 Comp. Limit	
Phs Dist Z4 Dir RCA	
Phs Dist Z4 Dir Comp. Limit	
Phs Dist Z4 Quad Rgt Bld	
Phs Dist Z4 Quad Rgt Bld RCA	
Phs Dist Z4 Quad Lft Bld	

Table 10–6: GROUPED ELEMENTS (Sheet 3 of 13)

SETTING	VALUE
Phs Dist Z4 Quad Lft Bld RCA	
Phs Dist Z4 Supv	
Phs Dist Z4 Volt Level	
Phs Dist Z4 Delay	
Phs Dist Z4 Blk	
Phs Dist Z4 Target	
Phs Dist Z4 Events	
GROUND DISTANCE Z1	
Gnd Dist Z1 Function	
Gnd Dist Z1 Direction	
Gnd Dist Z1 Shape	
Gnd Dist Z1 Z0/Z1 Mag	
Gnd Dist Z1 Z0/Z1 Ang	
Gnd Dist Z1 Z0M/Z1 Mag	
Gnd Dist Z1 Z0M/Z1 Ang	
Gnd Dist Z1 Reach	
Gnd Dist Z1 RCA	
Gnd Dist Z1 Comp Limit	
Gnd Dist Z1 Dir RCA	
Gnd Dist Z1 Dir Comp Limit	
Gnd Dist Z1 Quad Rgt Bld	
Gnd Dist Z1 Quad Rgt Bld RCA	
Gnd Dist Z1 Quad Lft Bld	
Gnd Dist Z1 Quad Lft Bld RCA	
Gnd Dist Z1 Supv	
Gnd Dist Z1 Volt Level	
Gnd Dist Z1 Delay	
Gnd Dist Z1 Block	
Gnd Dist Z1 Target	
Gnd Dist Z1 Events	
GROUND DISTANCE Z2	
Gnd Dist Z2 Function	
Gnd Dist Z2 Direction	
Gnd Dist Z2 Shape	
Gnd Dist Z2 Z0/Z2 Mag	
Gnd Dist Z2 Z0/Z2 Ang	
Gnd Dist Z2 Z0M/Z2 Mag	
Gnd Dist Z2 Z0M/Z2 Ang	
Gnd Dist Z2 Reach	
Gnd Dist Z2 RCA	
Gnd Dist Z2 Comp Limit	
Gnd Dist Z2 Dir RCA	
Gnd Dist Z2 Dir Comp Limit	
Gnd Dist Z2 Quad Rgt Bld	
Gnd Dist Z2 Quad Rgt Bld RCA	
Gnd Dist Z2 Quad Lft Bld	
Gnd Dist Z2 Quad Lft Bld RCA	

Table 10–6: GROUPED ELEMENTS (Sheet 4 of 13)

SETTING	VALUE
Gnd Dist Z2 Supv	
Gnd Dist Z2 Volt Level	
Gnd Dist Z2 Delay	
Gnd Dist Z2 Block	
Gnd Dist Z2 Target	
Gnd Dist Z2 Events	
GROUND DISTANCE Z3	
Gnd Dist Z3 Function	
Gnd Dist Z3 Direction	
Gnd Dist Z3 Shape	
Gnd Dist Z3 Z0/Z3 Mag	
Gnd Dist Z3 Z0/Z3 Ang	
Gnd Dist Z3 Z0M/Z3 Mag	
Gnd Dist Z3 Z0M/Z3 Ang	
Gnd Dist Z3 Reach	
Gnd Dist Z3 RCA	
Gnd Dist Z3 Comp Limit	
Gnd Dist Z3 Dir RCA	
Gnd Dist Z3 Dir Comp Limit	
Gnd Dist Z3 Quad Rgt Bld	
Gnd Dist Z3 Quad Rgt Bld RCA	
Gnd Dist Z3 Quad Lft Bld	
Gnd Dist Z3 Quad Lft Bld RCA	
Gnd Dist Z3 Supv	
Gnd Dist Z3 Volt Level	
Gnd Dist Z3 Delay	
Gnd Dist Z3 Block	
Gnd Dist Z3 Target	
Gnd Dist Z3 Events	
GROUND DISTANCE Z4	
Gnd Dist Z4 Function	
Gnd Dist Z4 Direction	
Gnd Dist Z4 Shape	
Gnd Dist Z4 Z0/Z4 Mag	
Gnd Dist Z4 Z0/Z4 Ang	
Gnd Dist Z4 Z0M/Z4 Mag	
Gnd Dist Z4 Z0M/Z4 Ang	
Gnd Dist Z4 Reach	
Gnd Dist Z4 RCA	
Gnd Dist Z4 Comp Limit	
Gnd Dist Z4 Dir RCA	
Gnd Dist Z4 Dir Comp Limit	
Gnd Dist Z4 Quad Rgt Bld	
Gnd Dist Z4 Quad Rgt Bld RCA	
Gnd Dist Z4 Quad Lft Bld	
Gnd Dist Z4 Quad Lft Bld RCA	
Gnd Dist Z4 Supv	

Table 10–6: GROUPED ELEMENTS (Sheet 5 of 13)

SETTING	VALUE
Gnd Dist Z4 Volt Level	
Gnd Dist Z4 Delay	
Gnd Dist Z4 Block	
Gnd Dist Z4 Target	
Gnd Dist Z4 Events	
POWER SWING DETECT	
Power Swing Function	
Power Swing Source	
Power Swing Mode	
Power Swing Supv	
Power Swing Fwd Reach	
Power Swing Fwd RCA	
Power Swing Rev Reach	
Power Swing Rev RCA	
Power Swing Outer Limit Angle	
Power Swing Middle Limit Angle	
Power Swing Inner Limit Angle	
Power Swing Pickup Delay 1	
Power Swing Reset Delay 1	
Power Swing Pickup Delay 2	
Power Swing Pickup Delay 3	
Power Swing Pickup Delay 4	
Power Swing Seal-In Delay 1	
Power Swing Trip Mode	
Power Swing Blk	
Power Swing Target	
Power Swing Events	
LOAD ENCROACHMENT	
Load Encroachment Function	
Load Encroachment Source	
Load Encroachment Min Volt	
Load Encroachment Reach	
Load Encroachment Angle	
Load Encroachment Pkp Delay	
Load Encroachment Rst Delay	
Load Encroachment Blk	
Load Encroachment Target	
Load Encroachment Events	
CURRENT ELEMENTS	
PHASE TOC1	
Phase TOC1 Function	
Phase TOC1 Signal Source	
Phase TOC1 Input	
Phase TOC1 Pickup	
Phase TOC1 Curve	
Phase TOC1 Multiplier	
Phase TOC1 Reset	

Table 10–6: GROUPED ELEMENTS (Sheet 6 of 13)

SETTING	VALUE
Phase TOC1 Voltage Restraint	
Phase TOC1 Block A	
Phase TOC1 Block B	
Phase TOC1 Block C	
Phase TOC1 Target	
Phase TOC1 Events	
PHASE TOC2	
Phase TOC2 Function	
Phase TOC2 Signal Source	
Phase TOC2 Input	
Phase TOC2 Pickup	
Phase TOC2 Curve	
Phase TOC2 Multiplier	
Phase TOC2 Reset	
Phase TOC2 Voltage Restraint	
Phase TOC2 Block A	
Phase TOC2 Block B	
Phase TOC2 Block C	
Phase TOC2 Target	
Phase TOC2 Events	
PHASE IOC1	
Phase IOC1 Function	
Phase IOC1 Signal Source	
Phase IOC1 Pickup	
Phase IOC1 Pickup Delay	
Phase IOC1 Reset Delay	
Phase IOC1 Block A	
Phase IOC1 Block B	
Phase IOC1 Block C	
Phase IOC1 Target	
Phase IOC1 Events	
PHASE IOC2	
Phase IOC2 Function	
Phase IOC2 Signal Source	
Phase IOC2 Pickup	
Phase IOC2 Pickup Delay	
Phase IOC2 Reset Delay	
Phase IOC2 Block A	
Phase IOC2 Block B	
Phase IOC2 Block C	
Phase IOC2 Target	
Phase IOC2 Events	
NEUTRAL TOC1	
Neutral TOC1 Function	
Neutral TOC1 Signal Source	
Neutral TOC1 Input	
Neutral TOC1 Pickup	

Table 10–6: GROUPED ELEMENTS (Sheet 7 of 13)

SETTING	VALUE
Neutral TOC1 Curve	
Neutral TOC1 TD Multiplier	
Neutral TOC1 Reset	
Neutral TOC1 Block	
Neutral TOC1 Target	
Neutral TOC1 Events	
NEUTRAL TOC2	
Neutral TOC2 Function	
Neutral TOC2 Signal Source	
Neutral TOC2 Input	
Neutral TOC2 Pickup	
Neutral TOC2 Curve	
Neutral TOC2 TD Multiplier	
Neutral TOC2 Reset	
Neutral TOC2 Block	
Neutral TOC2 Target	
Neutral TOC2 Events	
NEUTRAL IOC1	
Neutral IOC1 Function	
Neutral IOC1 Signal Source	
Neutral IOC1 Pickup	
Neutral IOC1 Pickup Delay	
Neutral IOC1 Reset Delay	
Neutral IOC1 Block	
Neutral IOC1 Target	
Neutral IOC1 Events	
NEUTRAL IOC2	
Neutral IOC2 Function	
Neutral IOC2 Signal Source	
Neutral IOC2 Pickup	
Neutral IOC2 Pickup Delay	
Neutral IOC2 Reset Delay	
Neutral IOC2 Block	
Neutral IOC2 Target	
Neutral IOC2 Events	
GROUND TOC1	
Ground TOC1 Function	
Ground TOC1 Signal Source	
Ground TOC1 Input	
Ground TOC1 Pickup	
Ground TOC1 Curve	
Ground TOC1 TD Multiplier	
Ground TOC1 Reset	
Ground TOC1 Block	
Ground TOC1 Target	
Ground TOC1 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 8 of 13)

SETTING	VALUE
GROUND TOC2	
Ground TOC2 Function	
Ground TOC2 Signal Source	
Ground TOC2 Input	
Ground TOC2 Pickup	
Ground TOC2 Curve	
Ground TOC2 TD Multiplier	
Ground TOC2 Reset	
Ground TOC2 Block	
Ground TOC2 Target	
Ground TOC2 Events	
GROUND IOC1	
Ground IOC1 Function	
Ground IOC1 Signal Source	
Ground IOC1 Pickup	
Ground IOC1 Pickup Delay	
Ground IOC1 Reset Delay	
Ground IOC1 Block	
Ground IOC1 Target	
Ground IOC1 Events	
GROUND IOC2	
Ground IOC2 Function	
Ground IOC2 Signal Source	
Ground IOC2 Pickup	
Ground IOC2 Pickup Delay	
Ground IOC2 Reset Delay	
Ground IOC2 Block	
Ground IOC2 Target	
Ground IOC2 Events	
NEG SEQ TOC1	
Neg. Seq. TOC1 Function	
Neg. Seq. TOC1 Signal Source	
Neg. Seq. TOC1 Pickup	
Neg. Seq. TOC1 Curve	
Neg. Seq. TOC1 TD Multiplier	
Neg. Seq. TOC1 Reset	
Neg. Seq. TOC1 Block	
Neg. Seq. TOC1 Target	
Neg. Seq. TOC1 Events	
NEG SEQ TOC2	
Neg. Seq. TOC2 Function	
Neg. Seq. TOC2 Signal Source	
Neg. Seq. TOC2 Pickup	
Neg. Seq. TOC2 Curve	
Neg. Seq. TOC2 TD Multiplier	
Neg. Seq. TOC2 Reset	
Neg. Seq. TOC2 Block	

Table 10–6: GROUPED ELEMENTS (Sheet 9 of 13)

SETTING	VALUE
Neg. Seq. TOC2 Target	
Neg. Seq. TOC2 Events	
NEG SEQ IOC1	
Neg. Seq. IOC1 Function	
Neg. Seq. IOC1 Signal Source	
Neg. Seq. IOC1 Pickup	
Neg. Seq. IOC1 Pickup Delay	
Neg. Seq. IOC1 Reset Delay	
Neg. Seq. IOC1 Block	
Neg. Seq. IOC1 Target	
Neg. Seq. IOC1 Events	
NEG SEQ IOC2	
Neg. Seq. IOC2 Function	
Neg. Seq. IOC2 Signal Source	
Neg. Seq. IOC2 Pickup	
Neg. Seq. IOC2 Pickup Delay	
Neg. Seq. IOC2 Reset Delay	
Neg. Seq. IOC2 Block	
Neg. Seq. IOC2 Target	
Neg. Seq. IOC2 Events	
CURRENT DIRECTIONALS	
PHASE DIRECTIONAL 1	
Phase Dir 1 Function	
Phase Dir 1 Signal Source	
Phase Dir 1 Block	
Phase Dir 1 ECA	
Phase Dir Pol V1 Threshold	
Phase Dir 1 Block When V Mem Exp	
Phase Dir 1 Target	
Phase Dir 1 Events	
PHASE DIRECTIONAL 2	
Phase Dir 2 Function	
Phase Dir 2 Signal Source	
Phase Dir 2 Block	
Phase Dir 2 ECA	
Phase Dir Pol V2 Threshold	
Phase Dir 2 Block When V Mem Exp	
Phase Dir 2 Target	
Phase Dir 2 Events	
NEUTRAL DIRECTIONAL OC1	
Neutral Dir OC1 Function	
Neutral Dir OC1 Source	
Neutral Dir OC1 Polarizing	
Neutral Dir OC1 Pol Volt	
Neutral Dir OC1 Op Curr	
Neutral Dir OC1 Offeset	
Neutral Dir OC1 Fwd ECA	

Table 10–6: GROUPED ELEMENTS (Sheet 10 of 13)

SETTING	VALUE
Neutral Dir OC1 Fwd Limit Angle	
Neutral Dir OC1 Fwd Pickup	
Neutral Dir OC1 Rev Limit Angle	
Neutral Dir OC1 Rev Pickup	
Neutral Dir OC1 Blk	
Neutral Dir OC1 Target	
Neutral Dir OC1 Events	
NEUTRAL DIRECTIONAL OC2	
Neutral Dir OC2 Function	
Neutral Dir OC2 Source	
Neutral Dir OC2 Polarizing	
Neutral Dir OC2 Pol Volt	
Neutral Dir OC2 Op Curr	
Neutral Dir OC2 Offeset	
Neutral Dir OC2 Fwd ECA	
Neutral Dir OC2 Fwd Limit Angle	
Neutral Dir OC2 Fwd Pickup	
Neutral Dir OC2 Rev Limit Angle	
Neutral Dir OC2 Rev Pickup	
Neutral Dir OC2 Blk	
Neutral Dir OC2 Target	
Neutral Dir OC2 Events	
NEG SEQ DIRECTIONAL OC1	
Neg Seq Dir OC1 Function	
Neg Seq Dir OC1 Source	
Neg Seq Dir OC1 Offset	
Neg Seq Dir OC1 Type	
Neg Seq Dir OC1 Fwd ECA	
Neg Seq Dir OC1 Fwd Limit Angle	
Neg Seq Dir OC1 Fwd Pickup	
Neg Seq Dir OC1 Rev Limit Angle	
Neg Seq Dir OC1 Rev Pickup	
Neg Seq Dir OC1 Block	
Neg Seq Dir OC1 Target	
Neg Seq Dir OC1 Events	
NEG SEQ DIRECTIONAL OC2	
Neg Seq Dir OC2 Function	
Neg Seq Dir OC2 Source	
Neg Seq Dir OC2 Offset	
Neg Seq Dir OC2 Type	
Neg Seq Dir OC2 Fwd ECA	
Neg Seq Dir OC2 Fwd Limit Angle	
Neg Seq Dir OC2 Fwd Pickup	
Neg Seq Dir OC2 Rev Limit Angle	
Neg Seq Dir OC2 Rev Pickup	
Neg Seq Dir OC2 Block	
Neg Seq Dir OC2 Target	

Table 10–6: GROUPED ELEMENTS (Sheet 11 of 13)

SETTING	VALUE
Neg Seq Dir OC2 Events	
BREAKER FAILURE ELEMENTS	
BREAKER FAILURE 1	
BF1 Function	
BF1 Mode	
BF1 Source	
BF1 Use Amp Supv	
BF1 Use Seal-In	
BF1 3-Pole Initiate	
BF1 Block	
BF1 Ph Amp Supv Pickup	
BF1 N Amp Supv Pickup	
BF1 Use Timer 1	
BF1 Timer 1 Pickup Delay	
BF1 Use Timer 2	
BF1 Timer 2 Pickup Delay	
BF1 Use Timer 3	
BF1 Timer 3 Pickup Delay	
BF1 Bkr POS1 ΦA/3P	
BF1 Bkr POS2 ΦA/3P	
BF1 Breaker Test On	
BF1 Ph Amp Hiset Pickup	
BF1 N Amp Hiset Pickup	
BF1 Ph Amp Loset Pickup	
BF1 N Amp Loset Pickup	
BF1 Loset Time Delay	
BF1 Trip Dropout Delay	
BF1 Target	
BF1 Events	
BF1 Ph A Initiate	
BF1 Ph B Initiate	
BF1 Ph C Initiate	
BF1 Bkr POS1 ΦB	
BF1 Bkr POS1 ΦC	
BF1 Bkr POS2 ΦB	
BF1 Bkr POS2 ΦC	
BREAKER FAILURE 2	
BF2 Function	
BF2 Mode	
BF2 Source	
BF2 Use Amp Supv	
BF2 Use Seal-In	
BF2 3-Pole Initiate	
BF2 Block	
BF2 Ph Amp Supv Pickup	
BF2 N Amp Supv Pickup	
BF2 Use Timer 1	

Table 10–6: GROUPED ELEMENTS (Sheet 12 of 13)

SETTING	VALUE
BF2 Timer 1 Pickup Delay	
BF2 Use Timer 2	
BF2 Timer 2 Pickup Delay	
BF2 Use Timer 3	
BF2 Timer 3 Pickup Delay	
BF2 Bkr POS1 ΦA/3P	
BF2 Bkr POS2 ΦA/3P	
BF2 Breaker Test On	
BF2 Ph Amp Hiset Pickup	
BF2 N Amp Hiset Pickup	
BF2 Ph Amp Loset Pickup	
BF2 N Amp Loset Pickup	
BF2 Loset Time Delay	
BF2 Trip Dropout Delay	
BF2 Target	
BF2 Events	
BF2 Ph A Initiate	
BF2 Ph B Initiate	
BF2 Ph C Initiate	
BF2 Bkr POS1 ΦB	
BF2 Bkr POS1 ΦC	
BF2 Bkr POS2 ΦB	
BF2 Bkr POS2 ΦC	
VOLTAGE ELEMENTS	
PHASE UNDERVOLTAGE 1	
Phase UV1 Function	
Phase UV1 Signal Source	
Phase UV1 Mode	
Phase UV1 Pickup	
Phase UV1 Curve	
Phase UV1 Delay	
Phase UV1 Minimum Voltage	
Phase UV1 Block	
Phase UV1 Target	
Phase UV1 Events	
PHASE UNDERVOLTAGE 2	
Phase UV2 Function	
Phase UV2 Signal Source	
Phase UV2 Mode	
Phase UV2 Pickup	
Phase UV2 Curve	
Phase UV2 Delay	
Phase UV2 Minimum Voltage	
Phase UV2 Block	
Phase UV2 Target	
Phase UV2 Events	

Table 10–6: GROUPED ELEMENTS (Sheet 13 of 13)

SETTING	VALUE
PHASE OVERVOLTAGE 1	
Phase OV1 Function	
Phase OV1 Signal Source	
Phase OV1 Pickup	
Phase OV1 Delay	
Phase OV1 Reset Delay	
Phase OV1 Block	
Phase OV1 Target	
Phase OV1 Events	
NEUTRAL OVERVOLTAGE 1	
Neutral OV1 Function	
Neutral OV1 Signal Source	
Neutral OV1 Pickup	
Neutral OV1 Pickup Delay	
Neutral OV1 Reset Delay	
Neutral OV1 Block	
Neutral OV1 Target	
Neutral OV1 Events	
NEGATIVE SEQUENCE OVERVOLTAGE	
Neg Seq OV Function	
Neg Seq OV Signal Source	
Neg Seq OV Pickup	
Neg Seq OV Delay	
Neg Seq OV Reset Delay	
Neg Seq OV Block	
Neg Seq OV Target	
Neg Seq OV Events	
AUXILIARY UNDERVOLTAGE 1	
Aux UV1 Function	
Aux UV1 Signal Source	
Aux UV1 Pickup	
Aux UV1 Curve	
Aux UV1 Delay	
Aux UV1 Minimum Voltage	
Aux UV1 Block	
Aux UV1 Target	
Aux UV1 Events	
AUXILIARY OVERVOLTAGE 1	
Aux OV1 Function	
Aux OV1 Signal Source	
Aux OV1 Pickup	
Aux OV1 Pickup Delay	
Aux OV1 Reset Delay	
Aux OV1 Block	
Aux OV1 Target	
Aux OV1 Events	

10.5.1 SETTINGS

Table 10–7: CONTROL ELEMENTS (Sheet 1 of 10)

SETTING	VALUE
SETTING GROUPS	
Setting Groups Function	
Setting Groups Block	
Group 2 Activate On	
Group 3 Activate On	
Group 4 Activate On	
Group 5 Activate On	
Group 6 Activate On	
Group 7 Activate On	
Group 8 Activate On	
Setting Group Events	
TRIP OUTPUT	
Trip Mode	
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	
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	
Trip Reclose Input-1	
Trip Reclose Input-2	
Trip Reclose Input-3	
Trip Reclose Input-4	
Trip Reclose Input-5	
Trip Reclose Input-6	
Trip Force 3-Pole	
Trip Pilot Priority	
Bkr ΦA Open	
Bkr ΦA Open	
Bkr ΦA Open	
Trip Events	
SYNCHROCHECK 1	
Synchk1 Function	
Synchk1 Block	
Synchk1 V1 Source	
Synchk1 V2 Source	
Synchk1 Max Volt Diff	
Synchk1 Max Angle Diff	

Table 10–7: CONTROL ELEMENTS (Sheet 2 of 10)

SETTING	VALUE
Synchk1 Max Freq Diff	
Synchk1 Dead Source Select	
Synchk1 Dead V1 Max Volt	
Synchk1 Dead V2 Max Volt	
Synchk1 Line V1 Min Volt	
Synchk1 Line V2 Min Volt	
Synchk1 Target	
Synchk1 Events	
SYNCHROCHECK 2	
Synchk2 Function	
Synchk2 Block	
Synchk2 V1 Source	
Synchk2 V2 Source	
Synchk2 Max Volt Diff	
Synchk2 Max Angle Diff	
Synchk2 Max Freq Diff	
Synchk2 Dead Source Select	
Synchk2 Dead V1 Max Volt	
Synchk2 Dead V2 Max Volt	
Synchk2 Line V1 Min Volt	
Synchk2 Line V2 Min Volt	
Synchk2 Target	
Synchk2 Events	
AUTORECLOSE	
AR Function	
AR Mode	
AR Max Number of Shots	
AR Block Bkr1	
AR Bkr 1 Mnl Close	
AR Close Time Bkr1	
AR Blk Time Upon Man Cls	
AR 1P Init	
AR 3P Init	
AR 3P TD Init	
AR 3-P Dead Time 1	
AR 3-P Dead Time 2	
AR Extend Dead T 1	
AR Dead Time 1 Extension	
AR Reset	
AR Reset Time	
AR Block	
AR Pause	
AR Incomplete Seq Time	
AR Block Bkr 2	

Table 10–7: CONTROL ELEMENTS (Sheet 3 of 10)

SETTING	VALUE
AR Bkr Mnl Close	
AR Close Time Bkr2	
AR Transfer 1 to 2	
AR Transfer 2 to 1	
AR Bkr1 Fail Option	
AR Bkr2 Fail Option	
AR 1-P Dead Time	
AR Bkr Sequence	
AR Transfer Time	
AR Event	
DIGITAL ELEMENT 1	
Digital Element 1 Function	
Dig Elem 1 Name	
Dig Elem 1 Input	
Dig Elem 1 Pickup Delay	
Dig Elem 1 Reset Delay	
Dig Elem 1 Block	
Digital Element 1 Target	
Digital Element 1 Events	
DIGITAL ELEMENT 2	
Digital Element 2 Function	
Dig Elem 2 Name	
Dig Elem 2 Input	
Dig Elem 2 Pickup Delay	
Dig Elem 2 Reset Delay	
Dig Elem 2 Block	
Digital Element 2 Target	
Digital Element 2 Events	
DIGITAL ELEMENT 3	
Digital Element 3 Function	
Dig Elem 3 Name	
Dig Elem 3 Input	
Dig Elem 3 Pickup Delay	
Dig Elem 3 Reset Delay	
Dig Elem 3 Block	
Digital Element 3 Target	
Digital Element 3 Events	
DIGITAL ELEMENT 4	
Digital Element 4 Function	
Dig Elem 4 Name	
Dig Elem 4 Input	
Dig Elem 4 Pickup Delay	
Dig Elem 4 Reset Delay	
Dig Elem 4 Block	
Digital Element 4 Target	
Digital Element 4 Events	

Table 10–7: CONTROL ELEMENTS (Sheet 4 of 10)

SETTING	VALUE
DIGITAL ELEMENT 5	
Digital Element 5 Function	
Dig Elem 5 Name	
Dig Elem 5 Input	
Dig Elem 5 Pickup Delay	
Dig Elem 5 Reset Delay	
Dig Elem 5 Block	
Digital Element 5 Target	
Digital Element 5 Events	
DIGITAL ELEMENT 6	
Digital Element 6 Function	
Dig Elem 6 Name	
Dig Elem 6 Input	
Dig Elem 6 Pickup Delay	
Dig Elem 6 Reset Delay	
Dig Elem 6 Block	
Digital Element 6 Target	
Digital Element 6 Events	
DIGITAL ELEMENT 7	
Digital Element 7 Function	
Dig Elem 7 Name	
Dig Elem 7 Input	
Dig Elem 7 Pickup Delay	
Dig Elem 7 Reset Delay	
Dig Elem 7 Block	
Digital Element 7 Target	
Digital Element 7 Events	
DIGITAL ELEMENT 8	
Digital Element 8 Function	
Dig Elem 8 Name	
Dig Elem 8 Input	
Dig Elem 8 Pickup Delay	
Dig Elem 8 Reset Delay	
Dig Elem 8 Block	
Digital Element 8 Target	
Digital Element 8 Events	
DIGITAL ELEMENT 9	
Digital Element 9 Function	
Dig Elem 9 Name	
Dig Elem 9 Input	
Dig Elem 9 Pickup Delay	
Dig Elem 9 Reset Delay	
Dig Elem 9 Block	
Digital Element 9 Target	
Digital Element 9 Events	
DIGITAL ELEMENT 10	
Digital Element 10 Function	

Table 10–7: CONTROL ELEMENTS (Sheet 5 of 10)

SETTING	VALUE
Dig Elem 10 Name	
Dig Elem 10 Input	
Dig Elem 10 Pickup Delay	
Dig Elem 10 Reset Delay	
Dig Elem 10 Block	
Digital Element 10 Target	
Digital Element 10 Events	
DIGITAL ELEMENT 11	
Digital Element 11 Function	
Dig Elem 11 Name	
Dig Elem 11 Input	
Dig Elem 11 Pickup Delay	
Dig Elem 11 Reset Delay	
Dig Elem 11 Block	
Digital Element 11 Target	
Digital Element 11 Events	
DIGITAL ELEMENT 12	
Digital Element 12 Function	
Dig Elem 12 Name	
Dig Elem 12 Input	
Dig Elem 12 Pickup Delay	
Dig Elem 12 Reset Delay	
Dig Elem 12 Block	
Digital Element 12 Target	
Digital Element 12 Events	
DIGITAL ELEMENT 13	
Digital Element 13 Function	
Dig Elem 13 Name	
Dig Elem 13 Input	
Dig Elem 13 Pickup Delay	
Dig Elem 13 Reset Delay	
Dig Elem 13 Block	
Digital Element 13 Target	
Digital Element 13 Events	
DIGITAL ELEMENT 14	
Digital Element 14 Function	
Dig Elem 14 Name	
Dig Elem 14 Input	
Dig Elem 14 Pickup Delay	
Dig Elem 14 Reset Delay	
Dig Elem 14 Block	
Digital Element 14 Target	
Digital Element 14 Events	
DIGITAL ELEMENT 15	
Digital Element 15 Function	
Dig Elem 15 Name	
Dig Elem 15 Input	

Table 10–7: CONTROL ELEMENTS (Sheet 6 of 10)

SETTING	VALUE
Dig Elem 15 Pickup Delay	
Dig Elem 15 Reset Delay	
Dig Elem 15 Block	
Digital Element 15 Target	
Digital Element 15 Events	
DIGITAL ELEMENT 16	
Digital Element 16 Function	
Dig Elem 16 Name	
Dig Elem 16 Input	
Dig Elem 16 Pickup Delay	
Dig Elem 16 Reset Delay	
Dig Elem 16 Block	
Digital Element 16 Target	
Digital Element 16 Events	
DIGITAL COUNTER 1	
Counter 1 Function	
Counter 1 Name	
Counter 1 Units	
Counter 1 Preset	
Counter 1 Compare	
Counter 1 Up	
Counter 1 Down	
Counter 1 Block	
Counter 1 Set to Preset	
Counter 1 Reset	
Counter 1 Freeze/Reset	
Counter 1 Freeze/Count	
DIGITAL COUNTER 2	
Counter 2 Function	
Counter 2 Name	
Counter 2 Units	
Counter 2 Preset	
Counter 2 Compare	
Counter 2 Up	
Counter 2 Down	
Counter 2 Block	
Counter 2 Set to Preset	
Counter 2 Reset	
Counter 2 Freeze/Reset	
Counter 2 Freeze/Count	
DIGITAL COUNTER 3	
Counter 3 Function	
Counter 3 Name	
Counter 3 Units	
Counter 3 Preset	
Counter 3 Compare	
Counter 3 Up	

Table 10–7: CONTROL ELEMENTS (Sheet 7 of 10)

SETTING	VALUE
Counter 3 Down	
Counter 3 Block	
Counter 3 Set to Preset	
Counter 3 Reset	
Counter 3 Freeze/Reset	
Counter 3 Freeze/Count	
DIGITAL COUNTER 4	
Counter 4 Function	
Counter 4 Name	
Counter 4 Units	
Counter 4 Preset	
Counter 4 Compare	
Counter 4 Up	
Counter 4 Down	
Counter 4 Block	
Counter 4 Set to Preset	
Counter 4 Reset	
Counter 4 Freeze/Reset	
Counter 4 Freeze/Count	
DIGITAL COUNTER 5	
Counter 5 Function	
Counter 5 Name	
Counter 5 Units	
Counter 5 Preset	
Counter 5 Compare	
Counter 5 Up	
Counter 5 Down	
Counter 5 Block	
Counter 5 Set to Preset	
Counter 5 Reset	
Counter 5 Freeze/Reset	
Counter 5 Freeze/Count	
DIGITAL COUNTER 6	
Counter 6 Function	
Counter 6 Name	
Counter 6 Units	
Counter 6 Preset	
Counter 6 Compare	
Counter 6 Up	
Counter 6 Down	
Counter 6 Block	
Counter 6 Set to Preset	
Counter 6 Reset	
Counter 6 Freeze/Reset	
Counter 6 Freeze/Count	
DIGITAL COUNTER 7	
Counter 7 Function	

Table 10–7: CONTROL ELEMENTS (Sheet 8 of 10)

SETTING	VALUE
Counter 7 Name	
Counter 7 Units	
Counter 7 Preset	
Counter 7 Compare	
Counter 7 Up	
Counter 7 Down	
Counter 7 Block	
Counter 7 Set to Preset	
Counter 7 Reset	
Counter 7 Freeze/Reset	
Counter 7 Freeze/Count	
DIGITAL COUNTER 8	
Counter 8 Function	
Counter 8 Name	
Counter 8 Units	
Counter 8 Preset	
Counter 8 Compare	
Counter 8 Up	
Counter 8 Down	
Counter 8 Block	
Counter 8 Set to Preset	
Counter 8 Reset	
Counter 8 Freeze/Reset	
Counter 8 Freeze/Count	
BREAKER 1 ARCING CURRENT	
Bkr 1 Arc Amp Function	
Bkr 1 Arc Amp Source	
Bkr 1 Arc Amp Init	
Bkr 1 Arc Amp Delay	
Bkr 1 Arc Amp Limit	
Bkr 1 Arc Amp Block	
Bkr 1 Arc Amp Target	
Bkr 1 Arc Amp Events	
BREAKER 2 ARCING CURRENT	
Bkr 2 Arc Amp Function	
Bkr 2 Arc Amp Source	
Bkr 2 Arc Amp Init	
Bkr 2 Arc Amp Delay	
Bkr 2 Arc Amp Limit	
Bkr 2 Arc Amp Block	
Bkr 2 Arc Amp Target	
Bkr 2 Arc Amp Events	
VT FUSE FAILURE	
VT Fuse Failure Function	
OPEN POLE DETECTOR	
Open Pole Function	
Open Pole Block	

Table 10–7: CONTROL ELEMENTS (Sheet 9 of 10)

SETTING	VALUE
Open Pole Voltage Supv	
Open Pole Current Pkp	
Open Pole Target	
Open Pole Events	
DUTT SCHEME	
DUTT Scheme Function	
DUTT Seal-In Delay	
DUTT No of Comm Bits	
DUTT RX1	
DUTT RX2	
DUTT RX3	
DUTT RX4	
DUTT Scheme Target	
DUTT Scheme Events	
PUTT SCHEME	
PUTT Scheme Function	
PUTT RX Pickup Delay	
PUTT Seal-In Delay	
PUTT No of Comm Bits	
PUTT RX1	
PUTT RX2	
PUTT RX3	
PUTT RX4	
PUTT Scheme Target	
PUTT Scheme Events	
POTT SCHEME	
POTT Scheme Function	
POTT Permissive Echo	
POTT RX Pickup Delay	
Trans Block Pickup Delay	
Trans Block Reset Delay	
Echo Duration	
Echo Lockout	
Line End Open Pickup Delay	
POTT Seal-In Delay	
Gnd Dir O/C Fwd	
POTT No of Comm Bits	
POTT RX1	
POTT RX2	
POTT RX3	
POTT RX4	
POTT Scheme Target	
POTT Scheme Events	
HYBRID POTT SCHEME	
Hyb POTT Scheme Function	
Hyb POTT Permissive Echo	
Hyb POTT Rx Pickup Delay	

Table 10–7: CONTROL ELEMENTS (Sheet 10 of 10)

SETTING	VALUE
Trans Block Pickup Delay	
Trans Bloick Reset Delay	
Echo Duration	
Echo Lockout	
Hyb POTT Seal-In Delay	
Gnd Dir O/C Fwd	
Gnd Dir O/C Rev	
Hyb POTT No of Comm Bits	
Hyb POTT RX1	
Hyb POTT RX2	
Hyb POTT RX3	
Hyb POTT RX4	
Hyb POTT Scheme Target	
Hyb POTT Scheme Event	
BLOCKING SCHEME	
Blocking Scheme Function	
Block Rx Co-ord Pkp Delay	
Trans Block Pickup Delay	
Trans Block Reset Delay	
Block Scheme Seal-In Delay	
Gnd Dir O/C Fwd	
Gnd Dir O/C Rev	
Block Scheme No of Comm Bits	
Block Scheme RX1	
Block Scheme RX2	
Block Scheme RX3	
Block Scheme RX4	
Block Scheme Target	
Block Scheme Event	

10.6.1 CONTACT INPUTS

Table 10–8: CONTACT INPUTS

CONTACT INPUT	ID	DEBNCE TIME	EVENTS	THRESHOLD

10.6.2 VIRTUAL INPUTS

Table 10–9: VIRTUAL INPUTS

VIRTUAL INPUT	FUNCTION	ID	TYPE	EVENTS
Virtual Input 1				
Virtual Input 2				
Virtual Input 3				
Virtual Input 4				
Virtual Input 5				
Virtual Input 6				
Virtual Input 7				
Virtual Input 8				
Virtual Input 9				
Virtual Input 10				
Virtual Input 11				
Virtual Input 12				
Virtual Input 13				
Virtual Input 14				
Virtual Input 15				
Virtual Input 16				
Virtual Input 17				
Virtual Input 18				
Virtual Input 19				
Virtual Input 20				
Virtual Input 21				
Virtual Input 22				
Virtual Input 23				
Virtual Input 24				
Virtual Input 25				
Virtual Input 26				
Virtual Input 27				
Virtual Input 28				
Virtual Input 29				
Virtual Input 30				
Virtual Input 31				
Virtual Input 32				

10.6.3 UCA SBO TIMER

Table 10–10: UCA SBO TIMER

UCA SBO TIMER	
UCA SBO Timeout	

10.6.4 CONTACT OUTPUTS

Table 10–11: CONTACT OUTPUTS

CONTACT OUTPUT	ID	OPERATE	SEAL-IN	EVENTS

10.6.5 VIRTUAL OUTPUTS

Table 10–12: VIRTUAL OUTPUTS (Sheet 1 of 2)

VIRTUAL OUTPUT	ID	EVENTS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
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22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		

Table 10–12: VIRTUAL OUTPUTS (Sheet 2 of 2)

VIRTUAL OUTPUT	ID	EVENTS
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
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59		
60		
61		
62		
63		
64		

10.6.6 REMOTE DEVICES

Table 10–13: REMOTE DEVICES

REMOTE DEVICE	ID
Remote Device 1	
Remote Device 2	
Remote Device 3	
Remote Device 4	
Remote Device 5	
Remote Device 6	
Remote Device 7	
Remote Device 8	
Remote Device 9	
Remote Device 10	
Remote Device 11	
Remote Device 12	
Remote Device 13	
Remote Device 14	
Remote Device 15	
Remote Device 16	

10.6.7 REMOTE INPUTS

Table 10–14: REMOTE INPUTS

REMOTE INPUT	REMOTE DEVICE	BIT PAIR	DEFAULT STATE	EVENTS
Remote Input 1				
Remote Input 2				
Remote Input 3				
Remote Input 4				
Remote Input 5				
Remote Input 6				
Remote Input 7				
Remote Input 8				
Remote Input 9				
Remote Input 10				
Remote Input 11				
Remote Input 12				
Remote Input 13				
Remote Input 14				
Remote Input 15				
Remote Input 16				
Remote Input 17				
Remote Input 18				
Remote Input 19				
Remote Input 20				
Remote Input 21				
Remote Input 22				
Remote Input 23				
Remote Input 24				
Remote Input 25				
Remote Input 26				
Remote Input 27				
Remote Input 28				
Remote Input 29				
Remote Input 30				
Remote Input 31				
Remote Input 32				

10.6.8 REMOTE OUTPUTS

Table 10–15: REMOTE OUTPUTS (Sheet 1 of 2)

OUTPUT #	OPERAND	EVENTS
REMOTE OUTPUTS – DNA		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
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19		
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21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		

Table 10–15: REMOTE OUTPUTS (Sheet 2 of 2)

OUTPUT #	OPERAND	EVENTS
REMOTE OUTPUTS – UserSt		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
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23		
24		
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26		
27		
28		
29		
30		
31		
32		

10.6.9 RESETTING

SETTING	VALUE
RESETTING	
Reset Operand	

10.7.1 DCMA INPUTS

Table 10–16: DCMA INPUTS

DCMA INPUT	FUNCTION	ID	UNITS	RANGE	VALUES	
					MIN	MAX

10.7.2 RTD INPUTS

Table 10–17: RTD INPUTS

RTD INPUT	FUNCTION	ID	TYPE

10.8.1 SETTINGS TABLES

Table 10–18: FORCE CONTACT INPUTS

FORCE CONTACT	INPUT

Table 10–19: FORCE CONTACT OUTPUTS

FORCE CONTACT	OUTPUT

A.1.1 PARAMETER LIST

Table A–1: FLEXANALOG PARAMETERS (Sheet 1 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6144	SRC 1 Ia RMS	SRC 1 Phase A Current RMS (A)
6146	SRC 1 Ib RMS	SRC 1 Phase B Current RMS (A)
6148	SRC 1 Ic RMS	SRC 1 Phase C Current RMS (A)
6150	SRC 1 In RMS	SRC 1 Neutral Current RMS (A)
6152	SRC 1 Ia Mag	SRC 1 Phase A Current Magnitude (A)
6154	SRC 1 Ia Angle	SRC 1 Phase A Current Angle (°)
6155	SRC 1 Ib Mag	SRC 1 Phase B Current Magnitude (A)
6157	SRC 1 Ib Angle	SRC 1 Phase B Current Angle (°)
6158	SRC 1 Ic Mag	SRC 1 Phase C Current Magnitude (A)
6160	SRC 1 Ic Angle	SRC 1 Phase C Current Angle (°)
6161	SRC 1 In Mag	SRC 1 Neutral Current Magnitude (A)
6163	SRC 1 In Angle	SRC 1 Neutral Current Angle (°)
6164	SRC 1 Ig RMS	SRC 1 Ground Current RMS (A)
6166	SRC 1 Ig Mag	SRC 1 Ground Current Magnitude (A)
6168	SRC 1 Ig Angle	SRC 1 Ground Current Angle (°)
6169	SRC 1 I_0 Mag	SRC 1 Zero Sequence Current Magnitude (A)
6171	SRC 1 I_0 Angle	SRC 1 Zero Sequence Current Angle (°)
6172	SRC 1 I_1 Mag	SRC 1 Positive Sequence Current Magnitude (A)
6174	SRC 1 I_1 Angle	SRC 1 Positive Sequence Current Angle (°)
6175	SRC 1 I_2 Mag	SRC 1 Negative Sequence Current Magnitude (A)
6177	SRC 1 I_2 Angle	SRC 1 Negative Sequence Current Angle (°)
6178	SRC 1 Igd Mag	SRC 1 Differential Ground Current Magnitude (A)
6180	SRC 1 Igd Angle	SRC 1 Differential Ground Current Angle (°)
6208	SRC 2 Ia RMS	SRC 2 Phase A Current RMS (A)
6210	SRC 2 Ib RMS	SRC 2 Phase B Current RMS (A)
6212	SRC 2 Ic RMS	SRC 2 Phase C Current RMS (A)
6214	SRC 2 In RMS	SRC 2 Neutral Current RMS (A)
6216	SRC 2 Ia Mag	SRC 2 Phase A Current Magnitude (A)
6218	SRC 2 Ia Angle	SRC 2 Phase A Current Angle (°)
6219	SRC 2 Ib Mag	SRC 2 Phase B Current Magnitude (A)
6221	SRC 2 Ib Angle	SRC 2 Phase B Current Angle (°)
6222	SRC 2 Ic Mag	SRC 2 Phase C Current Magnitude (A)
6224	SRC 2 Ic Angle	SRC 2 Phase C Current Angle (°)
6225	SRC 2 In Mag	SRC 2 Neutral Current Magnitude (A)
6227	SRC 2 In Angle	SRC 2 Neutral Current Angle (°)
6228	SRC 2 Ig RMS	SRC 2 Ground Current RMS (A)
6230	SRC 2 Ig Mag	SRC 2 Ground Current Magnitude (A)
6232	SRC 2 Ig Angle	SRC 2 Ground Current Angle (°)
6233	SRC 2 I_0 Mag	SRC 2 Zero Sequence Current Magnitude (A)
6235	SRC 2 I_0 Angle	SRC 2 Zero Sequence Current Angle (°)
6236	SRC 2 I_1 Mag	SRC 2 Positive Sequence Current Magnitude (A)
6238	SRC 2 I_1 Angle	SRC 2 Positive Sequence Current Angle (°)
6239	SRC 2 I_2 Mag	SRC 2 Negative Sequence Current Magnitude (A)
6241	SRC 2 I_2 Angle	SRC 2 Negative Sequence Current Angle (°)
6242	SRC 2 Igd Mag	SRC 2 Differential Ground Current Magnitude (A)

A

Table A–1: FLEXANALOG PARAMETERS (Sheet 2 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6244	SRC 2 Igd Angle	SRC 2 Differential Ground Current Angle (°)
6656	SRC 1 Vag RMS	SRC 1 Phase AG Voltage RMS (V)
6658	SRC 1 Vbg RMS	SRC 1 Phase BG Voltage RMS (V)
6660	SRC 1 Vcg RMS	SRC 1 Phase CG Voltage RMS (V)
6662	SRC 1 Vag Mag	SRC 1 Phase AG Voltage Magnitude (V)
6664	SRC 1 Vag Angle	SRC 1 Phase AG Voltage Angle (°)
6665	SRC 1 Vbg Mag	SRC 1 Phase BG Voltage Magnitude (V)
6667	SRC 1 Vbg Angle	SRC 1 Phase BG Voltage Angle (°)
6668	SRC 1 Vcg Mag	SRC 1 Phase CG Voltage Magnitude (V)
6670	SRC 1 Vcg Angle	SRC 1 Phase CG Voltage Angle (°)
6671	SRC 1 Vab RMS	SRC 1 Phase AB Voltage RMS (V)
6673	SRC 1 Vbc RMS	SRC 1 Phase BC Voltage RMS (V)
6675	SRC 1 Vca RMS	SRC 1 Phase CA Voltage RMS (V)
6677	SRC 1 Vab Mag	SRC 1 Phase AB Voltage Magnitude (V)
6679	SRC 1 Vab Angle	SRC 1 Phase AB Voltage Angle (°)
6680	SRC 1 Vbc Mag	SRC 1 Phase BC Voltage Magnitude (V)
6682	SRC 1 Vbc Angle	SRC 1 Phase BC Voltage Angle (°)
6683	SRC 1 Vca Mag	SRC 1 Phase CA Voltage Magnitude (V)
6685	SRC 1 Vca Angle	SRC 1 Phase CA Voltage Angle (°)
6686	SRC 1 Vx RMS	SRC 1 Auxiliary Voltage RMS (V)
6688	SRC 1 Vx Mag	SRC 1 Auxiliary Voltage Magnitude (V)
6690	SRC 1 Vx Angle	SRC 1 Auxiliary Voltage Angle (°)
6691	SRC 1 V_0 Mag	SRC 1 Zero Sequence Voltage Magnitude (V)
6693	SRC 1 V_0 Angle	SRC 1 Zero Sequence Voltage Angle (°)
6694	SRC 1 V_1 Mag	SRC 1 Positive Sequence Voltage Magnitude (V)
6696	SRC 1 V_1 Angle	SRC 1 Positive Sequence Voltage Angle (°)
6697	SRC 1 V_2 Mag	SRC 1 Negative Sequence Voltage Magnitude (V)
6699	SRC 1 V_2 Angle	SRC 1 Negative Sequence Voltage Angle (°)
6720	SRC 2 Vag RMS	SRC 2 Phase AG Voltage RMS (V)
6722	SRC 2 Vbg RMS	SRC 2 Phase BG Voltage RMS (V)
6724	SRC 2 Vcg RMS	SRC 2 Phase CG Voltage RMS (V)
6726	SRC 2 Vag Mag	SRC 2 Phase AG Voltage Magnitude (V)
6728	SRC 2 Vag Angle	SRC 2 Phase AG Voltage Angle (°)
6729	SRC 2 Vbg Mag	SRC 2 Phase BG Voltage Magnitude (V)
6731	SRC 2 Vbg Angle	SRC 2 Phase BG Voltage Angle (°)
6732	SRC 2 Vcg Mag	SRC 2 Phase CG Voltage Magnitude (V)
6734	SRC 2 Vcg Angle	SRC 2 Phase CG Voltage Angle (°)
6735	SRC 2 Vab RMS	SRC 2 Phase AB Voltage RMS (V)
6737	SRC 2 Vbc RMS	SRC 2 Phase BC Voltage RMS (V)
6739	SRC 2 Vca RMS	SRC 2 Phase CA Voltage RMS (V)
6741	SRC 2 Vab Mag	SRC 2 Phase AB Voltage Magnitude (V)
6743	SRC 2 Vab Angle	SRC 2 Phase AB Voltage Angle (°)
6744	SRC 2 Vbc Mag	SRC 2 Phase BC Voltage Magnitude (V)
6746	SRC 2 Vbc Angle	SRC 2 Phase BC Voltage Angle (°)
6747	SRC 2 Vca Mag	SRC 2 Phase CA Voltage Magnitude (V)
6749	SRC 2 Vca Angle	SRC 2 Phase CA Voltage Angle (°)
6750	SRC 2 Vx RMS	SRC 2 Auxiliary Voltage RMS (V)

Table A–1: FLEXANALOG PARAMETERS (Sheet 3 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
6752	SRC 2 Vx Mag	SRC 2 Auxiliary Voltage Magnitude (V)
6754	SRC 2 Vx Angle	SRC 2 Auxiliary Voltage Angle (°)
6755	SRC 2 V_0 Mag	SRC 2 Zero Sequence Voltage Magnitude (V)
6757	SRC 2 V_0 Angle	SRC 2 Zero Sequence Voltage Angle (°)
6758	SRC 2 V_1 Mag	SRC 2 Positive Sequence Voltage Magnitude (V)
6760	SRC 2 V_1 Angle	SRC 2 Positive Sequence Voltage Angle (°)
6761	SRC 2 V_2 Mag	SRC 2 Negative Sequence Voltage Magnitude (V)
6763	SRC 2 V_2 Angle	SRC 2 Negative Sequence Voltage Angle (°)
7168	SRC 1 P	SRC 1 Three Phase Real Power (W)
7170	SRC 1 Pa	SRC 1 Phase A Real Power (W)
7172	SRC 1 Pb	SRC 1 Phase B Real Power (W)
7174	SRC 1 Pc	SRC 1 Phase C Real Power (W)
7176	SRC 1 Q	SRC 1 Three Phase Reactive Power (var)
7178	SRC 1 Qa	SRC 1 Phase A Reactive Power (var)
7180	SRC 1 Qb	SRC 1 Phase B Reactive Power (var)
7182	SRC 1 Qc	SRC 1 Phase C Reactive Power (var)
7184	SRC 1 S	SRC 1 Three Phase Apparent Power (VA)
7186	SRC 1 Sa	SRC 1 Phase A Apparent Power (VA)
7188	SRC 1 Sb	SRC 1 Phase B Apparent Power (VA)
7190	SRC 1 Sc	SRC 1 Phase C Apparent Power (VA)
7192	SRC 1 PF	SRC 1 Three Phase Power Factor
7193	SRC 1 Phase A PF	SRC 1 Phase A Power Factor
7194	SRC 1 Phase B PF	SRC 1 Phase B Power Factor
7195	SRC 1 Phase C PF	SRC 1 Phase C Power Factor
7200	SRC 2 P	SRC 2 Three Phase Real Power (W)
7202	SRC 2 Pa	SRC 2 Phase A Real Power (W)
7204	SRC 2 Pb	SRC 2 Phase B Real Power (W)
7206	SRC 2 Pc	SRC 2 Phase C Real Power (W)
7208	SRC 2 Q	SRC 2 Three Phase Reactive Power (var)
7210	SRC 2 Qa	SRC 2 Phase A Reactive Power (var)
7212	SRC 2 Qb	SRC 2 Phase B Reactive Power (var)
7214	SRC 2 Qc	SRC 2 Phase C Reactive Power (var)
7216	SRC 2 S	SRC 2 Three Phase Apparent Power (VA)
7218	SRC 2 Sa	SRC 2 Phase A Apparent Power (VA)
7220	SRC 2 Sb	SRC 2 Phase B Apparent Power (VA)
7222	SRC 2 Sc	SRC 2 Phase C Apparent Power (VA)
7224	SRC 2 PF	SRC 2 Three Phase Power Factor
7225	SRC 2 Phase A PF	SRC 2 Phase A Power Factor
7226	SRC 2 Phase B PF	SRC 2 Phase B Power Factor
7227	SRC 2 Phase C PF	SRC 2 Phase C Power Factor
7552	SRC 1 Frequency	SRC 1 Frequency (Hz)
7553	SRC 2 Frequency	SRC 2 Frequency (Hz)
8704	Brk 1 Arc Amp A	Breaker 1 Arcing Amp Phase A (kA2-cyc)
8706	Brk 1 Arc Amp B	Breaker 1 Arcing Amp Phase B (kA2-cyc)
8708	Brk 1 Arc Amp C	Breaker 1 Arcing Amp Phase C (kA2-cyc)
8710	Brk 2 Arc Amp A	Breaker 2 Arcing Amp Phase A (kA2-cyc)
8712	Brk 2 Arc Amp B	Breaker 2 Arcing Amp Phase B (kA2-cyc)

Table A–1: FLEXANALOG PARAMETERS (Sheet 4 of 4)

SETTING	DISPLAY TEXT	DESCRIPTION
8714	Brk 2 Arc Amp C	Breaker 2 Arcing Amp Phase C (kA2-cyc)
9216	Synchchk 1 Delta V	Synchrocheck 1 Delta Voltage (V)
9218	Synchchk 1 Delta F	Synchrocheck 1 Delta Frequency (Hz)
9219	Synchchk 1 Delta Phs	Synchrocheck 1 Delta Phase (°)
9220	Synchchk 2 Delta V	Synchrocheck 2 Delta Voltage (V)
9222	Synchchk 2 Delta F	Synchrocheck 2 Delta Frequency (Hz)
9223	Synchchk 2 Delta Phs	Synchrocheck 2 Delta Phase (°)
9248	1 S1 S2 Angle	Power Swing S1 S2 Angle (°)
32768	Tracking Frequency	Tracking Frequency (Hz)
39425	FlexElement 1 OpSig	FlexElement 1 Actual
39427	FlexElement 2 OpSig	FlexElement 2 Actual
39429	FlexElement 3 OpSig	FlexElement 3 Actual
39431	FlexElement 4 OpSig	FlexElement 4 Actual
39433	FlexElement 5 OpSig	FlexElement 5 Actual
39435	FlexElement 6 OpSig	FlexElement 6 Actual
39437	FlexElement 7 OpSig	FlexElement 7 Actual
39439	FlexElement 8 OpSig	FlexElement 8 Actual
39441	FlexElement 9 OpSig	FlexElement 9 Actual
39443	FlexElement 10 OpSig	FlexElement 10 Actual
39445	FlexElement 11 OpSig	FlexElement 11 Actual
39447	FlexElement 12 OpSig	FlexElement 12 Actual
39449	FlexElement 13 OpSig	FlexElement 13 Actual
39451	FlexElement 14 OpSig	FlexElement 14 Actual
39453	FlexElement 15 OpSig	FlexElement 15 Actual
39455	FlexElement 16 OpSig	FlexElement 16 Actual
40960	Communications Group	Groups Communications Group
40971	Active Setting Group	Current Setting Group

B.1.1 INTRODUCTION

The UR series relays support a number of communications protocols to allow connection to equipment such as personal computers, RTUs, SCADA masters, and programmable logic controllers. The Modicon Modbus RTU protocol is the most basic protocol supported by the UR. Modbus is available via RS232 or RS485 serial links or via ethernet (using the Modbus/TCP specification). The following description is intended primarily for users who wish to develop their own master communication drivers and applies to the serial Modbus RTU protocol. Note that:

- The UR always acts as a slave device, meaning that it never initiates communications; it only listens and responds to requests issued by a master computer.
- For Modbus®, a subset of the Remote Terminal Unit (RTU) protocol format is supported that allows extensive monitoring, programming, and control functions using read and write register commands.

B.1.2 PHYSICAL LAYER

The Modbus® RTU protocol is hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232 and RS485. The relay includes a faceplate (front panel) RS232 port and two rear terminal communications ports that may be configured as RS485, fiber optic, 10BaseT, or 10BaseF. Data flow is half-duplex in all configurations. See Chapter 3: HARDWARE for details on wiring.

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame. This can be important for transmission through modems at high bit rates (11 bit data frames are not supported by many modems at baud rates greater than 300).

The baud rate and parity are independently programmable for each communications port. Baud rates of 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, or 115200 bps are available. Even, odd, and no parity are available. Refer to the COMMUNICATIONS section of the SETTINGS chapter for further details.

The master device in any system must know the address of the slave device with which it is to communicate. The relay will not act on a request from a master if the address in the request does not match the relay's slave address (unless the address is the broadcast address – see below).

A single setting selects the slave address used for all ports, with the exception that for the faceplate port, the relay will accept any address when the Modbus® RTU protocol is used.

B.1.3 DATA LINK LAYER

Communications takes place in packets which are groups of asynchronously framed byte data. The master transmits a packet to the slave and the slave responds with a packet. The end of a packet is marked by 'dead-time' on the communications line. The following describes general format for both transmit and receive packets. For exact details on packet formatting, refer to subsequent sections describing each function code.

Table B–1: MODBUS PACKET FORMAT

DESCRIPTION	SIZE
SLAVE ADDRESS	1 byte
FUNCTION CODE	1 byte
DATA	N bytes
CRC	2 bytes
DEAD TIME	3.5 bytes transmission time

SLAVE ADDRESS

This is the address of the slave device that is intended to receive the packet sent by the master and to perform the desired action. Each slave device on a communications bus must have a unique address to prevent bus contention. All of the relay's ports have the same address which is programmable from 1 to 254; see Chapter 5 for details. Only the addressed slave will respond to a packet that starts with its address. Note that the faceplate port is an exception to this rule; it will act on a message containing any slave address.

A master transmit packet with a slave address of 0 indicates a broadcast command. All slaves on the communication link will take action based on the packet, but none will respond to the master. Broadcast mode is only recognized when associated with FUNCTION CODE 05h. For any other function code, a packet with broadcast mode slave address 0 will be ignored.

FUNCTION CODE

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This is one of the supported functions codes of the unit which tells the slave what action to perform. See the SUPPORTED FUNCTION CODES section for complete details. An exception response from the slave is indicated by setting the high order bit of the function code in the response packet. See the EXCEPTION RESPONSES section for further details.

DATA

This will be a variable number of bytes depending on the function code. This may include actual values, settings, or addresses sent by the master to the slave or by the slave to the master.

CRC

This is a two byte error checking code. The RTU version of Modbus® includes a 16 bit cyclic redundancy check (CRC-16) with every packet which is an industry standard method used for error detection. If a Modbus® slave device receives a packet in which an error is indicated by the CRC, the slave device will not act upon or respond to the packet thus preventing any erroneous operations. See the CRC-16 ALGORITHM section for a description of how to calculate the CRC.

DEAD TIME

A packet is terminated when no data is received for a period of 3.5 byte transmission times (about 15 ms at 2400 bps, 2 ms at 19200 bps, and 300 µs at 115200 bps). Consequently, the transmitting device must not allow gaps between bytes longer than this interval. Once the dead time has expired without a new byte transmission, all slaves start listening for a new packet from the master except for the addressed slave.

B.1.4 CRC-16 ALGORITHM

The CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (11000000000000101B). The 16 bit remainder of the division is appended to the end of the packet, MSByte first. The resulting packet including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred. This algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped, since it does not affect the value of the remainder.

Note: A C programming language implementation of the CRC algorithm will be provided upon request.

Table B–2: CRC-16 ALGORITHM

SYMBOLS:	-->	data transfer
	A	16 bit working register
	Alow	low order byte of A
	Ahigh	high order byte of A
	CRC	16 bit CRC-16 result
	i,j	loop counters
	(+)	logical EXCLUSIVE-OR operator
	N	total number of data bytes
	Di	i-th data byte (i = 0 to N-1)
	G	16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed
	shr (x)	right shift operator (th LSbit of x is shifted into a carry flag, a '0' is shifted into the MSbit of x, all other bits are shifted right one location)

ALGORITHM:	1.	FFFF (hex) --> A	
	2.	0 --> i	
	3.	0 --> j	
	4.	Di (+) Alow --> Alow	
	5.	j + 1 --> j	
	6.	shr (A)	
	7.	Is there a carry?	No: go to 8 Yes: G (+) A --> A and continue.
	8.	Is j = 8?	No: go to 5 Yes: continue
	9.	i + 1 --> i	
	10.	Is i = N?	No: go to 3 Yes: continue
	11.	A --> CRC	

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B.2.1 SUPPORTED FUNCTION CODES

Modbus® officially defines function codes from 1 to 127 though only a small subset is generally needed. The relay supports some of these functions, as summarized in the following table. Subsequent sections describe each function code in detail.

FUNCTION CODE		MODBUS DEFINITION	GE POWER MANAGEMENT DEFINITION
HEX	DEC		
03	3	Read Holding Registers	Read Actual Values or Settings
04	4	Read Holding Registers	Read Actual Values or Settings
05	5	Force Single Coil	Execute Operation
06	6	Preset Single Register	Store Single Setting
10	16	Preset Multiple Registers	Store Multiple Settings

B.2.2 FUNCTION CODE 03H/04H: READ ACTUAL VALUES OR SETTINGS

This function code allows the master to read one or more consecutive data registers (actual values or settings) from a relay. Data registers are always 16 bit (two byte) values transmitted with high order byte first. The maximum number of registers that can be read in a single packet is 125. See the section MODBUS® MEMORY MAP for exact details on the data registers.

Since some PLC implementations of Modbus® only support one of function codes 03h and 04h, the relay interpretation allows either function code to be used for reading one or more consecutive data registers. The data starting address will determine the type of data being read. Function codes 03h and 04h are therefore identical.

The following table shows the format of the master and slave packets. The example shows a master device requesting 3 register values starting at address 4050h from slave device 11h (17 decimal); the slave device responds with the values 40, 300, and 0 from registers 4050h, 4051h, and 4052h, respectively.

Table B–3: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	04
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	50
NUMBER OF REGISTERS - hi	00
NUMBER OF REGISTERS - lo	03
CRC - lo	A7
CRC - hi	4A

SLAVE RESPONSE	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	04
BYTE COUNT	06
DATA #1 - hi	00
DATA #1 - lo	28
DATA #2 - hi	01
DATA #2 - lo	2C
DATA #3 - hi	00
DATA #3 - lo	00
CRC - lo	0D
CRC - hi	60

B.2.3 FUNCTION CODE 05H: EXECUTE OPERATION

This function code allows the master to perform various operations in the relay. Available operations are in the table SUMMARY OF OPERATION CODES.

The following table shows the format of the master and slave packets. The example shows a master device requesting the slave device 11H (17 dec) to perform a reset. The hi and lo CODE VALUE bytes always have the values 'FF' and '00' respectively and are a remnant of the original Modbus® definition of this function code.

Table B–4: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION		SLAVE RESPONSE	
PACKET FORMAT	EXAMPLE (HEX)	PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11	SLAVE ADDRESS	11
FUNCTION CODE	05	FUNCTION CODE	05
OPERATION CODE - hi	00	OPERATION CODE - hi	00
OPERATION CODE - lo	01	OPERATION CODE - lo	01
CODE VALUE - hi	FF	CODE VALUE - hi	FF
CODE VALUE - lo	00	CODE VALUE - lo	00
CRC - lo	DF	CRC - lo	DF
CRC - hi	6A	CRC - hi	6A

Table B–5: SUMMARY OF OPERATION CODES (FUNCTION CODE 05H)

OPERATION CODE (HEX)	DEFINITION	DESCRIPTION
0000	NO OPERATION	Does not do anything.
0001	RESET	Performs the same function as the faceplate RESET key.
0005	CLEAR EVENT RECORDS	Performs the same function as the faceplate **CLEAR EVENT RECORDS** menu command.
0006	CLEAR OSCILLOGRAPHY	Clears all oscillography records.
1000 to 101F	VIRTUAL IN 1-32 ON/OFF	Sets the states of Virtual Inputs 1 to 32 either "ON" or "OFF".

B.2.4 FUNCTION CODE 06H: STORE SINGLE SETTING

This function code allows the master to modify the contents of a single setting register in an relay. Setting registers are always 16 bit (two byte) values transmitted high order byte first.

The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h to slave device 11h (17 dec).

Table B–6: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION		SLAVE RESPONSE	
PACKET FORMAT	EXAMPLE (HEX)	PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11	SLAVE ADDRESS	11
FUNCTION CODE	06	FUNCTION CODE	06
DATA STARTING ADDRESS - hi	40	DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51	DATA STARTING ADDRESS - lo	51
DATA - hi	00	DATA - hi	00
DATA - lo	C8	DATA - lo	C8
CRC - lo	CE	CRC - lo	CE
CRC - hi	DD	CRC - hi	DD

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B.2.5 FUNCTION CODE 10H: STORE MULTIPLE SETTINGS

This function code allows the master to modify the contents of a one or more consecutive setting registers in a relay. Setting registers are 16-bit (two byte) values transmitted high order byte first. The maximum number of setting registers that can be stored in a single packet is 60. The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h, and the value 1 at memory map address 4052h to slave device 11h (17 dec).

Table B–7: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	10
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
NUMBER OF SETTINGS - hi	00
NUMBER OF SETTINGS - lo	02
BYTE COUNT	04
DATA #1 - high order byte	00
DATA #1 - low order byte	C8
DATA #2 - high order byte	00
DATA #2 - low order byte	01
CRC - low order byte	12
CRC - high order byte	62

SLAVE RESPONSE	
PACKET FORMAT	EXMAPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	10
DATA STARTING ADDRESS - hi	40
DATA STARTING ADDRESS - lo	51
NUMBER OF SETTINGS - hi	00
NUMBER OF SETTINGS - lo	02
CRC - lo	07
CRC - hi	64

B.2.6 EXCEPTION RESPONSES

Programming or operation errors usually happen because of illegal data in a packet. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response packet to the master with the high order bit of the function code set to 1.

The following table shows the format of the master and slave packets. The example shows a master device sending the unsupported function code 39h to slave device 11.

Table B–8: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

MASTER TRANSMISSION	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	39
CRC - low order byte	CD
CRC - high order byte	F2

SLAVE RESPONSE	
PACKET FORMAT	EXAMPLE (HEX)
SLAVE ADDRESS	11
FUNCTION CODE	B9
ERROR CODE	01
CRC - low order byte	93
CRC - high order byte	95

B.3.1 OBTAINING UR FILES USING MODBUS® PROTOCOL

The UR relay has a generic file transfer facility, meaning that you use the same method to obtain all of the different types of files from the unit. The Modbus registers that implement file transfer are found in the "Modbus File Transfer (Read/Write)" and "Modbus File Transfer (Read Only)" modules, starting at address 3100 in the Modbus Memory Map. To read a file from the UR relay, use the following steps:

1. Write the filename to the "Name of file to read" register using a write multiple registers command. If the name is shorter than 80 characters, you may write only enough registers to include all the text of the filename. Filenames are not case sensitive.
2. Repeatedly read all the registers in "Modbus File Transfer (Read Only)" using a read multiple registers command. It is not necessary to read the entire data block, since the UR relay will remember which was the last register you read. The "position" register is initially zero and thereafter indicates how many bytes (2 times the number of registers) you have read so far. The "size of..." register indicates the number of bytes of data remaining to read, to a maximum of 244.
3. Keep reading until the "size of..." register is smaller than the number of bytes you are transferring. This condition indicates end of file. Discard any bytes you have read beyond the indicated block size.
4. If you need to re-try a block, read only the "size of.." and "block of data", without reading the position. The file pointer is only incremented when you read the position register, so the same data block will be returned as was read in the previous operation. On the next read, check to see if the position is where you expect it to be, and discard the previous block if it is not (this condition would indicate that the UR relay did not process your original read request).

The UR relay retains connection-specific file transfer information, so files may be read simultaneously on multiple Modbus connections.

a) OBTAINING FILES FROM THE UR USING OTHER PROTOCOLS

All the files available via Modbus may also be retrieved using the standard file transfer mechanisms in other protocols (for example, TFTP or MMS).

b) COMTRADE, OSCILLOGRAPHY AND DATA LOGGER FILES

Oscillography and data logger files are formatted using the COMTRADE file format per IEEE PC37.111 Draft 7c (02 September 1997). The files may be obtained in either text or binary COMTRADE format.

c) READING OSCILLOGRAPHY FILES

Familiarity with the oscillography feature is required to understand the following description. Refer to the OSCILLOGRAPHY section in the SETTINGS chapter for additional details.

The Oscillography_Number_of_Triggers register is incremented by one every time a new oscillography file is triggered (captured) and cleared to zero when oscillography data is cleared. When a new trigger occurs, the associated oscillography file is assigned a file identifier number equal to the incremented value of this register; the newest file number is equal to the Oscillography_Number_of_Triggers register. This register can be used to determine if any new data has been captured by periodically reading it to see if the value has changed; if the number has increased then new data is available.

The Oscillography_Number_of_Records setting specifies the maximum number of files (and the number of cycles of data per file) that can be stored in memory of the relay. The Oscillography_Available_Records register specifies the actual number of files that are stored and still available to be read out of the relay.

Writing ‘Yes’ (i.e. the value 1) to the Oscillography_Clear_Data register clears oscillography data files, clears both the Oscillography_Number_of_Triggers and Oscillography_Available_Records registers to zero, and sets the Oscillography_Last_Cleared_Date to the present date and time.

To read binary COMTRADE oscillography files, read the following filenames:

- OSCnnnn.CFG
- OSCnnn.DAT

Replace "nnn" with the desired oscillography trigger number. For ASCII format, use the following file names

- OSCAnnnn.CFG
- OSCAnnn.DAT

d) READING DATA LOGGER FILES

Familiarity with the data logger feature is required to understand this description. Refer to the DATA LOGGER section of Chapter 5 for details. To read the entire data logger in binary COMTRADE format, read the following files.

- datalog.cfg
- datalog.dat

To read the entire data logger in ASCII COMTRADE format, read the following files.

- dataloga.cfg
- dataloga.dat

To limit the range of records to be returned in the COMTRADE files, append the following to the filename before writing it:

- To read from a specific time to the end of the log: <space> startTime
- To read a specific range of records: <space> startTime <space> endTime
- Replace <startTime> and <endTime> with Julian dates (seconds since Jan. 1 1970) as numeric text.

e) READING EVENT RECORDER FILES

To read the entire event recorder contents in ASCII format (the only available format), use the following filename:

- `EVT.TXT`

To read from a specific record to the end of the log, use the following filename:

- `EVTnnn.TXT` (replace "nnn" with the desired starting record number)

f) READING FAULT REPORT FILES

Fault report data has been available via the UR file retrieval mechanism since firmware version 2.00. The file name is **`faultReport#####.htm`**. The ##### refers to the fault report record number. The fault report number is a counter that indicates how many fault reports have ever occurred. The counter rolls over at a value of 65535. Only the last ten fault reports are available for retrieval; a request for a non-existent fault report file will yield a null file. The current value fault report counter is available in “Number of Fault Reports” Modbus register at location 0x3020.

For example, if 14 fault reports have occurred then the files `faultReport5.htm`, `faultReport6.htm`, up to `faultReport14.htm` are available to be read. The expected use of this feature has an external master periodically polling the “Number of Fault Reports' register. If the value changes, then the master reads all the new files.

The contents of the file is in standard HTML notation and can be viewed via any commercial browser.

B.3.2 MODBUS® PASSWORD OPERATION

The COMMAND password is set up at memory location 4000. Storing a value of "0" removes COMMAND password protection. When reading the password setting, the encrypted value (zero if no password is set) is returned. COMMAND security is required to change the COMMAND password. Similarly, the SETTING password is set up at memory location 4002. These are the same settings and encrypted values found in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ PASSWORD SECURITY** menu via the keypad. Enabling password security for the faceplate display will also enable it for Modbus, and vice-versa.

To gain COMMAND level security access, the COMMAND password must be entered at memory location 4008. To gain SETTING level security access, the SETTING password must be entered at memory location 400A. The entered SETTING password must match the current SETTING password setting, or must be zero, to change settings or download firmware.

COMMAND and SETTING passwords each have a 30-minute timer. Each timer starts when you enter the particular password, and is re-started whenever you “use” it. For example, writing a setting re-starts the SETTING password timer and writing a command register or forcing a coil re-starts the COMMAND password timer. The value read at memory location 4010 can be used to confirm whether a COMMAND password is enabled or disabled (0 for Disabled). The value read at memory location 4011 can be used to confirm whether a SETTING password is enabled or disabled.

COMMAND or SETTING password security access is restricted to the particular port or particular TCP/IP connection on which the entry was made. Passwords must be entered when accessing the relay through other ports or connections, and the passwords must be re-entered after disconnecting and re-connecting on TCP/IP.

B.4.1 MODBUS® MEMORY MAP

Table B–9: MODBUS MEMORY MAP (Sheet 1 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Product Information (Read Only)						
0000	UR Product Type	0 to 65535	---	1	F001	0
0002	Product Version	0 to 655.35	---	0.01	F001	1
Product Information (Read Only -- Written by Factory)						
0010	Serial Number	---	---	---	F203	"0"
0020	Manufacturing Date	0 to 4294967295	---	1	F050	0
0022	Modification Number	0 to 65535	---	1	F001	0
0040	Order Code	---	---	---	F204	"Order Code x "
0090	Ethernet MAC Address	---	---	---	F072	0
0093	Reserved (13 items)	---	---	---	F001	0
00A0	CPU Module Serial Number	---	---	---	F203	(none)
00B0	CPU Supplier Serial Number	---	---	---	F203	(none)
00C0	Ethernet Sub Module Serial Number (8 items)	---	---	---	F203	(none)
Self Test Targets (Read Only)						
0200	Self Test States (2 items)	0 to 4294967295	0	1	F143	0
Front Panel (Read Only)						
0204	LED Column x State (9 items)	0 to 65535	---	1	F501	0
0220	Display Message	---	---	---	F204	(none)
Keypress Emulation (Read/Write)						
0280	Simulated keypress – write zero before each keystroke	0 to 26	---	1	F190	0 (No key – use between real key)
Virtual Input Commands (Read/Write Command) (32 modules)						
0400	Virtual Input x State	0 to 1	---	1	F108	0 (Off)
0401	...Repeated for module number 2					
0402	...Repeated for module number 3					
0403	...Repeated for module number 4					
0404	...Repeated for module number 5					
0405	...Repeated for module number 6					
0406	...Repeated for module number 7					
0407	...Repeated for module number 8					
0408	...Repeated for module number 9					
0409	...Repeated for module number 10					
040A	...Repeated for module number 11					
040B	...Repeated for module number 12					
040C	...Repeated for module number 13					
040D	...Repeated for module number 14					
040E	...Repeated for module number 15					
040F	...Repeated for module number 16					
0410	...Repeated for module number 17					
0411	...Repeated for module number 18					
0412	...Repeated for module number 19					
0413	...Repeated for module number 20					
0414	...Repeated for module number 21					
0415	...Repeated for module number 22					
0416	...Repeated for module number 23					
0417	...Repeated for module number 24					
0418	...Repeated for module number 25					
0419	...Repeated for module number 26					
041A	...Repeated for module number 27					
041B	...Repeated for module number 28					
041C	...Repeated for module number 29					

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Table B–9: MODBUS MEMORY MAP (Sheet 2 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
041D	...Repeated for module number 30					
041E	...Repeated for module number 31					
041F	...Repeated for module number 32					
Digital Counter States (Read Only Non-Volatile) (8 modules)						
0800	Digital Counter x Value	–2147483647 to 2147483647	---	1	F004	0
0802	Digital Counter x Frozen	–2147483647 to 2147483647	---	1	F004	0
0804	Digital Counter x Frozen Time Stamp	0 to 4294967295	---	1	F050	0
0806	Digital Counter x Frozen Time Stamp us	0 to 4294967295	---	1	F003	0
0808	...Repeated for module number 2					
0810	...Repeated for module number 3					
0818	...Repeated for module number 4					
0820	...Repeated for module number 5					
0828	...Repeated for module number 6					
0830	...Repeated for module number 7					
0838	...Repeated for module number 8					
Flex States (Read Only)						
0900	Flex State Bits (16 items)	0 to 65535	---	1	F001	0
Element States (Read Only)						
1000	Element Operate States (64 items)	0 to 65535	---	1	F502	0
User Displays Actuals (Read Only)						
1080	Formatted user-definable displays (8 items)	---	---	---	F200	(none)
Modbus User Map Actuals (Read Only)						
1200	User Map Values (256 items)	0 to 65535	---	1	F001	0
Element Targets (Read Only)						
14C0	Target Sequence	0 to 65535	---	1	F001	0
14C1	Number of Targets	0 to 65535	---	1	F001	0
Element Targets (Read/Write)						
14C2	Target to Read	0 to 65535	---	1	F001	0
Element Targets (Read Only)						
14C3	Target Message	---	---	---	F200	"."
Digital I/O States (Read Only						
1500	Contact Input States (6 items)	0 to 65535	---	1	F500	0
1508	Virtual Input States (2 items)	0 to 65535	---	1	F500	0
1510	Contact Output States (4 items)	0 to 65535	---	1	F500	0
1518	Contact Output Current States (4 items)	0 to 65535	---	1	F500	0
1520	Contact Output Voltage States (4 items)	0 to 65535	---	1	F500	0
1528	Virtual Output States (4 items)	0 to 65535	---	1	F500	0
1530	Contact Output Detectors (4 items)	0 to 65535	---	1	F500	0
Remote I/O States (Read Only)						
1540	Remote Device x States	0 to 65535	---	1	F500	0
1542	Remote Input x States (2 items)	0 to 65535	---	1	F500	0
1550	Remote Devices Online	0 to 1	---	1	F126	0 (No)
Remote Device Status (Read Only) (16 modules)						
1551	Remote Device x StNum	0 to 4294967295	---	1	F003	0
1553	Remote Device x SqNum	0 to 4294967295	---	1	F003	0
1555	...Repeated for module number 2					
1559	...Repeated for module number 3					
155D	...Repeated for module number 4					
1561	...Repeated for module number 5					
1565	...Repeated for module number 6					
1569	...Repeated for module number 7					
156D	...Repeated for module number 8					
1571	...Repeated for module number 9					

Table B–9: MODBUS MEMORY MAP (Sheet 3 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1575	...Repeated for module number 10					
1579	...Repeated for module number 11					
157D	...Repeated for module number 12					
1581	...Repeated for module number 13					
1585	...Repeated for module number 14					
1589	...Repeated for module number 15					
158D	...Repeated for module number 16					
Ethernet Fibre Channel Status (Read/Write)						
1610	Ethernet Primary Fibre Channel Status	0 to 2	---	1	F134	0 (Fail)
1611	Ethernet Secondary Fibre Channel Status	0 to 2	---	1	F134	0 (Fail)
Data Logger Actuals (Read Only)						
1618	Data Logger Channel Count	0 to 16	CHNL	1	F001	0
1619	Time of oldest available samples	0 to 4294967295	seconds	1	F050	0
161B	Time of newest available samples	0 to 4294967295	seconds	1	F050	0
161D	Data Logger Duration	0 to 999.9	DAYS	0.1	F001	0
Source Current (Read Only) (6 modules)						
1800	Phase A Current RMS	0 to 999999.999	A	0.001	F060	0
1802	Phase B Current RMS	0 to 999999.999	A	0.001	F060	0
1804	Phase C Current RMS	0 to 999999.999	A	0.001	F060	0
1806	Neutral Current RMS	0 to 999999.999	A	0.001	F060	0
1808	Phase A Current Magnitude	0 to 999999.999	A	0.001	F060	0
180A	Phase A Current Angle	-359.9 to 0	°	0.1	F002	0
180B	Phase B Current Magnitude	0 to 999999.999	A	0.001	F060	0
180D	Phase B Current Angle	-359.9 to 0	°	0.1	F002	0
180E	Phase C Current Magnitude	0 to 999999.999	A	0.001	F060	0
1810	Phase C Current Angle	-359.9 to 0	°	0.1	F002	0
1811	Neutral Current Magnitude	0 to 999999.999	A	0.001	F060	0
1813	Neutral Current Angle	-359.9 to 0	°	0.1	F002	0
1814	Ground Current RMS	0 to 999999.999	A	0.001	F060	0
1816	Ground Current Magnitude	0 to 999999.999	A	0.001	F060	0
1818	Ground Current Angle	-359.9 to 0	°	0.1	F002	0
1819	Zero Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0
181B	Zero Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
181C	Positive Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0
181E	Positive Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
181F	Negative Sequence Current Magnitude	0 to 999999.999	A	0.001	F060	0
1821	Negative Sequence Current Angle	-359.9 to 0	°	0.1	F002	0
1822	Differential Ground Current Magnitude	0 to 999999.999	A	0.001	F060	0
1824	Differential Ground Current Angle	-359.9 to 0	°	0.1	F002	0
1825	Reserved (27 items)	---	---	---	F001	0
1840	...Repeated for module number 2					
1880	...Repeated for module number 3					
18C0	...Repeated for module number 4					
1900	...Repeated for module number 5					
1940	...Repeated for module number 6					
Source Voltage (Read Only) (6 modules)						
1A00	Phase AG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A02	Phase BG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A04	Phase CG Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A06	Phase AG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A08	Phase AG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A09	Phase BG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A0B	Phase BG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A0C	Phase CG Voltage Magnitude	0 to 999999.999	V	0.001	F060	0

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Table B–9: MODBUS MEMORY MAP (Sheet 4 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1A0E	Phase CG Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A0F	Phase AB or AC Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A11	Phase BC or BA Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A13	Phase CA or CB Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A15	Phase AB or AC Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A17	Phase AB or AC Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A18	Phase BC or BA Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A1A	Phase BC or BA Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A1B	Phase CA or CB Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A1D	Phase CA or CB Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A1E	Auxiliary Voltage RMS	0 to 999999.999	V	0.001	F060	0
1A20	Auxiliary Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A22	Auxiliary Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A23	Zero Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A25	Zero Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A26	Positive Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A28	Positive Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A29	Negative Sequence Voltage Magnitude	0 to 999999.999	V	0.001	F060	0
1A2B	Negative Sequence Voltage Angle	-359.9 to 0	°	0.1	F002	0
1A2C	Reserved (20 items)	---	---	---	F001	0
1A40	...Repeated for module number 2					
1A80	...Repeated for module number 3					
1AC0	...Repeated for module number 4					
1B00	...Repeated for module number 5					
1B40	...Repeated for module number 6					
Source Power (Read Only) (6 modules)						
1C00	Three Phase Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C02	Phase A Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C04	Phase B Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C06	Phase C Real Power	-1000000000000 to 1000000000000	W	0.001	F060	0
1C08	Three Phase Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C0A	Phase A Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C0C	Phase B Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C0E	Phase C Reactive Power	-1000000000000 to 1000000000000	var	0.001	F060	0
1C10	Three Phase Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C12	Phase A Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C14	Phase B Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C16	Phase C Apparent Power	-1000000000000 to 1000000000000	VA	0.001	F060	0
1C18	Three Phase Power Factor	-0.999 to 1	---	0.001	F013	0
1C19	Phase A Power Factor	-0.999 to 1	---	0.001	F013	0
1C1A	Phase B Power Factor	-0.999 to 1	---	0.001	F013	0
1C1B	Phase C Power Factor	-0.999 to 1	---	0.001	F013	0
1C1C	Reserved (4 items)	---	---	---	F001	0
1C20	...Repeated for module number 2					
1C40	...Repeated for module number 3					
1C60	...Repeated for module number 4					

Table B–9: MODBUS MEMORY MAP (Sheet 5 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
1C80	...Repeated for module number 5					
1CA0	...Repeated for module number 6					
Source Frequency (Read Only) (6 modules)						
1D80	Frequency	2 to 90	Hz	0.01	F001	0
1D81	...Repeated for module number 2					
1D82	...Repeated for module number 3					
1D83	...Repeated for module number 4					
1D84	...Repeated for module number 5					
1D85	...Repeated for module number 6					
Breaker Arcing Current Actuals (Read Only Non-Volatile) (2 modules)						
2200	Breaker x Arcing Amp Phase A	0 to 99999999	kA2-cyc	1	F060	0
2202	Breaker x Arcing Amp Phase B	0 to 99999999	kA2-cyc	1	F060	0
2204	Breaker x Arcing Amp Phase C	0 to 99999999	kA2-cyc	1	F060	0
2206	...Repeated for module number 2					
Breaker Arcing Current Commands (Read/Write Command) (2 modules)						
220C	Breaker x Arcing Clear Command	0 to 1	---	1	F126	0 (No)
220D	...Repeated for module number 2					
Fault Location (Read Only)						
2350	Prefault Phase A Current Magnitude	0 to 999999.999	---	0.001	F060	0
2352	Prefault Phase B Current Magnitude	0 to 999999.999	---	0.001	F060	0
2354	Prefault Phase C Current Magnitude	0 to 999999.999	---	0.001	F060	0
2356	Prefault Zero Seq Current	0 to 999999.999	---	0.001	F060	0
2358	Prefault Pos Seq Current	0 to 999999.999	---	0.001	F060	0
235A	Prefault Neg Seq Current	0 to 999999.999	---	0.001	F060	0
235C	Prefault Phase A Voltage	0 to 999999.999	---	0.001	F060	0
235E	Prefault Phase B Voltage	0 to 999999.999	---	0.001	F060	0
2360	Prefault Phase C Voltage	0 to 999999.999	---	0.001	F060	0
Synchrocheck Actuals (Read Only) (2 modules)						
2400	Synchrocheck X Delta Voltage	-1000000000000 to 1000000000000	V	1	F060	0
2402	Synchrocheck X Delta Frequency	0 to 655.35	Hz	0.01	F001	0
2403	Synchrocheck X Delta Phase	0 to 359.9	°	0.1	F001	0
2404	...Repeated for module number 2					
Autoreclose Status (Read Only) (6 modules)						
2410	Autoreclose Count	0 to 65535	---	1	F001	0
2411	...Repeated for module number 2					
2412	...Repeated for module number 3					
2413	...Repeated for module number 4					
2414	...Repeated for module number 5					
2415	...Repeated for module number 6					
Expanded FlexStates (Read Only)						
2B00	FlexStates, one per register (256 items)	0 to 1	---	1	F108	0 (Off)
Expanded Digital I/O states (Read Only)						
2D00	Contact Input States, one per register (96 items)	0 to 1	---	1	F108	0 (Off)
2D80	Contact Output States, one per register (64 items)	0 to 1	---	1	F108	0 (Off)
2E00	Virtual Output States, one per register (64 items)	0 to 1	---	1	F108	0 (Off)
Expanded Remote I/O Status (Read Only)						
2F00	Remote Device States, one per register (16 items)	0 to 1	---	1	F155	0 (Offline)
2F80	Remote Input States, one per register (32 items)	0 to 1	---	1	F108	0 (Off)
Oscillography Values (Read Only)						
3000	Oscillography Number of Triggers	0 to 65535	---	1	F001	0
3001	Oscillography Available Records	0 to 65535	---	1	F001	0
3002	Oscillography Last Cleared Date	0 to 400000000	---	1	F050	0
3004	Oscillography Number Of Cycles Per Record	0 to 65535	---	1	F001	0

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Table B–9: MODBUS MEMORY MAP (Sheet 6 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Oscillography Commands (Read/Write Command)						
3005	Oscillography Force Trigger	0 to 1	---	1	F126	0 (No)
3011	Oscillography Clear Data	0 to 1	---	1	F126	0 (No)
Fault Report Indexing (Read Only Non-Volatile)						
3020	Number Of Fault Reports	0 to 65535	---	1	F001	0
Fault Reports (Read Only Non-Volatile) (10 modules)						
3030	Fault Time	0 to 4294967295	---	1	F050	0
3032	...Repeated for module number 2					
3034	...Repeated for module number 3					
3036	...Repeated for module number 4					
3038	...Repeated for module number 5					
303A	...Repeated for module number 6					
303C	...Repeated for module number 7					
303E	...Repeated for module number 8					
3040	...Repeated for module number 9					
3042	...Repeated for module number 10					
Modbus File Transfer (Read/Write)						
3100	Name of file to read	---	---	---	F204	(none)
Modbus File Transfer (Read Only)						
3200	Character position of current block within file	0 to 4294967295	---	1	F003	0
3202	Size of currently-available data block	0 to 65535	---	1	F001	0
3203	Block of data from requested file (122 items)	0 to 65535	---	1	F001	0
Event Recorder (Read Only)						
3400	Events Since Last Clear	0 to 4294967295	---	1	F003	0
3402	Number of Available Events	0 to 4294967295	---	1	F003	0
3404	Event Recorder Last Cleared Date	0 to 4294967295	---	1	F050	0
Event Recorder (Read/Write Command)						
3406	Event Recorder Clear Command	0 to 1	---	1	F126	0 (No)
DCMA Input Values (Read Only) (24 modules)						
34C0	DCMA Inputs x Value	-9999.999 to 9999.999	---	0.001	F004	0
34C2	...Repeated for module number 2					
34C4	...Repeated for module number 3					
34C6	...Repeated for module number 4					
34C8	...Repeated for module number 5					
34CA	...Repeated for module number 6					
34CC	...Repeated for module number 7					
34CE	...Repeated for module number 8					
34D0	...Repeated for module number 9					
34D2	...Repeated for module number 10					
34D4	...Repeated for module number 11					
34D6	...Repeated for module number 12					
34D8	...Repeated for module number 13					
34DA	...Repeated for module number 14					
34DC	...Repeated for module number 15					
34DE	...Repeated for module number 16					
34E0	...Repeated for module number 17					
34E2	...Repeated for module number 18					
34E4	...Repeated for module number 19					
34E6	...Repeated for module number 20					
34E8	...Repeated for module number 21					
34EA	...Repeated for module number 22					
34EC	...Repeated for module number 23					
34EE	...Repeated for module number 24					

Table B–9: MODBUS MEMORY MAP (Sheet 7 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
RTD Input Values (Read Only) (48 modules)						
34F0	RTD Inputs x Value	-32768 to 32767	°C	1	F002	0
34F1	...Repeated for module number 2					
34F2	...Repeated for module number 3					
34F3	...Repeated for module number 4					
34F4	...Repeated for module number 5					
34F5	...Repeated for module number 6					
34F6	...Repeated for module number 7					
34F7	...Repeated for module number 8					
34F8	...Repeated for module number 9					
34F9	...Repeated for module number 10					
34FA	...Repeated for module number 11					
34FB	...Repeated for module number 12					
34FC	...Repeated for module number 13					
34FD	...Repeated for module number 14					
34FE	...Repeated for module number 15					
34FF	...Repeated for module number 16					
3500	...Repeated for module number 17					
3501	...Repeated for module number 18					
3502	...Repeated for module number 19					
3503	...Repeated for module number 20					
3504	...Repeated for module number 21					
3505	...Repeated for module number 22					
3506	...Repeated for module number 23					
3507	...Repeated for module number 24					
3508	...Repeated for module number 25					
3509	...Repeated for module number 26					
350A	...Repeated for module number 27					
350B	...Repeated for module number 28					
350C	...Repeated for module number 29					
350D	...Repeated for module number 30					
350E	...Repeated for module number 31					
350F	...Repeated for module number 32					
3510	...Repeated for module number 33					
3511	...Repeated for module number 34					
3512	...Repeated for module number 35					
3513	...Repeated for module number 36					
3514	...Repeated for module number 37					
3515	...Repeated for module number 38					
3516	...Repeated for module number 39					
3517	...Repeated for module number 40					
3518	...Repeated for module number 41					
3519	...Repeated for module number 42					
351A	...Repeated for module number 43					
351B	...Repeated for module number 44					
351C	...Repeated for module number 45					
351D	...Repeated for module number 46					
351E	...Repeated for module number 47					
351F	...Repeated for module number 48					
Ohm Input Values (Read Only) (2 modules)						
3520	Ohm Inputs x Value	0 to 65535	Ω	1	F001	0
3521	...Repeated for module number 2					
Passwords (Read/Write Command)						
4000	Command Password Setting	0 to 4294967295	---	1	F003	0

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Table B–9: MODBUS MEMORY MAP (Sheet 8 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Passwords (Read/Write Setting)						
4002	Setting Password Setting	0 to 4294967295	---	1	F003	0
Passwords (Read/Write)						
4008	Command Password Entry	0 to 4294967295	---	1	F003	0
400A	Setting Password Entry	0 to 4294967295	---	1	F003	0
Passwords (Read Only)						
4010	Command Password Status	0 to 1	---	1	F102	0 (Disabled)
4011	Setting Password Status	0 to 1	---	1	F102	0 (Disabled)
Preferences (Read/Write Setting)						
4050	Flash Message Time	0.5 to 10	s	0.1	F001	10
4051	Default Message Timeout	10 to 900	s	1	F001	300
4052	Default Message Intensity	0 to 3	---	1	F101	0 (25%)
Communications (Read/Write Setting)						
407E	COM1 minimum response time	0 to 1000	ms	10	F001	0
407F	COM2 minimum response time	0 to 1000	ms	10	F001	0
4080	Modbus Slave Address	1 to 254	---	1	F001	254
4083	RS485 Com1 Baud Rate	0 to 11	---	1	F112	5 (19200)
4084	RS485 Com1 Parity	0 to 2	---	1	F113	0 (None)
4085	RS485 Com2 Baud Rate	0 to 11	---	1	F112	5 (19200)
4086	RS485 Com2 Parity	0 to 2	---	1	F113	0 (None)
4087	IP Address	0 to 4294967295	---	1	F003	56554706
4089	IP Subnet Mask	0 to 4294967295	---	1	F003	4294966272
408B	Gateway IP Address	0 to 4294967295	---	1	F003	56554497
408D	Network Address NSAP	---	---	---	F074	0
4097	Default GOOSE Update Time	1 to 60	s	1	F001	60
4098	Ethernet Primary Fibre Channel Link Monitor	0 to 1	---	1	F102	0 (Disabled)
4099	Ethernet Secondary Fibre Channel Link Monitor	0 to 1	---	1	F102	0 (Disabled)
409A	DNP Port	0 to 4	---	1	F177	0 (NONE)
409B	DNP Address	0 to 65519	---	1	F001	255
409C	DNP Client Addresses (2 items)	0 to 4294967295	---	1	F003	0
40A0	TCP Port Number for the Modbus protocol	1 to 65535	---	1	F001	502
40A1	TCP/UDP Port Number for the DNP Protocol	1 to 65535	---	1	F001	20000
40A2	TCP Port Number for the UCA/MMS Protocol	1 to 65535	---	1	F001	102
40A3	TCP Port No. for the HTTP (Web Server) Protocol	1 to 65535	---	1	F001	80
40A4	Main UDP Port Number for the TFTP Protocol	1 to 65535	---	1	F001	69
40A5	Data Transfer UDP Port Numbers for the TFTP Protocol (zero means "automatic") (2 items)	0 to 65535	---	1	F001	0
40A7	DNP Unsolicited Responses Function	0 to 1	---	1	F102	0 (Disabled)
40A8	DNP Unsolicited Responses Timeout	0 to 60	s	1	F001	5
40A9	DNP Unsolicited Responses Max Retries	1 to 255	---	1	F001	10
40AA	DNP Unsolicited Responses Destination Address	0 to 65519	---	1	F001	1
40AB	Ethernet Operation Mode	0 to 1	---	1	F192	0 (Half-Duplex)
40AC	DNP User Map Function	0 to 1	---	1	F102	0 (Disabled)
40AD	DNP Number of Sources used in Analog points list	1 to 6	---	1	F001	1
40AE	DNP Current Scale Factor	0 to 5	---	1	F194	2 (1)
40AF	DNP Voltage Scale Factor	0 to 5	---	1	F194	2 (1)
40B0	DNP Power Scale Factor	0 to 5	---	1	F194	2 (1)
40B1	DNP Energy Scale Factor	0 to 5	---	1	F194	2 (1)
40B2	DNP Other Scale Factor	0 to 5	---	1	F194	2 (1)
40B3	DNP Current Default Deadband	0 to 65535	---	1	F001	30000
40B4	DNP Voltage Default Deadband	0 to 65535	---	1	F001	30000
40B5	DNP Power Default Deadband	0 to 65535	---	1	F001	30000
40B6	DNP Energy Default Deadband	0 to 65535	---	1	F001	30000
40B7	DNP Other Default Deadband	0 to 65535	---	1	F001	30000

Table B–9: MODBUS MEMORY MAP (Sheet 9 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
40B8	DNP IIN Time Sync Bit Period	1 to 10080	min	1	F001	1440
40B9	DNP Message Fragment Size	30 to 2048	---	1	F001	240
40BA	DNP Client Address 3	0 to 4294967295	---	1	F003	0
40BC	DNP Client Address 4	0 to 4294967295	---	1	F003	0
40BE	DNP Client Address 5	0 to 4294967295	---	1	F003	0
40C0	DNP Communications Reserved (8 items)	0 to 1	---	1	F001	0
40C8	UCA Logical Device Name	---	---	---	F203	"UCADevice"
40D0	UCA Communications Reserved (16 items)	0 to 1	---	1	F001	0
40E0	TCP Port Number for the IEC 60870-5-104 Protocol	1 to 65535	---	1	F001	2404
40E1	IEC 60870-5-104 Protocol Function	0 to 1	---	1	F102	0 (Disabled)
40E2	IEC 60870-5-104 Protocol Common Addr of ASDU	0 to 65535	---	1	F001	0
40E3	IEC 60870-5-104 Protocol Cyclic Data Tx Period	1 to 65535	s	1	F001	60
40E4	IEC No. of Sources used in M_ME_NC_1 point list	1 to 6	---	1	F001	1
40E5	IEC Current Default Threshold	0 to 65535	---	1	F001	30000
40E6	IEC Voltage Default Threshold	0 to 65535	---	1	F001	30000
40E7	IEC Power Default Threshold	0 to 65535	---	1	F001	30000
40E8	IEC Energy Default Threshold	0 to 65535	---	1	F001	30000
40E9	IEC Other Default Threshold	0 to 65535	---	1	F001	30000
40EA	IEC Communications Reserved (22 items)	0 to 1	---	1	F001	0
4100	DNP Binary Input Block of 16 Points (58 items)	0 to 58	---	1	F197	0 (Not Used)
Data Logger Commands (Read/Write Command)						
4170	Clear Data Logger	0 to 1	---	1	F126	0 (No)
Data Logger (Read/Write Setting)						
4180	Data Logger Rate	0 to 7	---	1	F178	1 (1 min)
4181	Data Logger Channel Settings (16 items)	---	---	---	F600	0
Clock (Read/Write Command)						
41A0	RTC Set Time	0 to 235959	---	1	F003	0
Clock (Read/Write Setting)						
41A2	SR Date Format	0 to 4294967295	---	1	F051	0
41A4	SR Time Format	0 to 4294967295	---	1	F052	0
41A6	IRIG-B Signal Type	0 to 2	---	1	F114	0 (None)
Fault Report Settings and Commands (Read/Write Setting)						
41B0	Fault Report Source	0 to 5	---	1	F167	0 (SRC 1)
41B1	Fault Report Trigger	0 to 65535	---	1	F300	0
Fault Report Settings and Commands (Read/Write Command)						
41B2	Fault Reports Clear Data Command	0 to 1	---	1	F126	0 (No)
Oscillography (Read/Write Setting)						
41C0	Oscillography Number of Records	1 to 64	---	1	F001	15
41C1	Oscillography Trigger Mode	0 to 1	---	1	F118	0 (Auto Overwrite)
41C2	Oscillography Trigger Position	0 to 100	%	1	F001	50
41C3	Oscillography Trigger Source	0 to 65535	---	1	F300	0
41C4	Oscillography AC Input Waveforms	0 to 4	---	1	F183	2 (16 samples/cycle)
41D0	Oscillography Analog Channel X (16 items)	0 to 65535	---	1	F600	0
4200	Oscillography Digital Channel X (63 items)	0 to 65535	---	1	F300	0
Trip and Alarm LEDs (Read/Write Setting)						
4260	Trip LED Input FlexLogic Operand	0 to 65535	---	1	F300	0
4261	Alarm LED Input FlexLogic Operand	0 to 65535	---	1	F300	0
User Programmable LEDs (Read/Write Setting) (48 modules)						
4280	FlexLogic Operand to Activate LED	0 to 65535	---	1	F300	0
4281	User LED type (latched or self-resetting)	0 to 1	---	1	F127	1 (Self-Reset)
4282	...Repeated for module number 2					
4284	...Repeated for module number 3					
4286	...Repeated for module number 4					
4288	...Repeated for module number 5					

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Table B–9: MODBUS MEMORY MAP (Sheet 10 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
428A	...Repeated for module number 6					
428C	...Repeated for module number 7					
428E	...Repeated for module number 8					
4290	...Repeated for module number 9					
4292	...Repeated for module number 10					
4294	...Repeated for module number 11					
4296	...Repeated for module number 12					
4298	...Repeated for module number 13					
429A	...Repeated for module number 14					
429C	...Repeated for module number 15					
429E	...Repeated for module number 16					
42A0	...Repeated for module number 17					
42A2	...Repeated for module number 18					
42A4	...Repeated for module number 19					
42A6	...Repeated for module number 20					
42A8	...Repeated for module number 21					
42AA	...Repeated for module number 22					
42AC	...Repeated for module number 23					
42AE	...Repeated for module number 24					
42B0	...Repeated for module number 25					
42B2	...Repeated for module number 26					
42B4	...Repeated for module number 27					
42B6	...Repeated for module number 28					
42B8	...Repeated for module number 29					
42BA	...Repeated for module number 30					
42BC	...Repeated for module number 31					
42BE	...Repeated for module number 32					
42C0	...Repeated for module number 33					
42C2	...Repeated for module number 34					
42C4	...Repeated for module number 35					
42C6	...Repeated for module number 36					
42C8	...Repeated for module number 37					
42CA	...Repeated for module number 38					
42CC	...Repeated for module number 39					
42CE	...Repeated for module number 40					
42D0	...Repeated for module number 41					
42D2	...Repeated for module number 42					
42D4	...Repeated for module number 43					
42D6	...Repeated for module number 44					
42D8	...Repeated for module number 45					
42DA	...Repeated for module number 46					
42DC	...Repeated for module number 47					
42DE	...Repeated for module number 48					
Installation (Read/Write Setting)						
43E0	Relay Programmed State	0 to 1	---	1	F133	0 (Not Programmed)
43E1	Relay Name	---	---	---	F202	"Relay-1"
CT Settings (Read/Write Setting) (6 modules)						
4480	Phase CT Primary	1 to 65000	A	1	F001	1
4481	Phase CT Secondary	0 to 1	---	1	F123	0 (1 A)
4482	Ground CT Primary	1 to 65000	A	1	F001	1
4483	Ground CT Secondary	0 to 1	---	1	F123	0 (1 A)
4484	...Repeated for module number 2					
4488	...Repeated for module number 3					
448C	...Repeated for module number 4					

Table B–9: MODBUS MEMORY MAP (Sheet 11 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
4490	...Repeated for module number 5					
4494	...Repeated for module number 6					
VT Settings (Read/Write Setting) (3 modules)						
4500	Phase VT Connection	0 to 1	---	1	F100	0 (Wye)
4501	Phase VT Secondary	50 to 240	V	0.1	F001	664
4502	Phase VT Ratio	1 to 24000	:1	1	F060	1
4504	Auxiliary VT Connection	0 to 6	---	1	F166	1 (Vag)
4505	Auxiliary VT Secondary	50 to 240	V	0.1	F001	664
4506	Auxiliary VT Ratio	1 to 24000	:1	1	F060	1
4508	...Repeated for module number 2					
4510	...Repeated for module number 3					
Source Settings (Read/Write Setting) (6 modules)						
4580	Source Name	---	---	---	F206	"SRC 1 "
4583	Source Phase CT	0 to 63	---	1	F400	0
4584	Source Ground CT	0 to 63	---	1	F400	0
4585	Source Phase VT	0 to 63	---	1	F400	0
4586	Source Auxiliary VT	0 to 63	---	1	F400	0
4587	...Repeated for module number 2					
458E	...Repeated for module number 3					
4595	...Repeated for module number 4					
459C	...Repeated for module number 5					
45A3	...Repeated for module number 6					
Power System (Read/Write Setting)						
4600	Nominal Frequency	25 to 60	Hz	1	F001	60
4601	Phase Rotation	0 to 1	---	1	F106	0 (ABC)
4602	Frequency And Phase Reference	0 to 5	---	1	F167	0 (SRC 1)
4603	Frequency Tracking	0 to 1	---	1	F102	1 (Enabled)
Line (Read/Write Setting)						
46D0	Line Pos Seq Impedance	0.01 to 250	Þ	0.01	F001	300
46D1	Line Pos Seq Impedance Angle	25 to 90	°	1	F001	75
46D2	Line Zero Seq Impedance	0.01 to 650	Þ	0.01	F001	900
46D3	Line Zero Seq Impedance Angle	25 to 90	°	1	F001	75
46D4	Line Length Units	0 to 1	---	1	F147	0 (km)
46D5	Line Length	0 to 2000	---	0.1	F001	1000
Breaker Control Global Settings (Read/Write Setting)						
46F0	UCA XCBR x SelTimOut	1 to 60	s	1	F001	30
Breaker Control (Read/Write Setting) (2 modules)						
4700	Breaker x Function	0 to 1	---	1	F102	0 (Disabled)
4701	Breaker x Name	---	---	---	F206	"Bkr 1 "
4704	Breaker x Mode	0 to 1	---	1	F157	0 (3-Pole)
4705	Breaker x Open	0 to 65535	---	1	F300	0
4706	Breaker x Close	0 to 65535	---	1	F300	0
4707	Breaker x Phase A 3 Pole	0 to 65535	---	1	F300	0
4708	Breaker x Phase B	0 to 65535	---	1	F300	0
4709	Breaker x Phase C	0 to 65535	---	1	F300	0
470A	Breaker x External Alarm	0 to 65535	---	1	F300	0
470B	Breaker x Alarm Delay	0 to 1000000	s	0.001	F003	0
470D	Breaker x Push Button Control	0 to 1	---	1	F102	0 (Disabled)
470E	Breaker x Manual Close Recal Time	0 to 1000000	s	0.001	F003	0
4710	Breaker x UCA XCBR x SBOClass	1 to 2	---	1	F001	1
4711	Breaker x UCA XCBR x SBOEna	0 to 1	---	1	F102	0 (Disabled)
4712	Breaker x Out Of Service	0 to 65535	---	1	F300	0
4713	Reserved (5 items)	0 to 65535		1	F001	0
4718	...Repeated for module number 2					

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Table B–9: MODBUS MEMORY MAP (Sheet 12 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
Synchrocheck (Read/Write Setting) (2 modules)						
4780	Synchrocheck Function	0 to 1	---	1	F102	0 (Disabled)
4781	Synchrocheck V1 Source	0 to 5	---	1	F167	0 (SRC 1)
4782	Synchrocheck V2 Source	0 to 5	---	1	F167	1 (SRC 2)
4783	Synchrocheck Max Volt Diff	0 to 100000	V	1	F060	10000
4785	Synchrocheck Max Angle Diff	0 to 100	°	1	F001	30
4786	Synchrocheck Max Freq Diff	0 to 2	Hz	0.01	F001	100
4787	Synchrocheck Dead Source Select	0 to 5	---	1	F176	1 (LV1 and DV2)
4788	Synchrocheck Dead V1 Max Volt	0 to 1.25	pu	0.01	F001	30
4789	Synchrocheck Dead V2 Max Volt	0 to 1.25	pu	0.01	F001	30
478A	Synchrocheck Live V1 Min Volt	0 to 1.25	pu	0.01	F001	70
478B	Synchrocheck Live V2 Min Volt	0 to 1.25	pu	0.01	F001	70
478C	Synchrocheck Target	0 to 2	---	1	F109	0 (Self-reset)
478D	Synchrocheck Events	0 to 1	---	1	F102	0 (Disabled)
478E	Synchrocheck Block	0 to 65535	---	1	F300	0
478F	Synchrocheck X Reserved	0 to 65535	---	1	F001	0
4790	...Repeated for module number 2					
Flexcurve A (Read/Write Setting)						
4800	FlexCurve A (120 items)	0 to 65535	ms	1	F011	0
Flexcurve B (Read/Write Setting)						
48F0	FlexCurve B (120 items)	0 to 65535	ms	1	F011	0
Modbus User Map (Read/Write Setting)						
4A00	Modbus Address Settings for User Map (256 items)	0 to 65535	---	1	F001	0
User Displays Settings (Read/Write Setting) (8 modules)						
4C00	User display top line text	---	---	---	F202	" "
4C0A	User display bottom line text	---	---	---	F202	" "
4C14	Modbus addresses of displayed items (5 items)	0 to 65535	---	1	F001	0
4C19	Reserved (7 items)	---	---	---	F001	0
4C20	...Repeated for module number 2					
4C40	...Repeated for module number 3					
4C60	...Repeated for module number 4					
4C80	...Repeated for module number 5					
4CA0	...Repeated for module number 6					
4CC0	...Repeated for module number 7					
4CE0	...Repeated for module number 8					
FlexLogic™ (Read/Write Setting)						
5000	FlexLogic Entry (512 items)	0 to 65535	---	1	F300	16384
FlexLogic™ Timers (Read/Write Setting) (32 modules)						
5800	Timer x Type	0 to 2	---	1	F129	0 (millisecond)
5801	Timer x Pickup Delay	0 to 60000	---	1	F001	0
5802	Timer x Dropout Delay	0 to 60000	---	1	F001	0
5803	Timer x Reserved (5 items)	0 to 65535	---	1	F001	0
5808	...Repeated for module number 2					
5810	...Repeated for module number 3					
5818	...Repeated for module number 4					
5820	...Repeated for module number 5					
5828	...Repeated for module number 6					
5830	...Repeated for module number 7					
5838	...Repeated for module number 8					
5840	...Repeated for module number 9					
5848	...Repeated for module number 10					
5850	...Repeated for module number 11					
5858	...Repeated for module number 12					
5860	...Repeated for module number 13					

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Table B–9: MODBUS MEMORY MAP (Sheet 13 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5868	...Repeated for module number 14					
5870	...Repeated for module number 15					
5878	...Repeated for module number 16					
5880	...Repeated for module number 17					
5888	...Repeated for module number 18					
5890	...Repeated for module number 19					
5898	...Repeated for module number 20					
58A0	...Repeated for module number 21					
58A8	...Repeated for module number 22					
58B0	...Repeated for module number 23					
58B8	...Repeated for module number 24					
58C0	...Repeated for module number 25					
58C8	...Repeated for module number 26					
58D0	...Repeated for module number 27					
58D8	...Repeated for module number 28					
58E0	...Repeated for module number 29					
58E8	...Repeated for module number 30					
58F0	...Repeated for module number 31					
58F8	...Repeated for module number 32					
Phase TOC (Read/Write Grouped Setting) (6 modules)						
5900	Phase TOC Function	0 to 1	---	1	F102	0 (Disabled)
5901	Phase TOC Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5902	Phase TOC Input	0 to 1	---	1	F122	0 (Phasor)
5903	Phase TOC Pickup	0 to 30	pu	0.001	F001	1000
5904	Phase TOC Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5905	Phase TOC Multiplier	0 to 600	---	0.01	F001	100
5906	Phase TOC Reset	0 to 1	---	1	F104	0 (Instantaneous)
5907	Phase TOC Voltage Restraint	0 to 1	---	1	F102	0 (Disabled)
5908	Phase TOC Block For Each Phase (3 items)	0 to 65535	---	1	F300	0
590B	Phase TOC Target	0 to 2	---	1	F109	0 (Self-reset)
590C	Phase TOC Events	0 to 1	---	1	F102	0 (Disabled)
590D	Reserved (3 items)	0 to 1	---	1	F001	0
5910	...Repeated for module number 2					
5920	...Repeated for module number 3					
5930	...Repeated for module number 4					
5940	...Repeated for module number 5					
5950	...Repeated for module number 6					
Phase IOC (Read/Write Grouped Setting) (12 modules)						
5A00	Phase IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5A01	Phase IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5A02	Phase IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5A03	Phase IOC1 Delay	0 to 600	s	0.01	F001	0
5A04	Phase IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5A05	Phase IOC1 Block For Each Phase (3 items)	0 to 65535	---	1	F300	0
5A08	Phase IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5A09	Phase IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5A0A	Reserved (6 items)	0 to 1	---	1	F001	0
5A10	...Repeated for module number 2					
5A20	...Repeated for module number 3					
5A30	...Repeated for module number 4					
5A40	...Repeated for module number 5					
5A50	...Repeated for module number 6					
5A60	...Repeated for module number 7					
5A70	...Repeated for module number 8					

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Table B–9: MODBUS MEMORY MAP (Sheet 14 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5A80	...Repeated for module number 9					
5A90	...Repeated for module number 10					
5AA0	...Repeated for module number 11					
5AB0	...Repeated for module number 12					
Neutral TOC (Read/Write Grouped Setting) (6 modules)						
5B00	Neutral TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5B01	Neutral TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5B02	Neutral TOC1 Input	0 to 1	---	1	F122	0 (Phasor)
5B03	Neutral TOC1 Pickup	0 to 30	pu	0.001	F001	1000
5B04	Neutral TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5B05	Neutral TOC1 Multiplier	0 to 600	---	0.01	F001	100
5B06	Neutral TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
5B07	Neutral TOC1 Block	0 to 65535	---	1	F300	0
5B08	Neutral TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5B09	Neutral TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5B0A	Reserved (6 items)	0 to 1	---	1	F001	0
5B10	...Repeated for module number 2					
5B20	...Repeated for module number 3					
5B30	...Repeated for module number 4					
5B40	...Repeated for module number 5					
5B50	...Repeated for module number 6					
Neutral IOC (Read/Write Grouped Setting) (12 modules)						
5C00	Neutral IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5C01	Neutral IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5C02	Neutral IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5C03	Neutral IOC1 Delay	0 to 600	s	0.01	F001	0
5C04	Neutral IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5C05	Neutral IOC1 Block	0 to 65535	---	1	F300	0
5C06	Neutral IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5C07	Neutral IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5C08	Reserved (8 items)	0 to 1	---	1	F001	0
5C10	...Repeated for module number 2					
5C20	...Repeated for module number 3					
5C30	...Repeated for module number 4					
5C40	...Repeated for module number 5					
5C50	...Repeated for module number 6					
5C60	...Repeated for module number 7					
5C70	...Repeated for module number 8					
5C80	...Repeated for module number 9					
5C90	...Repeated for module number 10					
5CA0	...Repeated for module number 11					
5CB0	...Repeated for module number 12					
Ground TOC (Read/Write Grouped Setting) (6 modules)						
5D00	Ground TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5D01	Ground TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5D02	Ground TOC1 Input	0 to 1	---	1	F122	0 (Phasor)
5D03	Ground TOC1 Pickup	0 to 30	pu	0.001	F001	1000
5D04	Ground TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
5D05	Ground TOC1 Multiplier	0 to 600	---	0.01	F001	100
5D06	Ground TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
5D07	Ground TOC1 Block	0 to 65535	---	1	F300	0
5D08	Ground TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5D09	Ground TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5D0A	Reserved (6 items)	0 to 1	---	1	F001	0

Table B–9: MODBUS MEMORY MAP (Sheet 15 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
5D10	...Repeated for module number 2					
5D20	...Repeated for module number 3					
5D30	...Repeated for module number 4					
5D40	...Repeated for module number 5					
5D50	...Repeated for module number 6					
Ground IOC (Read/Write Grouped Setting) (12 modules)						
5E00	Ground IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
5E01	Ground IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
5E02	Ground IOC1 Pickup	0 to 30	pu	0.001	F001	1000
5E03	Ground IOC1 Delay	0 to 600	s	0.01	F001	0
5E04	Ground IOC1 Reset Delay	0 to 600	s	0.01	F001	0
5E05	Ground IOC1 Block	0 to 65535	---	1	F300	0
5E06	Ground IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
5E07	Ground IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
5E08	Reserved (8 items)	0 to 1	---	1	F001	0
5E10	...Repeated for module number 2					
5E20	...Repeated for module number 3					
5E30	...Repeated for module number 4					
5E40	...Repeated for module number 5					
5E50	...Repeated for module number 6					
5E60	...Repeated for module number 7					
5E70	...Repeated for module number 8					
5E80	...Repeated for module number 9					
5E90	...Repeated for module number 10					
5EA0	...Repeated for module number 11					
5EB0	...Repeated for module number 12					
Disturbance Detector (Read/Write Grouped Setting)						
5F20	DD Function	0 to 1	---	1	F102	0 (Disabled)
5F21	DD Non Cur Supervision	0 to 65535	---	1	F300	0
5F22	DD Control Logic	0 to 65535	---	1	F300	0
5F23	DD Logic Seal In	0 to 65535	---	1	F300	0
5F24	DD Events	0 to 1	---	1	F102	0 (Disabled)
Negative Sequence TOC (Read/Write Grouped Setting) (2 modules)						
6300	Negative Sequence TOC1 Function	0 to 1	---	1	F102	0 (Disabled)
6301	Negative Sequence TOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
6302	Negative Sequence TOC1 Pickup	0 to 30	pu	0.001	F001	1000
6303	Negative Sequence TOC1 Curve	0 to 14	---	1	F103	0 (IEEE Mod Inv)
6304	Negative Sequence TOC1 Multiplier	0 to 600	---	0.01	F001	100
6305	Negative Sequence TOC1 Reset	0 to 1	---	1	F104	0 (Instantaneous)
6306	Negative Sequence TOC1 Block	0 to 65535	---	1	F300	0
6307	Negative Sequence TOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
6308	Negative Sequence TOC1 Events	0 to 1	---	1	F102	0 (Disabled)
6309	Reserved (7 items)	0 to 1	---	1	F001	0
6310	...Repeated for module number 2					
Negative Sequence IOC (Read/Write Grouped Setting) (2 modules)						
6400	Negative Sequence IOC1 Function	0 to 1	---	1	F102	0 (Disabled)
6401	Negative Sequence IOC1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
6402	Negative Sequence IOC1 Pickup	0 to 30	pu	0.001	F001	1000
6403	Negative Sequence IOC1 Delay	0 to 600	s	0.01	F001	0
6404	Negative Sequence IOC1 Reset Delay	0 to 600	s	0.01	F001	0
6405	Negative Sequence IOC1 Block	0 to 65535	---	1	F300	0
6406	Negative Sequence IOC1 Target	0 to 2	---	1	F109	0 (Self-reset)
6407	Negative Sequence IOC1 Events	0 to 1	---	1	F102	0 (Disabled)
6408	Reserved (8 items)	0 to 1	---	1	F001	0

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Table B–9: MODBUS MEMORY MAP (Sheet 16 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6410	...Repeated for module number 2					
Negative Sequence Overvoltage (Read/Write Grouped Setting)						
64A0	Negative Sequence Overvoltage Function	0 to 1	---	1	F102	0 (Disabled)
64A1	Negative Sequence Overvoltage Source	0 to 5	---	1	F167	0 (SRC 1)
64A2	Negative Sequence Overvoltage Pickup	0 to 1.25	pu	0.001	F001	300
64A3	Negative Sequence Overvoltage Pickup Delay	0 to 600	s	0.01	F001	50
64A4	Negative Sequence Overvoltage Reset Delay	0 to 600	s	0.01	F001	50
64A5	Negative Sequence Overvoltage Block	0 to 65535	---	1	F300	0
64A6	Negative Sequence Overvoltage Target	0 to 2	---	1	F109	0 (Self-reset)
64A7	Negative Sequence Overvoltage Events	0 to 1	---	1	F102	0 (Disabled)
Power Swing Detect (Read/Write Grouped Setting)						
65C0	Power Swing Function	0 to 1	---	1	F102	0 (Disabled)
65C1	Power Swing Source	0 to 5	---	1	F167	0 (SRC 1)
65C2	Power Swing Mode	0 to 1	---	1	F513	0 (Two Step)
65C3	Power Swing Supv	0.05 to 30	pu	0.001	F001	600
65C4	Power Swing Fwd Reach	0.1 to 500	ohms	0.01	F001	5000
65C5	Power Swing Fwd Rca	40 to 90	º	1	F001	75
65C6	Power Swing Rev Reach	0.1 to 500	ohms	0.01	F001	5000
65C7	Power Swing Rev Rca	40 to 90	º	1	F001	75
65C8	Outer Limit Angle	40 to 140	º	1	F001	120
65C9	Middle Limit Angle	40 to 140	º	1	F001	90
65CA	Inner Limit Angle	40 to 140	º	1	F001	60
65CB	Delay 1 Pickup	0 to 65.535	s	0.001	F001	30
65CC	Delay 1 Reset	0 to 65.535	s	0.001	F001	50
65CD	Delay 2 Pickup	0 to 65.535	s	0.001	F001	17
65CE	Delay 3 Pickup	0 to 65.535	s	0.001	F001	9
65CF	Delay 4 Pickup	0 to 65.535	s	0.001	F001	17
65D0	Seal In Delay	0 to 65.535	s	0.001	F001	400
65D1	Trip Mode	0 to 1	---	1	F514	0 (Delayed)
65D2	Power Swing Block	0 to 65535	---	1	F300	0
65D3	Power Swing Target	0 to 2	---	1	F109	0 (Self-reset)
65D4	Power Swing Event	0 to 1	---	1	F102	0 (Disabled)
Load Encroachment (Read/Write Grouped Setting)						
6700	Load Encroachment Function	0 to 1	---	1	F102	0 (Disabled)
6701	Load Encroachment Source	0 to 5	---	1	F167	0 (SRC 1)
6702	Load Encroachment Min Volt	0 to 3	pu	0.001	F001	250
6703	Load Encroachment Reach	0.02 to 250	Þ	0.01	F001	100
6704	Load Encroachment Angle	5 to 50	°	1	F001	30
6705	Load Encroachment Pkp Delay	0 to 65.535	s	0.001	F001	0
6706	Load Encroachment Rst Delay	0 to 65.535	s	0.001	F001	0
6707	Load Encroachment Block	0 to 65535	---	1	F300	0
6708	Load Encroachment Target	0 to 2	---	1	F109	0 (Self-reset)
6709	Load Encroachment Events	0 to 1	---	1	F102	0 (Disabled)
670A	Load Encroachment Reserved (6 items)	0 to 65535	---	1	F001	0
Trip Output (Read/Write Setting)						
6800	Trip Mode	0 to 2	---	1	F195	0 (Disabled)
6801	Trip 3-Pole Input1	0 to 65535	---	1	F300	0
6802	Trip 3-Pole Input2	0 to 65535	---	1	F300	0
6803	Trip 3-Pole Input3	0 to 65535	---	1	F300	0
6804	Trip 3-Pole Input4	0 to 65535	---	1	F300	0
6805	Trip 3-Pole Input5	0 to 65535	---	1	F300	0
6806	Trip 3-Pole Input6	0 to 65535	---	1	F300	0
6807	Trip 1-Pole Input1	0 to 65535	---	1	F300	0
6808	Trip 1-Pole Input2	0 to 65535	---	1	F300	0

Table B–9: MODBUS MEMORY MAP (Sheet 17 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6809	Trip 1-Pole Input3	0 to 65535	---	1	F300	0
680A	Trip 1-Pole Input4	0 to 65535	---	1	F300	0
680B	Trip 1-Pole Input5	0 to 65535	---	1	F300	0
680C	Trip 1-Pole Input6	0 to 65535	---	1	F300	0
680D	Trip Reclose Input1	0 to 65535	---	1	F300	0
680E	Trip Reclose Input2	0 to 65535	---	1	F300	0
680F	Trip Reclose Input3	0 to 65535	---	1	F300	0
6810	Trip Reclose Input4	0 to 65535	---	1	F300	0
6811	Trip Reclose Input5	0 to 65535	---	1	F300	0
6812	Trip Reclose Input6	0 to 65535	---	1	F300	0
6813	Trip Force 3-Pole	0 to 65535	---	1	F300	0
6814	Trip Pilot Priority	0 to 65.535	s	0.001	F001	0
6815	BKR Phase A Open	0 to 65535	---	1	F300	0
6816	BKR Phase B Open	0 to 65535	---	1	F300	0
6817	BKR Phase C Open	0 to 65535	---	1	F300	0
6818	Trip Events	0 to 1	---	1	F102	0 (Disabled)
6819	Reserved (7 items)	0 to 1	---	1	F001	0
Open Pole Detect (1P) (Read/Write Setting)						
6820	Open Pole Function	0 to 1	---	1	F102	0 (Disabled)
6821	Open Pole Block	0 to 65535	---	1	F300	0
6822	Open Pole Voltage SUPV	0 to 1	---	1	F102	0 (Disabled)
6823	Open Pole Current PKP	0 to 30	pu	0.001	F001	50
6824	Open Pole Target	0 to 2	---	1	F109	0 (Self-reset)
6825	Open Pole Events	0 to 1	---	1	F102	0 (Disabled)
6826	Reserved (10 items)	0 to 1	---	1	F001	0
Pilot DUTT (1P) (Read/Write Setting)						
6830	DUTT D60 Function	0 to 1	---	1	F102	0 (Disabled)
6831	DUTT D60 Seal In Delay	0 to 65.535	s	0.001	F001	0
6832	DUTT 1P No of Comm Bits	0 to 2	---	1	F198	0 (1)
6833	DUTT D60 RX1	0 to 65535	---	1	F300	0
6834	DUTT D60 RX2	0 to 65535	---	1	F300	0
6835	DUTT D60 RX3	0 to 65535	---	1	F300	0
6836	DUTT D60 RX4	0 to 65535	---	1	F300	0
6837	DUTT 1P Target	0 to 2	---	1	F109	0 (Self-reset)
6838	DUTT 1P Event	0 to 1	---	1	F102	0 (Disabled)
6839	Reserved (7 items)	0 to 1	---	1	F001	0
Pilot PUTT (1P) (Read/Write Setting)						
6840	PUTT 1P Scheme Function	0 to 1	---	1	F102	0 (Disabled)
6841	PUTT 1P Rx Pickup Delay	0 to 65.535	s	0.001	F001	0
6842	PUTT 1P Seal In Delay	0 to 65.535	s	0.001	F001	0
6843	PUTT 1P No of Comm Bits	0 to 2	---	1	F198	0 (1)
6844	PUTT 1P Rx1	0 to 65535	---	1	F300	0
6845	PUTT 1P Rx2	0 to 65535	---	1	F300	0
6846	PUTT 1P Rx3	0 to 65535	---	1	F300	0
6847	PUTT 1P Rx4	0 to 65535	---	1	F300	0
6848	PUTT 1P Target	0 to 2	---	1	F109	0 (Self-reset)
6849	PUTT 1P Event	0 to 1	---	1	F102	0 (Disabled)
684A	Reserved (6 items)	0 to 1	---	1	F001	0
Pilot POTT (1P) (Read/Write Setting)						
6850	POTT 1P Scheme Function	0 to 1	---	1	F102	0 (Disabled)
6851	POTT 1P Permissive Echo	0 to 1	---	1	F102	0 (Disabled)
6852	POTT 1P Rx Pickup Delay	0 to 65.535	s	0.001	F001	0
6853	POTT 1P Trans Block Pickup Delay	0 to 65.535	s	0.001	F001	20
6854	POTT 1P Trans Block Reset Delay	0 to 65.535	s	0.001	F001	90

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Table B–9: MODBUS MEMORY MAP (Sheet 18 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6855	POTT 1P Echo Duration	0 to 65.535	s	0.001	F001	100
6856	POTT 1P Echo Lockout	0 to 65.535	s	0.001	F001	250
6857	POTT 1P Line End Open Pickup Delay	0 to 65.535	s	0.001	F001	50
6858	POTT 1P Seal In Delay	0 to 65.535	s	0.001	F001	0
6859	POTT 1P Gnd Dir OC Fwd	0 to 65535	---	1	F300	0
685A	POTT 1P No of Comm Bits	0 to 2	---	1	F198	0 (1)
685B	POTT 1P Rx1	0 to 65535	---	1	F300	0
685C	POTT 1P Rx2	0 to 65535	---	1	F300	0
685D	POTT 1P Rx3	0 to 65535	---	1	F300	0
685E	POTT 1P Rx4	0 to 65535	---	1	F300	0
685F	POTT 1P Target	0 to 2	---	1	F109	0 (Self-reset)
6860	POTT 1P Event	0 to 1	---	1	F102	0 (Disabled)
6861	Reserved (7 items)	0 to 1	---	1	F001	0
Pilot Hybrid POTT (1P) (Read/Write Setting)						
6868	Hybrid POTT 1P Scheme Function	0 to 1	---	1	F102	0 (Disabled)
6869	Hybrid POTT 1P Permissive Echo	0 to 1	---	1	F102	0 (Disabled)
686A	Hybrid POTT 1P Rx Pickup Delay	0 to 65.535	s	0.001	F001	0
686B	Hybrid POTT 1P Trans Block Pickup Delay	0 to 65.535	s	0.001	F001	20
686C	Hybrid POTT 1P Trans Block Reset Delay	0 to 65.535	s	0.001	F001	90
686D	Hybrid POTT 1P Echo Duration	0 to 65.535	s	0.001	F001	100
686E	Hybrid POTT 1P Echo Lockout	0 to 65.535	s	0.001	F001	250
686F	Hybrid POTT 1P Seal In Delay	0 to 65.535	---	0.001	F001	0
6870	Hybrid POTT 1P Gnd Dir OC Fwd	0 to 65535	---	1	F300	0
6871	Hybrid POTT 1P Gnd Dir OC Rev	0 to 65535	---	1	F300	0
6872	Hybrid POTT 1P No of Comm Bits	0 to 2	---	1	F198	0 (1)
6873	Hybrid POTT 1P Rx1	0 to 65535	---	1	F300	0
6874	Hybrid POTT 1P Rx2	0 to 65535	---	1	F300	0
6875	Hybrid POTT 1P Rx3	0 to 65535	---	1	F300	0
6876	Hybrid POTT 1P Rx4	0 to 65535	---	1	F300	0
6877	Hybrid POTT 1P Target	0 to 2	---	1	F109	0 (Self-reset)
6878	Hybrid POTT 1P Event	0 to 1	---	1	F102	0 (Disabled)
6879	Reserved (7 items)	0 to 1	---	1	F001	0
Pilot Blocking (1P) (Read/Write Setting)						
6880	Blocking Scheme 1P Function	0 to 1	---	1	F102	0 (Disabled)
6881	Block 1P Rx Coord Pickup Delay	0 to 65.535	s	0.001	F001	10
6882	Block 1P Transient Block Pickup Delay	0 to 65.535	s	0.001	F001	30
6883	Block 1P Transient Block Reset Delay	0 to 65.535	s	0.001	F001	90
6884	Blocking Scheme 1P Seal In Delay	0 to 65.535	s	0.001	F001	0
6885	Blocking Scheme 1P Gnd Dir OC Fwd	0 to 65535	---	1	F300	0
6886	Blocking Scheme 1P Gnd Dir OC Rev	0 to 65535	---	1	F300	0
6887	Blocking Scheme 1P No of Comm Bits	0 to 2	---	1	F198	0 (1)
6888	Blocking Scheme 1P Rx1	0 to 65535	---	1	F300	0
6889	Blocking Scheme 1P Rx2	0 to 65535	---	1	F300	0
688A	Blocking Scheme 1P Rx3	0 to 65535	---	1	F300	0
688B	Blocking Scheme 1P Rx4	0 to 65535	---	1	F300	0
688C	Blocking 1P Target	0 to 2	---	1	F109	0 (Self-reset)
688D	Blocking 1P Event	0 to 1	---	1	F102	0 (Disabled)
688E	Reserved (2 items)	0 to 1	---	1	F001	0
Autoreclose 1P 3P (Read/Write Setting)						
6890	AR Mode	0 to 3	---	1	F080	0 (1 & 3 Pole)
6891	AR Max Num Shots	1 to 2	---	1	F001	2
6892	AR Block BKR1	0 to 65535	---	1	F300	0
6893	AR Close Time BKR1	0 to 655.35	s	0.01	F001	10
6894	AR BKR Man Close	0 to 65535	---	1	F300	0

Table B–9: MODBUS MEMORY MAP (Sheet 19 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
6895	AR Function	0 to 1	---	1	F102	0 (Disabled)
6896	AR Blk Time Mnl Cls	0 to 655.35	s	0.01	F001	1000
6897	AR 1P Init	0 to 65535	---	1	F300	0
6898	AR 3P Init	0 to 65535	---	1	F300	0
6899	AR 3P TD Init	0 to 65535	---	1	F300	0
689A	AR Multi P Fault	0 to 65535	---	1	F300	0
689B	AR BKR 1 Pole Open	0 to 65535	---	1	F300	0
689C	AR BKR 3 Pole Open	0 to 65535	---	1	F300	0
689D	AR 3P Dead Time 1	0 to 655.35	s	0.01	F001	50
689E	AR 3P Dead Time 2	0 to 655.35	s	0.01	F001	120
689F	AR Extend Dead T1	0 to 65535	---	1	F300	0
68A0	AR Dead T1 Extension	0 to 655.35	s	0.01	F001	50
68A1	AR Reset	0 to 65535	---	1	F300	0
68A2	AR Reset Time	0 to 655.35	s	0.01	F001	6000
68A3	AR BKR Closed	0 to 65535	---	1	F300	0
68A4	AR Block	0 to 65535	---	1	F300	0
68A5	AR Pause	0 to 65535	---	1	F300	0
68A6	AR Inc Seq Time	0 to 655.35	s	0.01	F001	500
68A7	AR Block BKR2	0 to 65535	---	1	F300	0
68A8	AR Close Time BKR2	0 to 655.35	s	0.01	F001	10
68A9	AR Transfer 1 to 2	0 to 1	---	1	F126	0 (No)
68AA	AR Transfer 2 to 1	0 to 1	---	1	F126	0 (No)
68AB	AR BKR1 Fail Option	0 to 1	---	1	F081	0 (Continue)
68AC	AR BKR2 Fail Option	0 to 1	---	1	F081	0 (Continue)
68AD	AR 1P Dead Time	0 to 655.35	s	0.01	F001	100
68AE	AR BKR Sequence	0 to 4	---	1	F082	3 (1 - 2)
68AF	AR Transfer Time	0 to 655.35	s	0.01	F001	400
68B0	AR Event	0 to 1	---	1	F102	0 (Disabled)
68B1	Reserved (16 items)	0 to 1	---	1	F102	0 (Disabled)
Phase Undervoltage (Read/Write Grouped Setting) (2 modules)						
7000	Phase UV1 Function	0 to 1	---	1	F102	0 (Disabled)
7001	Phase UV1 Signal Source	0 to 5	---	1	F167	0 (SRC 1)
7002	Phase UV1 Pickup	0 to 3	pu	0.001	F001	1000
7003	Phase UV1 Curve	0 to 1	---	1	F111	0 (Definite Time)
7004	Phase UV1 Delay	0 to 600	s	0.01	F001	100
7005	Phase UV1 Minimum Voltage	0 to 3	pu	0.001	F001	100
7006	Phase UV1 Block	0 to 65535	---	1	F300	0
7007	Phase UV1 Target	0 to 2	---	1	F109	0 (Self-reset)
7008	Phase UV1 Events	0 to 1	---	1	F102	0 (Disabled)
7009	Phase UV Measurement Mode	0 to 1	---	1	F186	0 (Phase to Ground)
700A	Reserved (6 items)	0 to 1	---	1	F001	0
7010	...Repeated for module number 2					
Phase Overvoltage (Read/Write Grouped Setting)						
7100	Phase OV1 Function	0 to 1	---	1	F102	0 (Disabled)
7101	Phase OV1 Source	0 to 5	---	1	F167	0 (SRC 1)
7102	Phase OV1 Pickup	0 to 3	pu	0.001	F001	1000
7103	Phase OV1 Delay	0 to 600	s	0.01	F001	100
7104	Phase OV1 Reset Delay	0 to 600	s	0.01	F001	100
7105	Phase OV1 Block	0 to 65535	---	1	F300	0
7106	Phase OV1 Target	0 to 2	---	1	F109	0 (Self-reset)
7107	Phase OV1 Events	0 to 1	---	1	F102	0 (Disabled)
7108	Reserved (8 items)	0 to 1	---	1	F001	0
Distance (Read/Write Grouped Setting)						
7120	Distance Signal Source	0 to 5	---	1	F167	0 (SRC 1)

Table B–9: MODBUS MEMORY MAP (Sheet 20 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7121	Memory Duration	5 to 25	cycles	1	F001	10
Phase Distance (Read/Write Grouped Setting) (4 modules)						
7130	Phase Distance Z x Function	0 to 1	---	1	F102	0 (Disabled)
7131	Phase Distance Z x Current Supervision	0.05 to 30	pu	0.001	F001	200
7132	Phase Distance Z x Reach	0.02 to 250	Þ	0.01	F001	200
7133	Phase Distance Z x Direction	0 to 1	---	1	F154	0 (Forward)
7134	Phase Distance Z x Comparator Limit	30 to 90	°	1	F001	90
7135	Phase Distance Z x Delay	0 to 65.535	s	0.001	F001	0
7136	Phase Distance Z x Block	0 to 65535	---	1	F300	0
7137	Phase Distance Z x Target	0 to 2	---	1	F109	0 (Self-reset)
7138	Phase Distance Z x Events	0 to 1	---	1	F102	0 (Disabled)
7139	Phase Distance Z x Shape	0 to 1	---	1	F120	0 (Mho)
713A	Phase Distance Z x RCA	30 to 90	°	1	F001	85
713B	Phase Distance Z x DIR RCA	30 to 90	°	1	F001	85
713C	Phase Distance Z x DIR Comp Limit	30 to 90	°	1	F001	90
713D	Phase Distance Z x Quad Right Blinder	0.02 to 500	Þ	0.01	F001	1000
713E	Phase Distance Z x Quad Right Blinder RCA	60 to 90	°	1	F001	85
713F	Phase Distance Z x Quad Left Blinder	0.02 to 500	Þ	0.01	F001	1000
7140	Phase Distance Z x Quad Left Blinder RCA	60 to 90	°	1	F001	85
7141	Phase Distance Zx Volt Limit	0 to 5	pu	0.001	F001	0
7142	Phase Distance Z x Reserved (2 items)	---	---	---	F001	0
7144	...Repeated for module number 2					
7158	...Repeated for module number 3					
716C	...Repeated for module number 4					
Ground Distance (Read/Write Grouped Setting) (4 modules)						
7190	Ground Distance Z x Function	0 to 1	---	1	F102	0 (Disabled)
7191	Ground Distance Z x Current Supervision	0.05 to 30	pu	0.001	F001	200
7192	Ground Distance Z x Reach	0.02 to 250	Þ	0.01	F001	200
7193	Ground Distance Z x Direction	0 to 1	---	1	F154	0 (Forward)
7194	Ground Distance Z x Comparator Limit	30 to 90	°	1	F001	90
7195	Ground Distance Z x Delay	0 to 65.535	s	0.001	F001	0
7196	Ground Distance Z x Block	0 to 65535	---	1	F300	0
7197	Ground Distance Z x Target	0 to 2	---	1	F109	0 (Self-reset)
7198	Ground Distance Z x Events	0 to 1	---	1	F102	0 (Disabled)
7199	Ground Distance Z x Shape	0 to 1	---	1	F120	0 (Mho)
719A	Ground Distance Z x Z0 Z1 Mag	0.5 to 7	---	0.01	F001	270
719B	Ground Distance Z x Z0 Z1 Ang	-90 to 90	°	1	F002	0
719C	Ground Distance Z x RCA	30 to 90	°	1	F001	85
719D	Ground Distance Z x DIR RCA	30 to 90	°	1	F001	85
719E	Ground Distance Z x DIR Comp Limit	30 to 90	°	1	F001	90
719F	Ground Distance Z x Quad Right Blinder	0.02 to 500	Þ	0.01	F001	1000
71A0	Ground Distance Z x Quad Right Blinder RCA	60 to 90	°	1	F001	85
71A1	Ground Distance Z x Quad Left Blinder	0.02 to 500	Þ	0.01	F001	1000
71A2	Ground Distance Z x Quad Left Blinder RCA	60 to 90	°	1	F001	85
71A3	Ground Distance Z x Z0M Z1 Mag	0 to 7	---	0.01	F001	0
71A4	Ground Distance Z x Z0M Z1 Ang	-90 to 90	°	1	F002	0
71A5	Ground Distance Z x Volt Level	0 to 5	pu	0.001	F001	0
71A6	Ground Distance Z x Reserved	---	---	---	F001	0
71A7	...Repeated for module number 2					
71BE	...Repeated for module number 3					
71D5	...Repeated for module number 4					
Line Pickup (Read/Write Grouped Setting)						
71F0	Line Pickup Function	0 to 1	---	1	F102	0 (Disabled)
71F1	Line Pickup Signal Source	0 to 5	---	1	F167	0 (SRC 1)

Table B–9: MODBUS MEMORY MAP (Sheet 21 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
71F2	Line Pickup Phase IOC Pickup	0 to 30	pu	0.001	F001	1000
71F3	Line Pickup Pos Seq UV Pickup	0 to 3	pu	0.001	F001	700
71F4	Line End Open Pickup Delay	0 to 65.535	s	0.001	F001	150
71F5	Line End Open Reset Delay	0 to 65.535	s	0.001	F001	90
71F6	Line Pickup Pos Seq OV Pickup Delay	0 to 65.535	s	0.001	F001	40
71F7	Autoreclose Coordination Pickup Delay	0 to 65.535	s	0.001	F001	45
71F8	Autoreclose Coordination Reset Delay	0 to 65.535	s	0.001	F001	5
71F9	Autoreclose Coordination Bypass	0 to 1	---	1	F102	1 (Enabled)
71FA	Line Pickup Block	0 to 65535	---	1	F300	0
71FB	Line Pickup Target	0 to 2	---	1	F109	0 (Self-reset)
71FC	Line Pickup Events	0 to 1	---	1	F102	0 (Disabled)
Breaker Failure (Read/Write Grouped Setting) (2 modules)						
7200	Breaker Failure x Function	0 to 1	---	1	F102	0 (Disabled)
7201	Breaker Failure x Mode	0 to 1	---	1	F157	0 (3-Pole)
7208	Breaker Failure x Source	0 to 5	---	1	F167	0 (SRC 1)
7209	Breaker Failure x Amp Supervision	0 to 1	---	1	F126	1 (Yes)
720A	Breaker Failure x Use Seal-In	0 to 1	---	1	F126	1 (Yes)
720B	Breaker Failure x Three Pole Initiate	0 to 65535	---	1	F300	0
720C	Breaker Failure x Block	0 to 65535	---	1	F300	0
720D	Breaker Failure x Phase Amp Supv Pickup	0.001 to 30	pu	0.001	F001	1050
720E	Breaker Failure x Neutral Amp Supv Pickup	0.001 to 30	pu	0.001	F001	1050
720F	Breaker Failure x Use Timer 1	0 to 1	---	1	F126	1 (Yes)
7210	Breaker Failure x Timer 1 Pickup	0 to 65.535	s	0.001	F001	0
7211	Breaker Failure x Use Timer 2	0 to 1	---	1	F126	1 (Yes)
7212	Breaker Failure x Timer 2 Pickup	0 to 65.535	s	0.001	F001	0
7213	Breaker Failure x Use Timer 3	0 to 1	---	1	F126	1 (Yes)
7214	Breaker Failure x Timer 3 Pickup	0 to 65.535	s	0.001	F001	0
7215	Breaker Failure x Breaker Status 1 Phase A/3P	0 to 65535	---	1	F300	0
7216	Breaker Failure x Breaker Status 2 Phase A/3P	0 to 65535	---	1	F300	0
7217	Breaker Failure x Breaker Test On	0 to 65535	---	1	F300	0
7218	Breaker Failure x Phase Amp Hiset Pickup	0.001 to 30	pu	0.001	F001	1050
7219	Breaker Failure x Neutral Amp Hiset Pickup	0.001 to 30	pu	0.001	F001	1050
721A	Breaker Failure x Phase Amp Loset Pickup	0.001 to 30	pu	0.001	F001	1050
721B	Breaker Failure x Neutral Amp Loset Pickup	0.001 to 30	pu	0.001	F001	1050
721C	Breaker Failure x Loset Time	0 to 65.535	s	0.001	F001	0
721D	Breaker Failure x Trip Dropout Delay	0 to 65.535	s	0.001	F001	0
721E	Breaker Failure x Target	0 to 2	---	1	F109	0 (Self-reset)
721F	Breaker Failure x Events	0 to 1	---	1	F102	0 (Disabled)
7220	Breaker Failure x Phase A Initiate	0 to 65535	---	1	F300	0
7221	Breaker Failure x Phase B Initiate	0 to 65535	---	1	F300	0
7222	Breaker Failure x Phase C Initiate	0 to 65535	---	1	F300	0
7223	Breaker Failure x Breaker Status 1 Phase B	0 to 65535	---	1	F300	0
7224	Breaker Failure x Breaker Status 1 Phase C	0 to 65535	---	1	F300	0
7225	Breaker Failure x Breaker Status 2 Phase B	0 to 65535	---	1	F300	0
7226	Breaker Failure x Breaker Status 2 Phase C	0 to 65535	---	1	F300	0
7227	...Repeated for module number 2					
Phase Directional (Read/Write Grouped Setting) (2 modules)						
7260	Phase DIR 1 Function	0 to 1	---	1	F102	0 (Disabled)
7261	Phase DIR 1 Source	0 to 5	---	1	F167	0 (SRC 1)
7262	Phase DIR 1 Block	0 to 65535	---	1	F300	0
7263	Phase DIR 1 ECA	0 to 359	---	1	F001	30
7264	Phase DIR 1 Pol V Threshold	0 to 3	pu	0.001	F001	50
7265	Phase DIR 1 Block OC	0 to 1	---	1	F126	0 (No)
7266	Phase DIR 1 Target	0 to 2	---	1	F109	0 (Self-reset)

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Table B–9: MODBUS MEMORY MAP (Sheet 22 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7267	Phase DIR 1 Events	0 to 1	---	1	F102	0 (Disabled)
7268	Reserved (8 items)	0 to 1	---	1	F001	0
7270	...Repeated for module number 2					
Neutral Directional OC (Read/Write Grouped Setting) (2 modules)						
7280	Neutral DIR OC1 Function	0 to 1	---	1	F102	0 (Disabled)
7281	Neutral DIR OC1 Source	0 to 5	---	1	F167	0 (SRC 1)
7282	Neutral DIR OC1 Polarizing	0 to 2	---	1	F230	0 (Voltage)
7283	Neutral DIR OC1 Forward ECA	-90 to 90	° Lag	1	F002	75
7284	Neutral DIR OC1 Forward Limit Angle	40 to 90	°	1	F001	90
7285	Neutral DIR OC1 Forward Pickup	0.002 to 30	pu	0.001	F001	50
7286	Neutral DIR OC1 Reverse Limit Angle	40 to 90	°	1	F001	90
7287	Neutral DIR OC1 Reverse Pickup	0.002 to 30	pu	0.001	F001	50
7288	Neutral DIR OC1 Target	0 to 2	---	1	F109	0 (Self-reset)
7289	Neutral DIR OC1 Block	0 to 65535	---	1	F300	0
728A	Neutral DIR OC1 Events	0 to 1	---	1	F102	0 (Disabled)
728B	Neutral DIR OC X Polarizing Voltage	0 to 1	---	1	F231	0 (Calculated V0)
728C	Neutral DIR OC X Op Current	0 to 1	---	1	F196	0 (Calculated 3I0)
728D	Neutral DIR OC X Offset	0 to 250	Þ	0.01	F001	0
728E	Reserved (2 items)	0 to 1	---	1	F001	0
7290	...Repeated for module number 2					
Negative Sequence Directional OC (Read/Write Grouped Setting) (2 modules)						
72A0	Negative Sequence DIR OC1 Function	0 to 1	---	1	F102	0 (Disabled)
72A1	Negative Sequence DIR OC1 Source	0 to 5	---	1	F167	0 (SRC 1)
72A2	Negative Sequence DIR OC1 Type	0 to 1	---	1	F179	0 (Neg Sequence)
72A3	Negative Sequence DIR OC1 Forward ECA	0 to 90	° Lag	1	F002	75
72A4	Negative Sequence DIR OC1 Forward Limit Angle	40 to 90	°	1	F001	90
72A5	Negative Sequence DIR OC1 Forward Pickup	0.05 to 30	pu	0.01	F001	5
72A6	Negative Sequence DIR OC1 Reverse Limit Angle	40 to 90	°	1	F001	90
72A7	Negative Sequence DIR OC1 Reverse Pickup	0.05 to 30	pu	0.01	F001	5
72A8	Negative Sequence DIR OC1 Target	0 to 2	---	1	F109	0 (Self-reset)
72A9	Negative Sequence DIR OC1 Block	0 to 65535	---	1	F300	0
72AA	Negative Sequence DIR OC1 Events	0 to 1	---	1	F102	0 (Disabled)
72AB	Negative Sequence DIR OC X Offset	0 to 250	Þ	0.01	F001	0
72AC	Reserved (4 items)	0 to 1	---	1	F001	0
72B0	...Repeated for module number 2					
Breaker Arcing Current Settings (Read/Write Setting) (2 modules)						
72C0	Breaker x Arcing Amp Function	0 to 1	---	1	F102	0 (Disabled)
72C1	Breaker x Arcing Amp Source	0 to 5	---	1	F167	0 (SRC 1)
72C2	Breaker x Arcing Amp Init	0 to 65535	---	1	F300	0
72C3	Breaker x Arcing Amp Delay	0 to 65.535	s	0.001	F001	0
72C4	Breaker x Arcing Amp Limit	0 to 50000	kA2-cyc	1	F001	1000
72C5	Breaker x Arcing Amp Block	0 to 65535	---	1	F300	0
72C6	Breaker x Arcing Amp Target	0 to 2	---	1	F109	0 (Self-reset)
72C7	Breaker x Arcing Amp Events	0 to 1	---	1	F102	0 (Disabled)
72C8	...Repeated for module number 2					
DCMA Inputs (Read/Write Setting) (24 modules)						
7300	DCMA Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7301	DCMA Inputs x ID	---	---	---	F205	"DCMA Ip 1 "
7307	DCMA Inputs x Reserved 1 (4 items)	0 to 65535	---	1	F001	0
730B	DCMA Inputs x Units	---	---	---	F206	"mA"
730E	DCMA Inputs x Range	0 to 6	---	1	F173	6 (4 to 20 mA)
730F	DCMA Inputs x Minimum Value	-9999.999 to 9999.999	---	0.001	F004	4000
7311	DCMA Inputs x Maximum Value	-9999.999 to 9999.999	---	0.001	F004	20000
7313	DCMA Inputs x Reserved (5 items)	0 to 65535	---	1	F001	0

Table B–9: MODBUS MEMORY MAP (Sheet 23 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
7318	...Repeated for module number 2					
7330	...Repeated for module number 3					
7348	...Repeated for module number 4					
7360	...Repeated for module number 5					
7378	...Repeated for module number 6					
7390	...Repeated for module number 7					
73A8	...Repeated for module number 8					
73C0	...Repeated for module number 9					
73D8	...Repeated for module number 10					
73F0	...Repeated for module number 11					
7408	...Repeated for module number 12					
7420	...Repeated for module number 13					
7438	...Repeated for module number 14					
7450	...Repeated for module number 15					
7468	...Repeated for module number 16					
7480	...Repeated for module number 17					
7498	...Repeated for module number 18					
74B0	...Repeated for module number 19					
74C8	...Repeated for module number 20					
74E0	...Repeated for module number 21					
74F8	...Repeated for module number 22					
7510	...Repeated for module number 23					
7528	...Repeated for module number 24					
RTD Inputs (Read/Write Setting) (48 modules)						
7540	RTD Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7541	RTD Inputs x ID	---	---	---	F205	"RTD Ip 1 "
7547	RTD Inputs x Reserved 1 (4 items)	0 to 65535	---	1	F001	0
754B	RTD Inputs x Type	0 to 3	---	1	F174	0 (100 Ω Platinum)
754C	RTD Inputs x Reserved 2 (4 items)	0 to 65535	---	1	F001	0
7550	...Repeated for module number 2					
7560	...Repeated for module number 3					
7570	...Repeated for module number 4					
7580	...Repeated for module number 5					
7590	...Repeated for module number 6					
75A0	...Repeated for module number 7					
75B0	...Repeated for module number 8					
75C0	...Repeated for module number 9					
75D0	...Repeated for module number 10					
75E0	...Repeated for module number 11					
75F0	...Repeated for module number 12					
7600	...Repeated for module number 13					
7610	...Repeated for module number 14					
7620	...Repeated for module number 15					
7630	...Repeated for module number 16					
7640	...Repeated for module number 17					
7650	...Repeated for module number 18					
7660	...Repeated for module number 19					
7670	...Repeated for module number 20					
7680	...Repeated for module number 21					
7690	...Repeated for module number 22					
76A0	...Repeated for module number 23					
76B0	...Repeated for module number 24					
76C0	...Repeated for module number 25					
76D0	...Repeated for module number 26					

B

Table B–9: MODBUS MEMORY MAP (Sheet 24 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
76E0	...Repeated for module number 27					
76F0	...Repeated for module number 28					
7700	...Repeated for module number 29					
7710	...Repeated for module number 30					
7720	...Repeated for module number 31					
7730	...Repeated for module number 32					
7740	...Repeated for module number 33					
7750	...Repeated for module number 34					
7760	...Repeated for module number 35					
7770	...Repeated for module number 36					
7780	...Repeated for module number 37					
7790	...Repeated for module number 38					
77A0	...Repeated for module number 39					
77B0	...Repeated for module number 40					
77C0	...Repeated for module number 41					
77D0	...Repeated for module number 42					
77E0	...Repeated for module number 43					
77F0	...Repeated for module number 44					
7800	...Repeated for module number 45					
7810	...Repeated for module number 46					
7820	...Repeated for module number 47					
7830	...Repeated for module number 48					
Ohm Inputs (Read/Write Setting) (2 modules)						
7840	Ohm Inputs x Function	0 to 1	---	1	F102	0 (Disabled)
7841	Ohm Inputs x ID	---	---	---	F205	"Ohm Ip 1 "
7847	Ohm Inputs x Reserved (9 items)	0 to 65535	---	1	F001	0
7850	...Repeated for module number 2					
Frequency (Read Only)						
8000	Tracking Frequency	2 to 90	Hz	0.01	F001	0
FlexState Settings (Read/Write Setting)						
8800	FlexState Parameters (256 items)	---	---	---	F300	0
FlexElement (Read/Write Setting) (16 modules)						
9000	FlexElement Function	0 to 1	---	1	F102	0 (Disabled)
9001	FlexElement Name	---	---	---	F206	"FxE \x040"
9004	FlexElement InputP	0 to 65535	---	1	F600	0
9005	FlexElement InputM	0 to 65535	---	1	F600	0
9006	FlexElement Compare	0 to 1	---	1	F516	0 (LEVEL)
9007	FlexElement Input	0 to 1	---	1	F515	0 (SIGNED)
9008	FlexElement Direction	0 to 1	---	1	F517	0 (OVER)
9009	FlexElement Hysteresis	0.1 to 50	%	0.1	F001	30
900A	FlexElement Pickup	-90 to 90	pu	0.001	F004	1000
900C	FlexElement DeltaT Units	0 to 2	---	1	F518	0 (Milliseconds)
900D	FlexElement DeltaT	20 to 86400	---	1	F003	20
900F	FlexElement Pkp Delay	0 to 65.535	s	0.001	F001	0
9010	FlexElement Rst Delay	0 to 65.535	s	0.001	F001	0
9011	FlexElement Block	0 to 65535	---	1	F300	0
9012	FlexElement Target	0 to 2	---	1	F109	0 (Self-reset)
9013	FlexElement Events	0 to 1	---	1	F102	0 (Disabled)
9014	...Repeated for module number 2					
9028	...Repeated for module number 3					
903C	...Repeated for module number 4					
9050	...Repeated for module number 5					
9064	...Repeated for module number 6					
9078	...Repeated for module number 7					

Table B–9: MODBUS MEMORY MAP (Sheet 25 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
908C	...Repeated for module number 8					
90A0	...Repeated for module number 9					
90B4	...Repeated for module number 10					
90C8	...Repeated for module number 11					
90DC	...Repeated for module number 12					
90F0	...Repeated for module number 13					
9104	...Repeated for module number 14					
9118	...Repeated for module number 15					
912C	...Repeated for module number 16					
FlexElement Actuals (Read Only) (16 modules)						
9A01	FlexElement Actual	-2147483.647 to 2147483.647	---	0.001	F004	0
9A03	...Repeated for module number 2					
9A05	...Repeated for module number 3					
9A07	...Repeated for module number 4					
9A09	...Repeated for module number 5					
9A0B	...Repeated for module number 6					
9A0D	...Repeated for module number 7					
9A0F	...Repeated for module number 8					
9A11	...Repeated for module number 9					
9A13	...Repeated for module number 10					
9A15	...Repeated for module number 11					
9A17	...Repeated for module number 12					
9A19	...Repeated for module number 13					
9A1B	...Repeated for module number 14					
9A1D	...Repeated for module number 15					
9A1F	...Repeated for module number 16					
Setting Groups (Read/Write Setting)						
A000	Setting Group for Modbus Comm (0 means group 1)	0 to 7	---	1	F001	0
A001	Setting Groups Block	0 to 65535	---	1	F300	0
A002	FlexLogic Operands to Activate Grps 2 to 8 (7 items)	0 to 65535	---	1	F300	0
A009	Setting Group Function	0 to 1	---	1	F102	0 (Disabled)
A00A	Setting Group Events	0 to 1	---	1	F102	0 (Disabled)
Setting Groups (Read Only)						
A00B	Current Setting Group	0 to 7	---	1	F001	0
VT Fuse Failure (Read/Write Setting) (6 modules)						
A040	VT Fuse Failure Function	0 to 1	---	1	F102	0 (Disabled)
A041	...Repeated for module number 2					
A042	...Repeated for module number 3					
A043	...Repeated for module number 4					
A044	...Repeated for module number 5					
A045	...Repeated for module number 6					
Digital Elements (Read/Write Setting) (16 modules)						
B000	Digital Element x Function	0 to 1	---	1	F102	0 (Disabled)
B001	Digital Element x Name	---	---	---	F203	"Dig Element 1 "
B015	Digital Element x Input	0 to 65535	---	1	F300	0
B016	Digital Element x Pickup Delay	0 to 999999.999	s	0.001	F003	0
B018	Digital Element x Reset Delay	0 to 999999.999	s	0.001	F003	0
B01A	Digital Element x Block	0 to 65535	---	1	F300	0
B01B	Digital Element x Target	0 to 2	---	1	F109	0 (Self-reset)
B01C	Digital Element x Events	0 to 1	---	1	F102	0 (Disabled)
B01D	Digital Element x Reserved (3 items)	---	---	---	F001	0
B020	...Repeated for module number 2					
B040	...Repeated for module number 3					

B

Table B–9: MODBUS MEMORY MAP (Sheet 26 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
B060	...Repeated for module number 4					
B080	...Repeated for module number 5					
B0A0	...Repeated for module number 6					
B0C0	...Repeated for module number 7					
B0E0	...Repeated for module number 8					
B100	...Repeated for module number 9					
B120	...Repeated for module number 10					
B140	...Repeated for module number 11					
B160	...Repeated for module number 12					
B180	...Repeated for module number 13					
B1A0	...Repeated for module number 14					
B1C0	...Repeated for module number 15					
B1E0	...Repeated for module number 16					
Digital Counter (Read/Write Setting) (8 modules)						
B300	Digital Counter x Function	0 to 1	---	1	F102	0 (Disabled)
B301	Digital Counter x Name	---	---	---	F205	"Counter 1 "
B307	Digital Counter x Units	---	---	---	F206	(none)
B30A	Digital Counter x Block	0 to 65535	---	1	F300	0
B30B	Digital Counter x Up	0 to 65535	---	1	F300	0
B30C	Digital Counter x Down	0 to 65535	---	1	F300	0
B30D	Digital Counter x Preset	-2147483647 to 2147483647	---	1	F004	0
B30F	Digital Counter x Compare	-2147483647 to 2147483647	---	1	F004	0
B311	Digital Counter x Reset	0 to 65535	---	1	F300	0
B312	Digital Counter x Freeze/Reset	0 to 65535	---	1	F300	0
B313	Digital Counter x Freeze/Count	0 to 65535	---	1	F300	0
B314	Digital Counter Set To Preset	0 to 65535	---	1	F300	0
B315	Digital Counter x Reserved (11 items)	---	---	---	F001	0
B320	...Repeated for module number 2					
B340	...Repeated for module number 3					
B360	...Repeated for module number 4					
B380	...Repeated for module number 5					
B3A0	...Repeated for module number 6					
B3C0	...Repeated for module number 7					
B3E0	...Repeated for module number 8					
Contact Inputs (Read/Write Setting) (96 modules)						
C000	Contact Input x Name	---	---	---	F205	"Cont Ip 1 "
C006	Contact Input x Events	0 to 1	---	1	F102	0 (Disabled)
C007	Contact Input x Debounce Time	0 to 16	ms	0.5	F001	20
C008	...Repeated for module number 2					
C010	...Repeated for module number 3					
C018	...Repeated for module number 4					
C020	...Repeated for module number 5					
C028	...Repeated for module number 6					
C030	...Repeated for module number 7					
C038	...Repeated for module number 8					
C040	...Repeated for module number 9					
C048	...Repeated for module number 10					
C050	...Repeated for module number 11					
C058	...Repeated for module number 12					
C060	...Repeated for module number 13					
C068	...Repeated for module number 14					
C070	...Repeated for module number 15					
C078	...Repeated for module number 16					

Table B–9: MODBUS MEMORY MAP (Sheet 27 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C080	...Repeated for module number 17					
C088	...Repeated for module number 18					
C090	...Repeated for module number 19					
C098	...Repeated for module number 20					
C0A0	...Repeated for module number 21					
C0A8	...Repeated for module number 22					
C0B0	...Repeated for module number 23					
C0B8	...Repeated for module number 24					
C0C0	...Repeated for module number 25					
C0C8	...Repeated for module number 26					
C0D0	...Repeated for module number 27					
C0D8	...Repeated for module number 28					
C0E0	...Repeated for module number 29					
C0E8	...Repeated for module number 30					
C0F0	...Repeated for module number 31					
C0F8	...Repeated for module number 32					
C100	...Repeated for module number 33					
C108	...Repeated for module number 34					
C110	...Repeated for module number 35					
C118	...Repeated for module number 36					
C120	...Repeated for module number 37					
C128	...Repeated for module number 38					
C130	...Repeated for module number 39					
C138	...Repeated for module number 40					
C140	...Repeated for module number 41					
C148	...Repeated for module number 42					
C150	...Repeated for module number 43					
C158	...Repeated for module number 44					
C160	...Repeated for module number 45					
C168	...Repeated for module number 46					
C170	...Repeated for module number 47					
C178	...Repeated for module number 48					
C180	...Repeated for module number 49					
C188	...Repeated for module number 50					
C190	...Repeated for module number 51					
C198	...Repeated for module number 52					
C1A0	...Repeated for module number 53					
C1A8	...Repeated for module number 54					
C1B0	...Repeated for module number 55					
C1B8	...Repeated for module number 56					
C1C0	...Repeated for module number 57					
C1C8	...Repeated for module number 58					
C1D0	...Repeated for module number 59					
C1D8	...Repeated for module number 60					
C1E0	...Repeated for module number 61					
C1E8	...Repeated for module number 62					
C1F0	...Repeated for module number 63					
C1F8	...Repeated for module number 64					
C200	...Repeated for module number 65					
C208	...Repeated for module number 66					
C210	...Repeated for module number 67					
C218	...Repeated for module number 68					
C220	...Repeated for module number 69					
C228	...Repeated for module number 70					

Table B–9: MODBUS MEMORY MAP (Sheet 28 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C230	...Repeated for module number 71					
C238	...Repeated for module number 72					
C240	...Repeated for module number 73					
C248	...Repeated for module number 74					
C250	...Repeated for module number 75					
C258	...Repeated for module number 76					
C260	...Repeated for module number 77					
C268	...Repeated for module number 78					
C270	...Repeated for module number 79					
C278	...Repeated for module number 80					
C280	...Repeated for module number 81					
C288	...Repeated for module number 82					
C290	...Repeated for module number 83					
C298	...Repeated for module number 84					
C2A0	...Repeated for module number 85					
C2A8	...Repeated for module number 86					
C2B0	...Repeated for module number 87					
C2B8	...Repeated for module number 88					
C2C0	...Repeated for module number 89					
C2C8	...Repeated for module number 90					
C2D0	...Repeated for module number 91					
C2D8	...Repeated for module number 92					
C2E0	...Repeated for module number 93					
C2E8	...Repeated for module number 94					
C2F0	...Repeated for module number 95					
C2F8	...Repeated for module number 96					
Contact Input Thresholds (Read/Write Setting)						
C600	Contact Input x Threshold (24 items)	0 to 3	---	1	F128	1 (33 Vdc)
Virtual Inputs Global Settings (Read/Write Setting)						
C680	Virtual Inputs SBO Timeout	1 to 60	s	1	F001	30
Virtual Inputs (Read/Write Setting) (32 modules)						
C690	Virtual Input x Function	0 to 1	---	1	F102	0 (Disabled)
C691	Virtual Input x Name	---	---	---	F205	"Virt Ip 1 "
C69B	Virtual Input x Programmed Type	0 to 1	---	1	F127	0 (Latched)
C69C	Virtual Input x Events	0 to 1	---	1	F102	0 (Disabled)
C69D	Virtual Input x UCA SBOClass	1 to 2	---	1	F001	1
C69E	Virtual Input x UCA SBOEna	0 to 1	---	1	F102	0 (Disabled)
C69F	Virtual Input x Reserved	---	---	---	F001	0
C6A0	...Repeated for module number 2					
C6B0	...Repeated for module number 3					
C6C0	...Repeated for module number 4					
C6D0	...Repeated for module number 5					
C6E0	...Repeated for module number 6					
C6F0	...Repeated for module number 7					
C700	...Repeated for module number 8					
C710	...Repeated for module number 9					
C720	...Repeated for module number 10					
C730	...Repeated for module number 11					
C740	...Repeated for module number 12					
C750	...Repeated for module number 13					
C760	...Repeated for module number 14					
C770	...Repeated for module number 15					
C780	...Repeated for module number 16					
C790	...Repeated for module number 17					

Table B–9: MODBUS MEMORY MAP (Sheet 29 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
C7A0	...Repeated for module number 18					
C7B0	...Repeated for module number 19					
C7C0	...Repeated for module number 20					
C7D0	...Repeated for module number 21					
C7E0	...Repeated for module number 22					
C7F0	...Repeated for module number 23					
C800	...Repeated for module number 24					
C810	...Repeated for module number 25					
C820	...Repeated for module number 26					
C830	...Repeated for module number 27					
C840	...Repeated for module number 28					
C850	...Repeated for module number 29					
C860	...Repeated for module number 30					
C870	...Repeated for module number 31					
C880	...Repeated for module number 32					
Virtual Outputs (Read/Write Setting) (64 modules)						
CC90	Virtual Output x Name	---	---	---	F205	"Virt Op 1 "
CC9A	Virtual Output x Events	0 to 1	---	1	F102	0 (Disabled)
CC9B	Virtual Output x Reserved (5 items)	---	---	---	F001	0
CCA0	...Repeated for module number 2					
CCB0	...Repeated for module number 3					
CCC0	...Repeated for module number 4					
CCD0	...Repeated for module number 5					
CCE0	...Repeated for module number 6					
CCF0	...Repeated for module number 7					
CD00	...Repeated for module number 8					
CD10	...Repeated for module number 9					
CD20	...Repeated for module number 10					
CD30	...Repeated for module number 11					
CD40	...Repeated for module number 12					
CD50	...Repeated for module number 13					
CD60	...Repeated for module number 14					
CD70	...Repeated for module number 15					
CD80	...Repeated for module number 16					
CD90	...Repeated for module number 17					
CDA0	...Repeated for module number 18					
CDB0	...Repeated for module number 19					
CDC0	...Repeated for module number 20					
CDD0	...Repeated for module number 21					
CDE0	...Repeated for module number 22					
CDF0	...Repeated for module number 23					
CE00	...Repeated for module number 24					
CE10	...Repeated for module number 25					
CE20	...Repeated for module number 26					
CE30	...Repeated for module number 27					
CE40	...Repeated for module number 28					
CE50	...Repeated for module number 29					
CE60	...Repeated for module number 30					
CE70	...Repeated for module number 31					
CE80	...Repeated for module number 32					
CE90	...Repeated for module number 33					
CEA0	...Repeated for module number 34					
CEB0	...Repeated for module number 35					
CEC0	...Repeated for module number 36					

B

Table B–9: MODBUS MEMORY MAP (Sheet 30 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
CED0	...Repeated for module number 37					
CEE0	...Repeated for module number 38					
CEF0	...Repeated for module number 39					
CF00	...Repeated for module number 40					
CF10	...Repeated for module number 41					
CF20	...Repeated for module number 42					
CF30	...Repeated for module number 43					
CF40	...Repeated for module number 44					
CF50	...Repeated for module number 45					
CF60	...Repeated for module number 46					
CF70	...Repeated for module number 47					
CF80	...Repeated for module number 48					
CF90	...Repeated for module number 49					
CFA0	...Repeated for module number 50					
CFB0	...Repeated for module number 51					
CFC0	...Repeated for module number 52					
CFD0	...Repeated for module number 53					
CFE0	...Repeated for module number 54					
CFF0	...Repeated for module number 55					
D000	...Repeated for module number 56					
D010	...Repeated for module number 57					
D020	...Repeated for module number 58					
D030	...Repeated for module number 59					
D040	...Repeated for module number 60					
D050	...Repeated for module number 61					
D060	...Repeated for module number 62					
D070	...Repeated for module number 63					
D080	...Repeated for module number 64					
Mandatory (Read/Write Setting)						
D280	Test Mode Function	0 to 1	---	1	F102	0 (Disabled)
Contact Outputs (Read/Write Setting) (64 modules)						
D290	Contact Output x Name	---	---	---	F205	"Cont Op 1 "
D29A	Contact Output x Operation	0 to 65535	---	1	F300	0
D29B	Contact Output x Seal-In	0 to 65535	---	1	F300	0
D29C	Reserved	---	---	1	F001	0
D29D	Contact Output x Events	0 to 1	---	1	F102	1 (Enabled)
D29E	Reserved (2 items)	---	---	---	F001	0
D2A0	...Repeated for module number 2					
D2B0	...Repeated for module number 3					
D2C0	...Repeated for module number 4					
D2D0	...Repeated for module number 5					
D2E0	...Repeated for module number 6					
D2F0	...Repeated for module number 7					
D300	...Repeated for module number 8					
D310	...Repeated for module number 9					
D320	...Repeated for module number 10					
D330	...Repeated for module number 11					
D340	...Repeated for module number 12					
D350	...Repeated for module number 13					
D360	...Repeated for module number 14					
D370	...Repeated for module number 15					
D380	...Repeated for module number 16					
D390	...Repeated for module number 17					
D3A0	...Repeated for module number 18					

B

Table B–9: MODBUS MEMORY MAP (Sheet 31 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
D3B0	...Repeated for module number 19					
D3C0	...Repeated for module number 20					
D3D0	...Repeated for module number 21					
D3E0	...Repeated for module number 22					
D3F0	...Repeated for module number 23					
D400	...Repeated for module number 24					
D410	...Repeated for module number 25					
D420	...Repeated for module number 26					
D430	...Repeated for module number 27					
D440	...Repeated for module number 28					
D450	...Repeated for module number 29					
D460	...Repeated for module number 30					
D470	...Repeated for module number 31					
D480	...Repeated for module number 32					
D490	...Repeated for module number 33					
D4A0	...Repeated for module number 34					
D4B0	...Repeated for module number 35					
D4C0	...Repeated for module number 36					
D4D0	...Repeated for module number 37					
D4E0	...Repeated for module number 38					
D4F0	...Repeated for module number 39					
D500	...Repeated for module number 40					
D510	...Repeated for module number 41					
D520	...Repeated for module number 42					
D530	...Repeated for module number 43					
D540	...Repeated for module number 44					
D550	...Repeated for module number 45					
D560	...Repeated for module number 46					
D570	...Repeated for module number 47					
D580	...Repeated for module number 48					
D590	...Repeated for module number 49					
D5A0	...Repeated for module number 50					
D5B0	...Repeated for module number 51					
D5C0	...Repeated for module number 52					
D5D0	...Repeated for module number 53					
D5E0	...Repeated for module number 54					
D5F0	...Repeated for module number 55					
D600	...Repeated for module number 56					
D610	...Repeated for module number 57					
D620	...Repeated for module number 58					
D630	...Repeated for module number 59					
D640	...Repeated for module number 60					
D650	...Repeated for module number 61					
D660	...Repeated for module number 62					
D670	...Repeated for module number 63					
D680	...Repeated for module number 64					
Reset (Read/Write Setting)						
D800	FlexLogic operand which initiates a reset	0 to 65535	---	1	F300	0
Force Contact Inputs (Read/Write Setting)						
D8B0	Force Contact Input x State (96 items)	0 to 2	---	1	F144	0 (Disabled)
Force Contact Outputs (Read/Write Setting)						
D910	Force Contact Output x State (64 items)	0 to 3	---	1	F131	0 (Disabled)
Remote Devices (Read/Write Setting) (16 modules)						
E000	Remote Device x ID	---	---	---	F202	"Remote Device 1 "

B

Table B–9: MODBUS MEMORY MAP (Sheet 32 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E00A	...Repeated for module number 2					
E014	...Repeated for module number 3					
E01E	...Repeated for module number 4					
E028	...Repeated for module number 5					
E032	...Repeated for module number 6					
E03C	...Repeated for module number 7					
E046	...Repeated for module number 8					
E050	...Repeated for module number 9					
E05A	...Repeated for module number 10					
E064	...Repeated for module number 11					
E06E	...Repeated for module number 12					
E078	...Repeated for module number 13					
E082	...Repeated for module number 14					
E08C	...Repeated for module number 15					
E096	...Repeated for module number 16					
Remote Inputs (Read/Write Setting) (32 modules)						
E100	Remote Input x Device	1 to 16	---	1	F001	1
E101	Remote Input x Bit Pair	0 to 64	---	1	F156	0 (None)
E102	Remote Input x Default State	0 to 1	---	1	F108	0 (Off)
E103	Remote Input x Events	0 to 1	---	1	F102	0 (Disabled)
E104	...Repeated for module number 2					
E108	...Repeated for module number 3					
E10C	...Repeated for module number 4					
E110	...Repeated for module number 5					
E114	...Repeated for module number 6					
E118	...Repeated for module number 7					
E11C	...Repeated for module number 8					
E120	...Repeated for module number 9					
E124	...Repeated for module number 10					
E128	...Repeated for module number 11					
E12C	...Repeated for module number 12					
E130	...Repeated for module number 13					
E134	...Repeated for module number 14					
E138	...Repeated for module number 15					
E13C	...Repeated for module number 16					
E140	...Repeated for module number 17					
E144	...Repeated for module number 18					
E148	...Repeated for module number 19					
E14C	...Repeated for module number 20					
E150	...Repeated for module number 21					
E154	...Repeated for module number 22					
E158	...Repeated for module number 23					
E15C	...Repeated for module number 24					
E160	...Repeated for module number 25					
E164	...Repeated for module number 26					
E168	...Repeated for module number 27					
E16C	...Repeated for module number 28					
E170	...Repeated for module number 29					
E174	...Repeated for module number 30					
E178	...Repeated for module number 31					
E17C	...Repeated for module number 32					
Remote Output DNA Pairs (Read/Write Setting) (32 modules)						
E600	Remote Output DNA x Operand	0 to 65535	---	1	F300	0
E601	Remote Output DNA x Events	0 to 1	---	1	F102	0 (Disabled)

Table B–9: MODBUS MEMORY MAP (Sheet 33 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E602	Remote Output DNA x Reserved (2 items)	0 to 1	---	1	F001	0
E604	...Repeated for module number 2					
E608	...Repeated for module number 3					
E60C	...Repeated for module number 4					
E610	...Repeated for module number 5					
E614	...Repeated for module number 6					
E618	...Repeated for module number 7					
E61C	...Repeated for module number 8					
E620	...Repeated for module number 9					
E624	...Repeated for module number 10					
E628	...Repeated for module number 11					
E62C	...Repeated for module number 12					
E630	...Repeated for module number 13					
E634	...Repeated for module number 14					
E638	...Repeated for module number 15					
E63C	...Repeated for module number 16					
E640	...Repeated for module number 17					
E644	...Repeated for module number 18					
E648	...Repeated for module number 19					
E64C	...Repeated for module number 20					
E650	...Repeated for module number 21					
E654	...Repeated for module number 22					
E658	...Repeated for module number 23					
E65C	...Repeated for module number 24					
E660	...Repeated for module number 25					
E664	...Repeated for module number 26					
E668	...Repeated for module number 27					
E66C	...Repeated for module number 28					
E670	...Repeated for module number 29					
E674	...Repeated for module number 30					
E678	...Repeated for module number 31					
E67C	...Repeated for module number 32					
Remote Output UserSt Pairs (Read/Write Setting) (32 modules)						
E680	Remote Output UserSt x Operand	0 to 65535	---	1	F300	0
E681	Remote Output UserSt x Events	0 to 1	---	1	F102	0 (Disabled)
E682	Remote Output UserSt x Reserved (2 items)	0 to 1	---	1	F001	0
E684	...Repeated for module number 2					
E688	...Repeated for module number 3					
E68C	...Repeated for module number 4					
E690	...Repeated for module number 5					
E694	...Repeated for module number 6					
E698	...Repeated for module number 7					
E69C	...Repeated for module number 8					
E6A0	...Repeated for module number 9					
E6A4	...Repeated for module number 10					
E6A8	...Repeated for module number 11					
E6AC	...Repeated for module number 12					
E6B0	...Repeated for module number 13					
E6B4	...Repeated for module number 14					
E6B8	...Repeated for module number 15					
E6BC	...Repeated for module number 16					
E6C0	...Repeated for module number 17					
E6C4	...Repeated for module number 18					
E6C8	...Repeated for module number 19					

B

Table B–9: MODBUS MEMORY MAP (Sheet 34 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
E6CC	...Repeated for module number 20					
E6D0	...Repeated for module number 21					
E6D4	...Repeated for module number 22					
E6D8	...Repeated for module number 23					
E6DC	...Repeated for module number 24					
E6E0	...Repeated for module number 25					
E6E4	...Repeated for module number 26					
E6E8	...Repeated for module number 27					
E6EC	...Repeated for module number 28					
E6F0	...Repeated for module number 29					
E6F4	...Repeated for module number 30					
E6F8	...Repeated for module number 31					
E6FC	...Repeated for module number 32					
Factory Service Password Protection (Read/Write)						
F000	Modbus Factory Password	0 to 4294967295	---	1	F003	0
Factory Service Password Protection (Read Only)						
F002	Factory Service Password Status	0 to 1	---	1	F102	0 (Disabled)
Factory Service - Initialization (Read Only -- Written by Factory)						
F008	Load Default Settings	0 to 1	---	1	F126	0 (No)
F009	Reboot Relay	0 to 1	---	1	F126	0 (No)
Factory Service - Calibration (Read Only -- Written by Factory)						
F010	Calibration	0 to 1	---	1	F102	0 (Disabled)
F011	DSP Card to Calibrate	0 to 15	---	1	F172	0 (F)
F012	Channel to Calibrate	0 to 7	---	1	F001	0
F013	Channel Type	0 to 6	---	1	F140	0 (Disabled)
F014	Channel Name	---	---	---	F201	"0"
Factory Service - Calibration (Read Only)						
F018	A/D Counts	-32767 to 32767	---	1	F002	0
Factory Service - Calibration (Read Only -- Written by Factory)						
F019	Offset	-32767 to 32767	---	1	F002	0
F01B	Gain Stage	0 to 1	---	1	F135	0 (x1)
F01C	CT Winding	0 to 1	---	1	F123	0 (1 A)
Factory Service - Calibration (Read Only)						
F01D	Measured Input	0 to 300	---	0.0001	F060	0
Factory Service - Calibration (Read Only -- Written by Factory)						
F01F	Gain Parameter	0.8 to 1.2	---	0.0001	F060	1
Factory Service - Calibration (Read Only)						
F02A	DSP Calibration Date	0 to 4294967295	---	1	F050	0
Factory Service - Debug Data (Read Only -- Written by Factory)						
F040	Debug Data 16 (16 items)	-32767 to 32767	---	1	F002	0
F050	Debug Data 32 (16 items)	-2147483647 to 2147483647	---	1	F004	0
Transducer Calibration (Read Only -- Written by Factory)						
F0A0	Transducer Calibration Function	0 to 1	---	1	F102	0 (Disabled)
F0A1	Transducer Card to Calibrate	0 to 15	---	1	F172	0 (F)
F0A2	Transducer Channel to Calibrate	0 to 7	---	1	F001	0
F0A3	Transducer Channel to Calibrate Type	0 to 3	---	1	F171	0 (dcmA IN)
F0A4	Transducer Channel to Calibrate Gain Stage	0 to 1	---	1	F170	0 (LOW)
Transducer Calibration (Read Only)						
F0A5	Transducer Channel to Calibrate Counts	0 to 4095	---	1	F001	0
Transducer Calibration (Read Only -- Written by Factory)						
F0A6	Transducer Channel to Calibrate Offset	-4096 to 4095	---	1	F002	0
F0A7	Transducer Channel to Calibrate Value	-1.1 to 366.5	---	0.001	F004	0
F0A9	Transducer Channel to Calibrate Gain	0.8 to 1.2	---	0.0001	F060	1

Table B–9: MODBUS MEMORY MAP (Sheet 35 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
F0AB	Transducer Calibration Date	0 to 4294967295	---	1	F050	0
Transducer Calibration (Read Only)						
F0AD	Transducer Channel to Calibrate Units	---	---	---	F206	(none)
Factory Service Software Revisions (Read Only)						
F0F0	Compile Date	0 to 4294967295	---	1	F050	0
F0F3	Boot Version	0 to 655.35	---	0.01	F001	1
F0F4	Front Panel Version	0 to 655.35	---	0.01	F001	1
F0F5	Boot Date	0 to 4294967295	---	1	F050	0
Factory Service - Serial EEPROM (Read Only -- Written by Factory)						
F100	Serial EEPROM Enable	0 to 1	---	1	F102	0 (Disabled)
F101	Serial EEPROM Slot	0 to 15	---	1	F172	0 (F)
F102	Serial EEPROM Load Factory Defaults	0 to 1	---	1	F126	0 (No)
F110	Serial EEPROM Module Serial Number	---	---	---	F203	(none)
F120	Serial EEPROM Supplier Serial Number	---	---	---	F203	(none)
F130	Serial EEPROM Sub Module Serial Number (8 items)	---	---	---	F203	(none)
Factory Service CPU Diagnostics (Read Only Non-Volatile)						
F200	Operating Hours	0 to 4294967295	---	1	F050	0
Factory Service CPU Diagnostics (Read Only)						
F210	DSP Spurious Interrupt Counter	0 to 4294967295	---	1	F003	0
Factory Service CPU Diagnostics (Read Only -- Written by Factory)						
F220	Real Time Profiling	0 to 1	---	1	F102	0 (Disabled)
F221	Enable Windview	0 to 1	---	1	F102	0 (Disabled)
F222	Factory Reload Cause	---	---	---	F200	(none)
F236	Clear Diagnostics	0 to 1	---	1	F126	0 (No)
Factory Service CPU Performance (Read Only)						
F300	CPU Utilization	0 to 100	%	0.1	F001	0
Factory Service CPU Performance (Read/Write)						
F301	CPU Overload	0 to 6553.5	%	0.1	F001	0
Factory Service CPU Performance (Read Only)						
F302	Protection Pass Time	0 to 65535	us	1	F001	0
Factory Service CPU Performance (Read/Write)						
F303	Protection Pass Worst Time	0 to 65535	us	1	F001	0
Factory Service DSP Diagnostics (Read Only) (3 modules)						
F380	DSP Checksum Error Counter	0 to 4294967295	---	1	F003	0
F382	DSP Corrupt Settings Counter	0 to 4294967295	---	1	F003	0
F384	DSP Out Of Sequence Error Counter	0 to 4294967295	---	1	F003	0
F386	DSP Flags Error Counter	0 to 4294967295	---	1	F003	0
F38D	DSP Error Flags	0 to 65535	---	1	F001	0
F38E	DSP Error Code	0 to 65535	---	1	F001	0
F38F	DSP Usage	0 to 100	---	0.1	F001	0
F390	...Repeated for module number 2					
F3A0	...Repeated for module number 3					
Factory Service FlexAnalog Distance (Read Only)						
F800	Distance Iab Magnitude	0 to 999999.999	pu	1	F060	0
F802	Distance Iab Angle	-180 to 180	°	0.01	F002	0
F803	Distance Ibc Magnitude	0 to 999999.999	pu	1	F060	0
F805	Distance Ibc Angle	-180 to 180	°	0.01	F002	0
F806	Distance Ica Magnitude	0 to 999999.999	pu	1	F060	0
F808	Distance Ica Angle	-180 to 180	°	0.01	F002	0
F809	Distance IabZ Vab Angle (4 items)	-180 to 180	°	0.01	F002	0
F80D	Distance IbcZ Vbc Angle (4 items)	-180 to 180	°	0.01	F002	0
F811	Distance IcaZ Vca Angle (4 items)	-180 to 180	°	0.01	F002	0
F815	Distance IagZ Vag Angle (4 items)	-180 to 180	°	0.01	F002	0
F819	Distance IbgZ Vbg Angle (4 items)	-180 to 180	°	0.01	F002	0

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Table B–9: MODBUS MEMORY MAP (Sheet 36 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
F81D	Distance IcgZ Vcg Angle (4 items)	-180 to 180	°	0.01	F002	0
F821	Distance I2Za Angle	-180 to 180	°	0.01	F002	0
F822	Distance I2Zb Angle	-180 to 180	°	0.01	F002	0
F823	Distance I2Zc Angle	-180 to 180	°	0.01	F002	0
F824	Distance Alpha IabZ Vab Angle	-180 to 180	°	0.01	F002	0
F825	Distance Alpha IbcZ Vbc Angle	-180 to 180	°	0.01	F002	0
F826	Distance Alpha IcaZ Vca Angle	-180 to 180	°	0.01	F002	0
F827	Distance Alpha IagZ Vag Angle	-180 to 180	°	0.01	F002	0
F828	Distance Alpha IbgZ Vbg Angle	-180 to 180	°	0.01	F002	0
F829	Distance Alpha IcgZ Vcg Angle	-180 to 180	°	0.01	F002	0
F82A	Distance IabZR Vab IabZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F82E	Distance IbcZR Vbc IbcZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F832	UNDEFINED (4 items)	-180 to 180	°	0.01	F002	0
F836	Distance IabZR Vab IabZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F83A	Distance IbcZR Vbc IbcZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F83E	Distance IcaZR Vca IcaZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F842	Distance IagZR Vag IagZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F846	Distance IbgZR Vbg IbgZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F84A	Distance IcgZR Vcg IcgZR Angle (4 items)	-180 to 180	°	0.01	F002	0
F84E	Distance IagZL Vag IagZL Angle (4 items)	-180 to 180	°	0.01	F002	0
F852	Distance IbgZL Vbg IbgZL Angle (4 items)	-180 to 180	°	0.01	F002	0
F856	Distance IcgZL Vcg IcgZL Angle (4 items)	-180 to 180	°	0.01	F002	0
Modbus File Transfer Area 2 (Read/Write)						
FA00	Name of file to read	---	---	---	F204	(none)
Modbus File Transfer Area 2 (Read Only)						
FB00	Character position of current block within file	0 to 4294967295	---	1	F003	0
FB02	Size of currently-available data block	0 to 65535	---	1	F001	0
FB03	Block of data from requested file (122 items)	0 to 65535	---	1	F001	0
Neutral Overvoltage (Read/Write Grouped Setting) (3 modules)						
FC00	Neutral OV X Function	0 to 1	---	1	F102	0 (Disabled)
FC01	Neutral OV X Signal Source	0 to 5	---	1	F167	0 (SRC 1)
FC02	Neutral OV X Pickup	0 to 1.25	pu	0.001	F001	300
FC03	Neutral OV X Pickup Delay	0 to 600	s	0.01	F001	100
FC04	Neutral OV X Reset Delay	0 to 600	s	0.01	F001	100
FC05	Neutral OV X Block	0 to 65535	---	1	F300	0
FC06	Neutral OV X Target	0 to 2	---	1	F109	0 (Self-reset)
FC07	Neutral OV X Events	0 to 1	---	1	F102	0 (Disabled)
FC08	Neutral OV Reserved (8 items)	0 to 65535	---	1	F001	0
FC10	...Repeated for module number 2					
FC20	...Repeated for module number 3					
Auxiliary Overvoltage (Read/Write Grouped Setting) (3 modules)						
FC30	Auxiliary OV X Function	0 to 1	---	1	F102	0 (Disabled)
FC31	Auxiliary OV X Signal Source	0 to 5	---	1	F167	0 (SRC 1)
FC32	Auxiliary OV X Pickup	0 to 3	pu	0.001	F001	300
FC33	Auxiliary OV X Pickup Delay	0 to 600	s	0.01	F001	100
FC34	Auxiliary OV X Reset Delay	0 to 600	s	0.01	F001	100
FC35	Auxiliary OV X Block	0 to 65535	---	1	F300	0
FC36	Auxiliary OV X Target	0 to 2	---	1	F109	0 (Self-reset)
FC37	Auxiliary OV X Events	0 to 1	---	1	F102	0 (Disabled)
FC38	Auxiliary OV X Reserved (8 items)	0 to 65535	---	1	F001	0
FC40	...Repeated for module number 2					
FC50	...Repeated for module number 3					
Auxiliary Undervoltage (Read/Write Grouped Setting) (3 modules)						
FC60	Auxiliary UV X Function	0 to 1	---	1	F102	0 (Disabled)

Table B–9: MODBUS MEMORY MAP (Sheet 37 of 37)

ADDR	REGISTER NAME	RANGE	UNITS	STEP	FORMAT	DEFAULT
FC61	Auxiliary UV X Signal Source	0 to 5	---	1	F167	0 (SRC 1)
FC62	Auxiliary UV X Pickup	0 to 3	pu	0.001	F001	700
FC63	Auxiliary UV X Delay	0 to 600	s	0.01	F001	100
FC64	Auxiliary UV X Curve	0 to 1	---	1	F111	0 (Definite Time)
FC65	Auxiliary UV X Minimum Voltage	0 to 3	pu	0.001	F001	100
FC66	Auxiliary UV X Block	0 to 65535	---	1	F300	0
FC67	Auxiliary UV X Target	0 to 2	---	1	F109	0 (Self-reset)
FC68	Auxiliary UV X Events	0 to 1	---	1	F102	0 (Disabled)
FC69	Auxiliary UV X Reserved (7 items)	0 to 65535	---	1	F001	0
FC70	...Repeated for module number 2					
FC80	...Repeated for module number 3					

B.4.2 MEMORY MAP DATA FORMATS

F001
UR_UINT16 UNSIGNED 16 BIT INTEGER

F002
UR_SINT16 SIGNED 16 BIT INTEGER

F003
UR_UINT32 UNSIGNED 32 BIT INTEGER (2 registers)

High order word is stored in the first register.
Low order word is stored in the second register.

F004
UR_SINT32 SIGNED 32 BIT INTEGER (2 registers)

High order word is stored in the first register/
Low order word is stored in the second register.

F005
UR_UINT8 UNSIGNED 8 BIT INTEGER

F006
UR_SINT8 SIGNED 8 BIT INTEGER

F011
UR_UINT16 FLEXCURVE DATA (120 points)

A FlexCurve is an array of 120 consecutive data points (x, y) which are interpolated to generate a smooth curve. The y-axis is the user defined trip or operation time setting; the x-axis is the pickup ratio and is pre-defined. Refer to format F119 for a listing of the pickup ratios; the enumeration value for the pickup ratio indicates the offset into the FlexCurve base address where the corresponding time value is stored.

F012
DISPLAY_SCALE DISPLAY SCALING
(unsigned 16-bit integer)

MSB indicates the SI units as a power of ten. LSB indicates the number of decimal points to display.

Example: Current values are stored as 32 bit numbers with three decimal places and base units in Amps. If the retrieved value is 12345.678 A and the display scale equals 0x0302 then the displayed value on the unit is 12.35 kA.

F013
POWER_FACTOR PWR FACTOR (SIGNED 16 BIT INTEGER)

Positive values indicate lagging power factor; negative values indicate leading.

F040
UR_UINT48 48-BIT UNSIGNED INTEGER

F050
UR_UINT32 TIME and DATE (UNSIGNED 32 BIT INTEGER)

Gives the current time in seconds elapsed since 00:00:00 January 1, 1970.

F051
UR_UINT32 DATE in SR format (alternate format for F050)

First 16 bits are Month/Day (MM/DD/xxxx). Month: 1=January, 2=February,...,12=December; Day: 1 to 31 in steps of 1
Last 16 bits are Year (xx/xx/YYYY): 1970 to 2106 in steps of 1

F052
UR_UINT32 TIME in SR format (alternate format for F050)

First 16 bits are Hours/Minutes (HH:MM:xx.xxx).
Hours: 0=12am, 1=1am,...,12=12pm,...23=11pm;
Minutes: 0 to 59 in steps of 1

Last 16 bits are Seconds (xx:xx:.SS.SSS): 0=00.000s, 1=00.001,...,59999=59.999s)

F060
FLOATING_POINT IEE FLOATING POINT (32 bits)

F070
HEX2 2 BYTES - 4 ASCII DIGITS

F071
HEX4 4 BYTES - 8 ASCII DIGITS

F072
HEX6 6 BYTES - 12 ASCII DIGITS

F073
HEX8 8 BYTES - 16 ASCII DIGITS

F074
HEX20 20 BYTES - 40 ASCII DIGITS

F100
ENUMERATION: VT CONNECTION TYPE

0 = Wye; 1 = Delta

F101
ENUMERATION: MESSAGE DISPLAY INTENSITY

0 = 25%, 1 = 50%, 2 = 75%, 3 = 100%

F102
ENUMERATION: DISABLED/ENABLED

0 = Disabled; 1 = Enabled

F103
ENUMERATION: CURVE SHAPES

bitmask	curve shape
0	IEEE Mod Inv
1	IEEE Very Inv
2	IEEE Ext Inv
3	IEC Curve A
4	IEC Curve B
5	IEC Curve C
6	IEC Short Inv
7	IAC Ext Inv

bitmask	curve shape
8	IAC Very Inv
9	IAC Inverse
10	IAC Short Inv
11	I2t
12	Definite Time
13	Flexcurve A
14	Flexcurve B

F104
ENUMERATION: RESET TYPE

0 = Instantaneous, 1 = Timed, 2 = Linear

F105
ENUMERATION: LOGIC INPUT

0 = Disabled, 1 = Input 1, 2 = Input 2

F106
ENUMERATION: PHASE ROTATION

0 = ABC, 1 = ACB

F108
ENUMERATION: OFF/ON

0 = Off, 1 = On

F109
ENUMERATION: CONTACT OUTPUT OPERATION

0 = Self-reset, 1 = Latched, 2 = Disabled

F110
ENUMERATION: CONTACT OUTPUT LED CONTROL

0 = Trip, 1 = Alarm, 2 = None

B

F111
ENUMERATION: UNDERVOLTAGE CURVE SHAPES

0 = Definite Time, 1 = Inverse Time

F112
ENUMERATION: RS485 BAUD RATES

bitmask	value
0	300
1	1200
2	2400
3	4800

bitmask	value
4	9600
5	19200
6	38400
7	57600

bitmask	value
8	115200
9	14400
10	28800
11	33600

F113
ENUMERATION: PARITY

0 = None, 1 = Odd, 2 = Even

F114
ENUMERATION: IRIG-B SIGNAL TYPE

0 = None, 1 = DC Shift, 2 = Amplitude Modulated

F115
ENUMERATION: BREAKER STATUS

0 = Auxiliary A, 1 = Auxiliary B

F117
ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS

0 = 1×72 cycles, 1 = 3×36 cycles, 2 = 7×18 cycles, 3 = 15×9 cycles

F118
ENUMERATION: OSCILLOGRAPHY MODE

0 = Automatic Overwrite, 1 = Protected

B

F119
ENUMERATION: FLEXCURVE PICKUP RATIOS

mask	value	mask	value	mask	value	mask	value
0	0.00	30	0.88	60	2.90	90	5.90
1	0.05	31	0.90	61	3.00	91	6.00
2	0.10	32	0.91	62	3.10	92	6.50
3	0.15	33	0.92	63	3.20	93	7.00
4	0.20	34	0.93	64	3.30	94	7.50
5	0.25	35	0.94	65	3.40	95	8.00
6	0.30	36	0.95	66	3.50	96	8.50
7	0.35	37	0.96	67	3.60	97	9.00
8	0.40	38	0.97	68	3.70	98	9.50
9	0.45	39	0.98	69	3.80	99	10.00
10	0.48	40	1.03	70	3.90	100	10.50
11	0.50	41	1.05	71	4.00	101	11.00
12	0.52	42	1.10	72	4.10	102	11.50
13	0.54	43	1.20	73	4.20	103	12.00
14	0.56	44	1.30	74	4.30	104	12.50
15	0.58	45	1.40	75	4.40	105	13.00
16	0.60	46	1.50	76	4.50	106	13.50
17	0.62	47	1.60	77	4.60	107	14.00
18	0.64	48	1.70	78	4.70	108	14.50
19	0.66	49	1.80	79	4.80	109	15.00
20	0.68	50	1.90	80	4.90	110	15.50
21	0.70	51	2.00	81	5.00	111	16.00
22	0.72	52	2.10	82	5.10	112	16.50
23	0.74	53	2.20	83	5.20	113	17.00
24	0.76	54	2.30	84	5.30	114	17.50
25	0.78	55	2.40	85	5.40	115	18.00
26	0.80	56	2.50	86	5.50	116	18.50
27	0.82	57	2.60	87	5.60	117	19.00
28	0.84	58	2.70	88	5.70	118	19.50
29	0.86	59	2.80	89	5.80	119	20.00

F120
ENUMERATION: DISTANCE SHAPE

0 = Mho, 1 = Quad

F122
ENUMERATION: ELEMENT INPUT SIGNAL TYPE

0 = Phasor, 1 = RMS

F123
ENUMERATION: CT SECONDARY

0 = 1 A, 1 = 5 A

F124
ENUMERATION: LIST OF ELEMENTS

bitmask	element
0	PHASE IOC1
1	PHASE IOC2
16	PHASE TOC1
17	PHASE TOC2
24	PH DIR1
25	PH DIR2
32	NEUTRAL IOC1
33	NEUTRAL IOC2
48	NEUTRAL TOC1
49	NEUTRAL TOC2
56	NTRL DIR
57	NTRL DIR
60	NEG SEQ
61	NEG SEQ
64	GROUND IOC1
65	GROUND IOC2
80	GROUND TOC1
81	GROUND TOC2
96	NEG SEQ
97	NEG SEQ
112	NEG SEQ
113	NEG SEQ
120	NEG SEQ
140	AUX UV1
144	PHASE UV1
145	PHASE UV2
148	AUX OV1
152	PHASE OV1
156	NEUTRAL OV1
160	PH DIST 1
161	PH DIST 2
162	PH DIST 3
163	PH DIST 4
168	LINE PICKUP
176	GND DIST 1
177	GND DIST 2
178	GND DIST 3
179	GND DIST 4
180	LOAD ENCHR
184	DUTT
185	PUTT
186	POTT
187	HYBRID POTT
188	BLOCK SCHEME
190	POWER SWING

bitmask	element
224	SRC1 VT
225	SRC2 VT
226	SRC3 VT
227	SRC4 VT
228	SRC5 VT
229	SRC6 VT
232	SRC1 50DD
233	SRC2 50DD
234	SRC3 50DD
235	SRC4 50DD
236	SRC5 50DD
237	SRC6 50DD
242	OPEN POLE
244	50DD
245	CONT MONITOR
246	CT FAIL
247	CT TROUBLE1
248	CT TROUBLE2
265	STATOR DIFF
272	BREAKER 1
273	BREAKER 2
280	BKR FAIL
281	BKR FAIL
288	BKR ARC
289	BKR ARC
296	ACCDNT ENRG
300	LOSS EXCIT
304	AR 1
305	AR 2
306	AR 3
307	AR 4
308	AR 5
309	AR 6
312	SYNC 1
313	SYNC 2
320	COLD LOAD
321	COLD LOAD
324	AMP UNBALANCE
325	AMP UNBALANCE
330	3RD HARM
336	SETTING GROUP
337	RESET
344	OVERFREQ 1
345	OVERFREQ 2
346	OVERFREQ 3
347	OVERFREQ 4
352	UNDERFREQ 1
353	UNDERFREQ 2

bitmask	element
354	UNDERFREQ 3
355	UNDERFREQ 4
356	UNDERFREQ 5
357	UNDERFREQ 6
400	FLEX ELEMENT 1
401	FLEX ELEMENT 2
402	FLEX ELEMENT 3
403	FLEX ELEMENT 4
404	FLEX ELEMENT 5
405	FLEX ELEMENT 6
406	FLEX ELEMENT 7
407	FLEX ELEMENT 8
408	FLEX ELEMENT 9
409	FLEX ELEMENT 10
410	FLEX ELEMENT 11
411	FLEX ELEMENT 12
412	FLEX ELEMENT 13
413	FLEX ELEMENT 14
414	FLEX ELEMENT 15
415	FLEX ELEMENT 16
512	DIG ELEM 1
513	DIG ELEM 2
514	DIG ELEM 3
515	DIG ELEM 4
516	DIG ELEM 5
517	DIG ELEM 6
518	DIG ELEM 7
519	DIG ELEM 8
520	DIG ELEM 9
521	DIG ELEM 10
522	DIG ELEM 11
523	DIG ELEM 12
524	DIG ELEM 13
525	DIG ELEM 14
526	DIG ELEM 15
527	DIG ELEM 16
544	COUNTER 1
545	COUNTER 2
546	COUNTER 3
547	COUNTER 4
548	COUNTER 5
549	COUNTER 6
550	COUNTER 7
551	COUNTER 8

F125
ENUMERATION: ACCESS LEVEL

0 = Restricted; 1 = Command, 2 = Setting, 3 = Factory Service

B

F126
ENUMERATION: NO/YES CHOICE

0 = No, 1 = Yes

F127
ENUMERATION: LATCHED OR SELF-RESETTING

0 = Latched, 1 = Self-Reset

F128
ENUMERATION: CONTACT INPUT THRESHOLD

0 = 16 Vdc, 1 = 30 Vdc, 2 = 80 Vdc, 3 =140 Vdc

F129
ENUMERATION: FLEXLOGIC TIMER TYPE

0 = millisecond, 1 = second, 2 = minute

F130
ENUMERATION: SIMULATION MODE

0 = Off. 1 = Pre-Fault, 2 = Fault, 3 = Post-Fault

F131
ENUMERATION: FORCED CONTACT OUTPUT STATE

0 = Disabled, 1 = Energized, 2 = De-energized, 3 = Freeze

F133
ENUMERATION: PROGRAM STATE

0 = Not Programmed, 1 = Programmed

F134
ENUMERATION: PASS/FAIL

0 = Fail, 1 = OK, 2 = n/a

F135
ENUMERATION: GAIN CALIBRATION

0 = 0x1, 1 = 1x16

F136
ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS

0 = 31 x 8 cycles, 1 = 15 x 16 cycles, 2 = 7 x 32 cycles
3 = 3 x 64 cycles, 4 = 1 x 128 cycles

F138
ENUMERATION: OSCILLOGRAPHY FILE TYPE

0 = Data File, 1 = Configuration File, 2 = Header File

F140
ENUMERATION: CURRENT, SENS CURRENT, VOLTAGE, DISABLED

0 = Disabled, 1 = Current 46A, 2 = Voltage 280V, 3 = Current 4.6A
4 = Current 2A, 5 = Notched 4.6A, 6 = Notched 2A

F141
ENUMERATION: SELF TEST ERROR

bitmask	error
0	ANY SELF TESTS
1	IRIG-B FAILURE
2	DSP ERROR
4	NO DSP INTERRUPTS
5	UNIT NOT CALIBRATED
9	PROTOTYPE FIRMWARE
10	FLEXLOGIC ERR TOKEN
11	EQUIPMENT MISMATCH
13	UNIT NOT PROGRAMMED
14	SYSTEM EXCEPTION
19	BATTERY FAIL
20	PRI ETHERNET FAIL
21	SEC ETHERNET FAIL
22	EEPROM DATA ERROR
23	SRAM DATA ERROR
24	PROGRAM MEMORY
25	WATCHDOG ERROR
26	LOW ON MEMORY
27	REMOTE DEVICE OFF
30	ANY MINOR ERROR
31	ANY MAJOR ERROR

F142
ENUMERATION: EVENT RECORDER ACCESS FILE TYPE

0 = All Record Data, 1 = Headers Only, 2 = Numeric Event Cause

F143
UR_UINT32: 32 BIT ERROR CODE (F141 specifies bit number)

A bit value of 0 = no error, 1 = error

F144
ENUMERATION: FORCED CONTACT INPUT STATE

0 = Disabled, 1 = Open, 2 = Closed

F145
ENUMERATION: ALPHABET LETTER

bitmask	type	bitmask	type	bitmask	type	bitmask	type
0	null	7	G	14	N	21	U
1	A	8	H	15	O	22	V
2	B	9	I	16	P	23	W
3	C	10	J	17	Q	24	X
4	D	11	K	18	R	25	Y
5	E	12	L	19	S	26	Z
6	F	13	M	20	T		

F146
ENUMERATION: MISC. EVENT CAUSES

bitmask	definition
0	EVENTS CLEARED
1	OSCILLOGRAPHY TRIGGERED
2	DATE/TIME CHANGED
3	DEF SETTINGS LOADED
4	TEST MODE ON
5	TEST MODE OFF
6	POWER ON
7	POWER OFF
8	RELAY IN SERVICE
9	RELAY OUT OF SERVICE
10	WATCHDOG RESET
11	OSCILLOGRAPHY CLEAR
12	REBOOT COMMAND

F147
ENUMERATION: LINE LENGTH UNITS

0 = km, 1 = miles

F148
ENUMERATION: FAULT TYPE

bitmask	fault type
0	NA
1	AG
2	BG
3	CG
4	AB
5	BC
6	AC
7	ABG
8	BCG
9	ACG
10	ABC
11	ABCG

F151
ENUMERATION: RTD SELECTION

bitmask	RTD#	bitmask	RTD#	bitmask	RTD#
0	NONE	17	RTD 17	33	RTD 33
1	RTD 1	18	RTD 18	34	RTD 34
2	RTD 2	19	RTD 19	35	RTD 35
3	RTD 3	20	RTD 20	36	RTD 36
4	RTD 4	21	RTD 21	37	RTD 37
5	RTD 5	22	RTD 22	38	RTD 38
6	RTD 6	23	RTD 23	39	RTD 39
7	RTD 7	24	RTD 24	40	RTD 40
8	RTD 8	25	RTD 25	41	RTD 41
9	RTD 9	26	RTD 26	42	RTD 42
10	RTD 10	27	RTD 27	43	RTD 43
11	RTD 11	28	RTD 28	44	RTD 44
12	RTD 12	29	RTD 29	45	RTD 45
13	RTD 13	30	RTD 30	46	RTD 46
14	RTD 14	31	RTD 31	47	RTD 47
15	RTD 15	32	RTD 32	48	RTD 48
16	RTD 16				

F152
ENUMERATION: SETTING GROUP

0 = Active Group, 1 = Group 1, 2 = Group 2, 3 = Group 3
4 = Group 4, 5 = Group 5, 6 = Group 6, 7 = Group 7, 8 = Group 8

F154
ENUMERATION: DISTANCE DIRECTION

0 = Forward, 1 = Reverse

F155
ENUMERATION: REMOTE DEVICE STATE

0 = Offline, 1 = Online

B

F156
ENUMERATION: REMOTE INPUT BIT PAIRS

bitmask	RTD#	bitmask	RTD#	bitmask	RTD#
0	NONE	22	DNA-22	44	UserSt-12
1	DNA-1	23	DNA-23	45	UserSt-13
2	DNA-2	24	DNA-24	46	UserSt-14
3	DNA-3	25	DNA-25	47	UserSt-15
4	DNA-4	26	DNA-26	48	UserSt-16
5	DNA-5	27	DNA-27	49	UserSt-17
6	DNA-6	28	DNA-28	50	UserSt-18
7	DNA-7	29	DNA-29	51	UserSt-19
8	DNA-8	30	DNA-30	52	UserSt-20
9	DNA-9	31	DNA-31	53	UserSt-21
10	DNA-10	32	DNA-32	54	UserSt-22
11	DNA-11	33	UserSt-1	55	UserSt-23
12	DNA-12	34	UserSt-2	56	UserSt-24
13	DNA-13	35	UserSt-3	57	UserSt-25
14	DNA-14	36	UserSt-4	58	UserSt-26
15	DNA-15	37	UserSt-5	59	UserSt-27
16	DNA-16	38	UserSt-6	60	UserSt-28
17	DNA-17	39	UserSt-7	61	UserSt-29
18	DNA-18	40	UserSt-8	62	UserSt-30
19	DNA-19	41	UserSt-9	63	UserSt-31
20	DNA-20	42	UserSt-10	64	UserSt-32
21	DNA-21	43	UserSt-11		

F157
ENUMERATION: BREAKER MODE

0 = 3-Pole, 1 = 1-Pole

F158
ENUMERATION: SCHEME CALIBRATION TEST

0 = Normal, 1 = Symmetry 1, 2 = Symmetry 2, 3 = Delay 1
4 = Delay 2

F159
ENUMERATION: BREAKER AUX CONTACT KEYING

0 = 52a, 1 = 52b, 2 = None

F166
ENUMERATION: AUXILIARY VT CONNECTION TYPE

0 = Vn, 1 = Vag, 2 = Vbg, 3 = Vcg, 4 = Vab, 5 = Vbc, 6 = Vca

F167
ENUMERATION: SIGNAL SOURCE

0 = SRC 1, 1 = SRC 2, 2 = SRC 3, 3 = SRC 4,
4 = SRC 5, 5 = SRC 6

F168
ENUMERATION: INRUSH INHIBIT FUNCTION

0 = Disabled, 1 = 2nd

F169
ENUMERATION: OVEREXCITATION INHIBIT FUNCTION

0 = Disabled, 1 = 5th

F170
ENUMERATION: LOW/HIGH OFFSET & GAIN TRANSDUCER I/O SELECTION

0 = LOW, 1 = HIGH

F171
ENUMERATION: TRANSDUCER CHANNEL INPUT TYPE

0 = dcmA IN, 1 = OHMS IN, 2 = RTD IN, 3 = dcmA OUT

F172
ENUMERATION: SLOT LETTERS

bitmask	slot	bitmask	slot	bitmask	slot	bitmask	slot
0	F	4	K	8	P	12	U
1	G	5	L	9	R	13	V
2	H	6	M	10	S	14	W
3	J	7	N	11	T	15	X

F173
ENUMERATION: TRANSDUCER DCMA I/O RANGE

bitmask	dcmA I/O range
0	0 to –1 mA
1	0 to 1 mA
2	–1 to 1 mA
3	0 to 5 mA
4	0 to 10 mA
5	0 to 20 mA
6	4 to 20 mA

F174
ENUMERATION: TRANSDUCER RTD INPUT TYPE

0 = 100 Ohm Platinum, 1 = 120 Ohm Nickel,
2 = 100 Ohm Nickel, 3 = 10 Ohm Copper

F175
ENUMERATION: PHASE LETTERS

0 = A, 1 = B, 2 = C

F176
ENUMERATION: SYNCHROCHECK DEAD SOURCE SELECT

bitmask	synchrocheck dead source
0	None
1	LV1 and DV2
2	DV1 and LV2
3	DV1 or DV2
4	DV1 Xor DV2
5	DV1 and DV2

F177
ENUMERATION: COMMUNICATION PORT

0 = NONE, 1 = COM1-RS485, 2 = COM2-RS485,
3 = FRONT PANEL-RS232, 4 = NETWORK

F178
ENUMERATION: DATA LOGGER RATES

0 = 1 sec, 1 = 1 min, 2 = 5 min, 3 = 10 min, 4 = 15 min,
5 = 20 min, 6 = 30 min, 7 = 60 min

F179
ENUMERATION: NEGATIVE SEQUENCE DIR OC TYPE

0 = Neg Sequence, 1 = Zero Sequence

F180
ENUMERATION: PHASE/GROUND

0 = PHASE, 1 = GROUND

F181
ENUMERATION: ODD/EVEN/NONE

0 = ODD, 1 = EVEN, 2 = NONE

F183
ENUMERATION AC INPUT WAVEFORMS

bitmask	definition
0	Off
1	8 samples/cycle
2	16 samples/cycle
3	32 samples/cycle
4	64 samples/cycle

F185
ENUMERATION PHASE A,B,C, GROUND SELECTOR

0 = A, 1 = B, 2 = C, 3 = G

F186
ENUMERATION MEASUREMENT MODE

0 = Phase to Ground, 1 = Phase to Phase

F190
ENUMERATION Simulated Keypress

bitmask	keypress
0	--- use between real keys
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	0
11	Decimal Pt
12	Plus/Minus

bitmask	keypress
13	Value Up
14	Value Down
15	Message Up
16	Message Down
17	Message Left
18	Message Right
19	Menu
20	Help
21	Escape
22	Enter
23	Reset
24	User 1
25	User 2
26	User 3

F192
ENUMERATION ETHERNET OPERATION MODE

0 = Half-Duplex, 1 = Full-Duplex

F194
ENUMERATION DNP SCALE

A bitmask of 0 = 0.01, 1 = 0.1, 2 = 1, 3 = 10, 4 = 100, 5 = 1000

B

F195
ENUMERATION SINGLE POLE TRIP MODE

A bitmask of 0 = Disabled, 1 = 3 Pole Only, 2 = 3 Pole & 1 Pole

F196
ENUMERATION NEUTRAL DIR OC OPERATE CURRENT

0 = Calculated 3I0, 1 = Measured IG

F197
ENUMERATION DNP BINARY INPUT POINT BLOCK

bitmask	Input Point Block
0	Not Used
1	Virtual Inputs 1 to 16
2	Virtual Inputs 17 to 32
3	Virtual Outputs 1 to 16
4	Virtual Outputs 17 to 32
5	Virtual Outputs 33 to 48
6	Virtual Outputs 49 to 64
7	Contact Inputs 1 to 16
8	Contact Inputs 17 to 32
9	Contact Inputs 33 to 48
10	Contact Inputs 49 to 64
11	Contact Inputs 65 to 80
12	Contact Inputs 81 to 96
13	Contact Outputs 1 to 16
14	Contact Outputs 17 to 32
15	Contact Outputs 33 to 48
16	Contact Outputs 49 to 64
17	Remote Inputs 1 to 16
18	Remote Inputs 17 to 32
19	Remote Devs 1 to 16
20	Elements 1 to 16
21	Elements 17 to 32
22	Elements 33 to 48
23	Elements 49 to 64
24	Elements 65 to 80
25	Elements 81 to 96
26	Elements 97 to 112
27	Elements 113 to 128
28	Elements 129 to 144
29	Elements 145 to 160
30	Elements 161 to 176
31	Elements 177 to 192
32	Elements 193 to 208
33	Elements 209 to 224
34	Elements 225 to 240
35	Elements 241 to 256
36	Elements 257 to 272
37	Elements 273 to 288
38	Elements 289 to 304
39	Elements 305 to 320
40	Elements 321 to 336
41	Elements 337 to 352
42	Elements 353 to 368
43	Elements 369 to 384
44	Elements 385 to 400
45	Elements 401 to 406
46	Elements 417 to 432
47	Elements 433 to 448
48	Elements 449 to 464
49	Elements 465 to 480
50	Elements 481 to 496
51	Elements 497 to 512
52	Elements 513 to 528
53	Elements 529 to 544
54	Elements 545 to 560
55	LED States 1 to 16
56	LED States 17 to 32
57	Self Tests 1 to 16
58	Self Tests 17 to 32

F200
TEXT40 40 CHARACTER ASCII TEXT

20 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F201
TEXT8 8 CHARACTER ASCII PASSCODE

4 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F202
TEXT20 20 CHARACTER ASCII TEXT

10 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

F203
TEXT16 16 CHARACTER ASCII TEXT

F204
TEXT80 80 CHARACTER ASCII TEXT

F205
TEXT12 12 CHARACTER ASCII TEXT

F206
TEXT6 6 CHARACTER ASCII TEXT

F207
TEXT4 4 CHARACTER ASCII TEXT

F208
TEXT2 2 CHARACTER ASCII TEXT

F222
ENUMERATION TEST ENUMERATION

0 = Test Enumeration 0, 1 = Test Enumeration 1

F230
ENUMERATION DIRECTIONAL POLARIZING

0 = Voltage, 1 = Current, 2 = Dual

F231
ENUMERATION POLARIZING VOLTAGE

0 = Calculated V0, 1 = Measured VX

F300
UR_UINT16 FLEXLOGIC BASE TYPE (6 bit type)

The FlexLogic™ BASE type is 6 bits and is combined with a 9 bit descriptor and 1 bit for protection element to form a 16 bit value. The combined bits are of the form: PTTTTTTDDDDDDDDD, where P bit if set, indicates that the FlexLogic™ type is associated with a protection element state and T represents bits for the BASE type, and D represents bits for the descriptor.

The values in square brackets indicate the base type with P prefix [PTTTTTT] and the values in round brackets indicate the descriptor range.

[0] Off(0) this is boolean FALSE value
[0] On (1)This is boolean TRUE value
[2] CONTACT INPUTS (1 - 96)
[3] CONTACT INPUTS OFF (1-96)
[4] VIRTUAL INPUTS (1-64)
[6] VIRTUAL OUTPUTS (1-64)
[10] CONTACT OUTPUTS VOLTAGE DETECTED (1-64)
[11] CONTACT OUTPUTS VOLTAGE OFF DETECTED (1-64)
[12] CONTACT OUTPUTS CURRENT DETECTED (1-64)
[13] CONTACT OUTPUTS CURRENT OFF DETECTED (1-64)
[14] REMOTE INPUTS (1-32)
[28] INSERT (Via Keypad only)
[32] END
[34] NOT (1 INPUT)
[36] 2 INPUT XOR (0)
[38] LATCH SET/RESET (2 INPUTS)
[40] OR (2-16 INPUTS)
[42] AND (2-16 INPUTS)
[44] NOR (2-16 INPUTS)
[46] NAND (2-16 INPUTS)
[48] TIMER (1-32)
[50] ASSIGN VIRTUAL OUTPUT (1 - 64)
[52] SELF-TEST ERROR (See F141 for range)
[56] ACTIVE SETTING GROUP (1-8)
[62] MISCELLANEOUS EVENTS (See F146 for range)
[64-127] ELEMENT STATES
(Refer to Memory Map Element States Section)

F400
UR_UINT16 CT/VT BANK SELECTION

bitmask	bank selection
0	Card 1 Contact 1 to 4
1	Card 1 Contact 5 to 8
2	Card 2 Contact 1 to 4
3	Card 2 Contact 5 to 8
4	Card 3 Contact 1 to 4
5	Card 3 Contact 5 to 8

F500
UR_UINT16 PACKED BITFIELD

First register indicates I/O state with bits 0(MSB)-15(LSB) corresponding to I/0 state 1-16. The second register indicates I/O state with bits 0-15 corresponding to I/0 state 17-32 (if required) The third register indicates I/O state with bits 0-15 corresponding to I/0 state 33-48 (if required). The fourth register indicates I/O state with bits 0-15 corresponding to I/0 state 49-64 (if required).

The number of registers required is determined by the specific data item. A bit value of 0 = Off, 1 = On

F501
UR_UINT16 LED STATUS

Low byte of register indicates LED status with bit 0 representing the top LED and bit 7 the bottom LED. A bit value of 1 indicates the LED is on, 0 indicates the LED is off.

F502
BITFIELD ELEMENT OPERATE STATES

Each bit contains the operate state for an element. See the F124 format code for a list of element IDs. The operate bit for element ID X is bit [X mod 16] in register [X/16].

F504
BITFIELD 3 PHASE ELEMENT STATE

bitmask	element state
0	Pickup
1	Operate
2	Pickup Phase A
3	Pickup Phase B
4	Pickup Phase C
5	Operate Phase A
6	Operate Phase B

bitmask	element state
7	Operate Phase C

F505
BITFIELD CONTACT OUTPUT STATE

0 = Contact State, 1 = Voltage Detected, 2 = Current Detected

F506|
BITFIELD 1 PHASE ELEMENT STATE

0 = Pickup, 1 = Operate

F507
BITFIELD COUNTER ELEMENT STATE

0 = Count Greater Than, 1 = Count Equal To, 2 = Count Less Than

F508
BITFIELD DISTANCE ELEMENT STATE

bitmask	distance element state
0	Pickup
1	Operate
2	Pickup AB
3	Pickup BC
4	Pickup CA
5	Operate AB
6	Operate BC
7	Operate CA
8	Timed
9	Operate IAB
10	Operate IBC
11	Operate ICA

F509
BITFIELD SIMPLE ELEMENT STATE

0 = Operate

F511
BITFIELD 3 PHASE SIMPLE ELEMENT STATE

0 = Operate, 1 = Operate A, 2 = Operate B, 3 = Operate C

F513
ENUMERATION POWER SWING MODE

0 = Two Step, 1 = Three Step

F514
ENUMERATION POWER SWING TRIP MODE

0 = Delayed, 1 = Early

F515
ENUMERATION ELEMENT INPUT MODE

0 = SIGNED, 1 = ABSOLUTE

F516
ENUMERATION ELEMENT COMPARE MODE

0 = LEVEL, 1 = DELTA

F517
ENUMERATION ELEMENT DIRECTION OPERATION

0 = OVER, 1 = UNDER

F518
ENUMERATION FlexElement Units

0 = Milliseconds, 1 = Seconds, 2 = Minutes

F600
UR_UINT16 FlexAnalog Parameter

The 16-bit value corresponds to the modbus address of the value to be used when this parameter is selected. Only certain values may be used as FlexAnalogs (basically all the metering quantities used in protection)

MMI_FLASH ENUMERATION
Flash message definitions for Front-panel MMI

bitmask	Flash Message
1	ADJUSTED VALUE HAS BEEN STORED
2	ENTERED PASSCODE IS INVALID
3	COMMAND EXECUTED
4	DEFAULT MESSAGE HAS BEEN ADDED
5	DEFAULT MESSAGE HAS BEEN REMOVED
6	INPUT FUNCTION IS ALREADY ASSIGNED
7	PRESS [ENTER] TO ADD AS DEFAULT
8	PRESS [ENTER] TO REMOVE MESSAGE
9	PRESS [ENTER] TO BEGIN TEXT EDIT
10	ENTRY MISMATCH - CODE NOT STORED
11	PRESSED KEY IS INVALID HERE
12	INVALID KEY: MUST BE IN LOCAL MODE
13	NEW PASSWORD HAS BEEN STORED
14	PLEASE ENTER A NON-ZERO PASSCODE
15	NO ACTIVE TARGETS (TESTING LEDS)
16	OUT OF RANGE - VALUE NOT STORED

bitmask	Flash Message
17	RESETTING LATCHED CONDITIONS
18	SETPOINT ACCESS IS NOW ALLOWED
19	SETPOINT ACCESS DENIED (PASSCODE)
20	SETPOINT ACCESS IS NOW RESTRICTED
21	NEW SETTING HAS BEEN STORED
22	SETPOINT ACCESS DENIED (SWITCH)
23	DATA NOT ACCEPTED
24	NOT ALL CONDITIONS HAVE BEEN RESET
25	DATE NOT ACCEPTED IRIGB IS ENABLED
26	NOT EXECUTED
27	DISPLAY ADDED TO USER DISPLAY LIST
28	DISPLAY NOT ADDED TO USER DISPLAY LIST
29	DISPLAY REMOVED FROM USER DISPLAY LIST

MMI_PASSWORD_TYPE ENUMERATION
Password types for display in password prompts

bitmask	password type
0	No
1	MASTER
2	SETTING
3	COMMAND
4	FACTORY

MMI_SETTING_TYPE ENUMERATION
Setting types for display in web pages

bitmask	Setting Type
0	Unrestricted Setting
1	Master-accessed Setting
2	Setting
3	Command
4	Factory Setting

B

C.1.1 UCA

The **Utility Communications Architecture** (UCA) version 2 represents an attempt by utilities and vendors of electronic equipment to produce standardized communications systems. There is a set of reference documents available from the Electric Power Research Institute (EPRI) and vendors of UCA/MMS software libraries that describe the complete capabilities of the UCA. Following, is a description of the subset of UCA/MMS features that are supported by the UR relay. The reference document set includes:

- Introduction to UCA version 2
- Generic Object Models for Substation & Feeder Equipment (GOMSFE)
- Common Application Service Models (CASM) and Mapping to MMS
- UCA Version 2 Profiles

These documents can be obtained from ftp://www.sisconet.com/epri/subdemo/uca2.0. It is strongly recommended that all those involved with any UCA implementation obtain this document set.

COMMUNICATION PROFILES:

The UCA specifies a number of possibilities for communicating with electronic devices based on the OSI Reference Model. The UR relay uses the seven layer OSI stack (TP4/CLNP and TCP/IP profiles). Refer to the "UCA Version 2 Profiles" reference document for details.

The TP4/CLNP profile requires the UR relay to have a network address or Network Service Access Point (NSAP) in order to establish a communication link. The TCP/IP profile requires the UR relay to have an IP address in order to establish a communication link. These addresses are set in the **SETTINGS ⇨ PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ NETWORK** menu. Note that the UR relay supports UCA operation over the TP4/CLNP or the TCP/IP stacks and also supports operation over both stacks simultaneously. It is possible to have up to two simultaneous connections. This is in addition to DNP and Modbus/TCP (non-UCA) connections.

C.1.2 MMS

The UCA specifies the use of the **Manufacturing Message Specification** (MMS) at the upper (Application) layer for transfer of real-time data. This protocol has been in existence for a number of years and provides a set of services suitable for the transfer of data within a substation LAN environment. Data can be grouped to form objects and be mapped to MMS services. Refer to the “GOMSFE” and “CASM” reference documents for details.

SUPPORTED OBJECTS:

The "GOMSFE" document describes a number of communication objects. Within these objects are items, some of which are mandatory and some of which are optional, depending on the implementation. The UR relay supports the following GOMSFE objects:

• DI (device identity)	• PHIZ (high impedance ground detector)
• GCTL (generic control)	• PIOC (instantaneous overcurrent relay)
• GIND (generic indicator)	• POVR (overvoltage relay)
• GLOBE (global data)	• PTOC (time overcurrent relay)
• MMXU (polyphase measurement unit)	• PUVR (under voltage relay)
• PBRL (phase balance current relay)	• PVPH (volts per hertz relay)
• PBRO (basic relay object)	• ctRATO (CT ratio information)
• PDIF (differential relay)	• vtRATO (VT ratio information)
• PDIS (distance)	• RREC (reclosing relay)
• PDOC (directional overcurrent)	• RSYN (synchronizing or synchronism-check relay)
• PFRQ (frequency relay)	• XCBR (circuit breaker)

UCA data can be accessed through the "UCADevice" MMS domain.

PEER-TO-PEER COMMUNICATION:

Peer-to-peer communication of digital state information, using the UCA GOOSE data object, is supported via the use of the UR Remote Inputs/Outputs feature. This feature allows digital points to be transferred between any UCA conforming devices.

FILE SERVICES:

MMS file services are supported to allow transfer of Oscillography, Event Record, or other files from a UR relay.

COMMUNICATION SOFTWARE UTILITIES:

The exact structure and values of the implemented objects implemented can be seen by connecting to a UR relay with an MMS browser, such as the “MMS Object Explorer and AXS4-MMS DDE/OPC” server from Sisco Inc.

NON-UCA DATA:

The UR relay makes available a number of non-UCA data items. These data items can be accessed through the "UR" MMS domain. UCA data can be accessed through the "UCADevice" MMS domain.

a) PROTOCOL IMPLEMENTATION AND CONFORMANCE STATEMENT (PICS)

NOTE

The UR relay functions as a server only; a UR relay cannot be configured as a client. Thus, the following list of supported services is for server operation only:

The MMS supported services are as follows:

CONNECTION MANAGEMENT SERVICES:

- Initiate
- Conclude
- Cancel
- Abort
- Reject

VMD SUPPORT SERVICES:

- Status
- GetNameList
- Identify

VARIABLE ACCESS SERVICES:

- Read
- Write
- InformationReport
- GetVariableAccessAttributes
- GetNamedVariableListAttributes

OPERATOR COMMUNICATION SERVICES:

(none)

SEMAPHORE MANAGEMENT SERVICES:

(none)

DOMAIN MANAGEMENT SERVICES:

- GetDomainAttributes

PROGRAM INVOCATION MANAGEMENT SERVICES:

(none)

EVENT MANAGEMENT SERVICES:

(none)

JOURNAL MANAGEMENT SERVICES:

(none)

FILE MANAGEMENT SERVICES:

- ObtainFile
- FileOpen
- FileRead
- FileClose
- FileDirectory

The following MMS parameters are supported:

- STR1 (Arrays)
- STR2 (Structures)
- NEST (Nesting Levels of STR1 and STR2) - 1
- VNAM (Named Variables)
- VADR (Unnamed Variables)
- VALT (Alternate Access Variables)
- VLIS (Named Variable Lists)
- REAL (ASN.1 REAL Type)

b) MODEL IMPLEMENTATION CONFORMANCE (MIC)

This section provides details of the UCA object models supported by the UR relay. Note that not all of the protective device functions are applicable to all UR relays.

Table C–1: DEVICE IDENTITY – DI

NAME	M/O	RWEC
Name	m	rw
Class	o	rw
d	o	rw
Own	o	rw
Loc	o	rw
VndID	m	r
CommID	o	rw

Table C–2: GENERIC CONTROL – GCTL

FC	NAME	CLASS	RWECS	DESCRIPTION
ST	BO<n>	SI	rw	Generic Single Point Indication
CO	BO<n>	SI	rw	Generic Binary Output
CF	BO<n>	SBOCF	rw	SBO Configuration
DC	LN	d	rw	Description for brick
	BO<n>	d	rw	Description for each point

NOTE

Actual instantiation of GCTL objects is as follows:

GCTL1 = Virtual Inputs (32 total points – SI1 to SI32); includes SBO functionality.

Table C–3: GENERIC INDICATOR – GIND

FC	NAME	CLASS	RWECS	DESCRIPTION
ST	SIG<n>	SIG	r	Generic Indication (block of 16)
DC	LN	d	rw	Description for brick
RP	BrcbST	BasRCB	rw	Controls reporting of STATUS

NOTE

Actual instantiation of GIND objects is as follows:

GIND1 = Contact Inputs (96 total points – SIG1 to SIG6)
GIND2 = Contact Outputs (64 total points – SIG1 to SIG4)
GIND3 = Virtual Inputs (32 total points – SIG1 to SIG2)
GIND4 = Virtual Outputs (64 total points – SIG1 to SIG4)
GIND5 = Remote Inputs (32 total points – SIG1 to SIG2)
GIND6 = Flexstates (16 total points – SIG1 representing Flexstates 1 to 16)

Table C–4: GLOBAL DATA – GLOBE

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	ModeDS	SIT	r	Device is: in test, off-line, available, or unhealthy
	LocRemDS	SIT	r	The mode of control, local or remote (DevST)
	ActSG	INT8U	r	Active Settings Group
	EditSG	INT8u	r	Settings Group selected for read/write operation
CO	CopySG	INT8U	w	Selects Settings Group for read/writer operation
	IndRs	BOOL	w	Resets ALL targets
CF	ClockTOD	BTIME	rw	Date and time
RP	GOOSE	PACT	rw	Reports IED Inputs and Ouputs

Table C–5: MEASUREMENT UNIT (POLYPHASE) – MMXU

OBJECT NAME	CLASS	RWECS	DESCRIPTION
V	WYE	rw	Voltage on phase A, B, C to G
PPV	DELTA	rw	Voltage on AB, BC, CA
A	WYE	rw	Current in phase A, B, C, and N
W	WYE	rw	Watts in phase A, B, C
TotW	AI	rw	Total watts in all three phases
Var	WYE	rw	Vars in phase A, B, C
TotVar	AI	rw	Total vars in all three phases
VA	WYE	rw	VA in phase A, B, C
TotVA	AI	rw	Total VA in all 3 phases
PF	WYE	rw	Power Factor for phase A, B, C
AvgPF	AI	rw	Average Power Factor for all three phases
Hz	AI	rw	Power system frequency
All MMXU.MX	ACF	rw	Configuration of ALL included MMXU.MX
LN	d	rw	Description for brick
All MMXU.MX	d	rw	Description of ALL included MMXU.MX
BrcbMX	BasRCB	rw	Controls reporting of measurements

NOTE

Actual instantiation of MMXU objects is as follows:

1 MMXU per Source (as determined from the ‘product order code’)

Table C–6: PROTECTIVE ELEMENTS

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	Out	BOOL	r	1 = Element operated, 2 = Element not operated
	Tar	PhsTar	r	Targets since last reset
	FctDS	SIT	r	Function is enabled/disabled
	PuGrp	INT8U	r	Settings group selected for use
CO	EnaDisFct	DCO	w	1 = Element function enabled, 0 = disabled
	RsTar	BO	w	Reset ALL Elements/Targets
	RsLat	BO	w	Reset ALL Elements/Targets
DC	LN	d	rw	Description for brick
	ElementSt	d	r	Element state string

The following GOMSFE objects are defined by the object model described via the above table:

- PBRO (basic relay object)
- PDIF (differential relay)
- PDIS (distance)
- PDOC (directional overcurrent)
- PFRQ (frequency relay)
- PHIZ (high impedance ground detector)
- PIOC (instantaneous overcurrent relay)
- POVR (over voltage relay)
- PTOC (time overcurrent relay)
- PUVR (under voltage relay)
- RSYN (synchronizing or synchronism-check relay)
- POVR (overvoltage)
- PVPH (volts per hertz relay)
- PBRL (phase balance current relay)

NOTE

Actual instantiation of these objects is determined by the number of the corresponding elements present in the UR as per the 'product order code'.

Table C–7: CT RATIO INFORMATION – ctRATO

OBJECT NAME	CLASS	RWECS	DESCRIPTION
PhsARat	RATIO	rw	Primary/secondary winding ratio
NeutARat	RATIO	rw	Primary/secondary winding ratio
LN	d	rw	Description for brick

NOTE

Actual instantiation of ctRATO objects is as follows:

1 ctRATO per Source (as determined from the 'product order code').

Table C–8: VT RATIO INFORMATION – vtRATO

OBJECT NAME	CLASS	RWECS	DESCRIPTION
PhsVRat	RATIO	rw	Primary/secondary winding ratio
LN	d	rw	Description for brick

NOTE

Actual instantiation of vtRATO objects is as follows:

1 vtRATO per Source (as determined from the 'product order code').

Table C–9: RECLOSING RELAY – RREC

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	Out	BOOL	r	1 = Element operated, 2 = Element not operated
	FctDS	SIT	r	Function is enabled/disabled
	PuGrp	INT8U	r	Settings group selected for use
SG	ReclSeq	SHOTS	rw	Reclosing Sequence
CO	EnaDisFct	DCO	w	1 = Element function enabled, 0 = disabled
	RsTar	BO	w	Reset ALL Elements/Targets
	RsLat	BO	w	Reset ALL Elements/Targets
CF	ReclSeq	ACF	rw	Configuration for RREC.SG
DC	LN	d	rw	Description for brick
	ElementSt	d	r	Element state string

C

NOTE

Actual instantiation of RREC objects is determined by the number of autoreclose elements present in the UR as per the ‘product order code’.

Also note that the SHOTS class data (i.e. Tmr1, Tmr2, Tmr3, Tmr4, RsTmr) is specified to be of type INT16S (16 bit signed integer); this data type is not large enough to properly display the full range of these settings from the UR. Numbers larger than 32768 will be displayed incorrectly.

Table C–10: RECLOSING RELAY – XCBR

FC	OBJECT NAME	CLASS	RWECS	DESCRIPTION
ST	SwDS	SIT	rw	Switch Device Status
	SwPoleDS	BSTR8	rw	Switch Pole Device Status
	PoleDiscSt	SI	rw	All CB poles did not operate within time interval
CO	ODSw	DCO	rw	The command to open/close the switch
CF	ODSwSBO	SBOCF	rw	Configuration for all included XCBR.CO
DC	LN	d	rw	Description for brick
RP	brcbST	BasRCB	rw	Controls reporting of Status Points

C.1.3 UCA REPORTING

A built-in TCP/IP connection timeout of two minutes is employed by the UR to detect "dead" connections. If there is no data traffic on a TCP connection for greater than two minutes, the connection will be aborted by the UR. This frees up the connection to be used by other clients. Therefore, when using UCA reporting, clients should configure BasRCB objects such that an integrity report will be issued at least every 2 minutes (120000 ms). This ensures that the UR will not abort the connection. If other MMS data is being polled on the same connection at least once every 2 minutes, this timeout will not apply.

D.1.1 INTEROPERABILITY DOCUMENT

This document is adapted from the IEC 60870-5-104 standard. For ths section the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

1. SYSTEM OR DEVICE:

☐ System Definition

☐ Controlling Station Definition (Master)

☒ **Controlled Station Definition (Slave)**

2. NETWORK CONFIGURATION:

■ ~~Point-to-Point~~ ■ ~~Multipoint~~

■ ~~Multiple Point-to-Point~~ ■ ~~Multipoint Star~~

3. PHYSICAL LAYER

Transmission Speed (control direction):

Unbalanced Interchange Circuit V.24/V.28 Standard:	**Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:**	**Balanced Interchange Circuit X.24/X.27:**
■ ~~100 bits/sec.~~	■ ~~2400 bits/sec.~~	■ ~~2400 bits/sec.~~
■ ~~200 bits/sec.~~	■ ~~4800 bits/sec.~~	■ ~~4800 bits/sec.~~
■ ~~300 bits/sec.~~	■ ~~9600 bits/sec.~~	■ ~~9600 bits/sec.~~
■ ~~600 bits/sec.~~		■ ~~19200 bits/sec.~~
■ ~~1200 bits/sec.~~		■ ~~38400 bits/sec.~~
		■ ~~56000 bits/sec.~~
		■ ~~64000 bits/sec.~~

Transmission Speed (monitor direction):

Unbalanced Interchange Circuit V.24/V.28 Standard:	**Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:**	**Balanced Interchange Circuit X.24/X.27:**
■ ~~100 bits/sec.~~	■ ~~2400 bits/sec.~~	■ ~~2400 bits/sec.~~
■ ~~200 bits/sec.~~	■ ~~4800 bits/sec.~~	■ ~~4800 bits/sec.~~
■ ~~300 bits/sec.~~	■ ~~9600 bits/sec.~~	■ ~~9600 bits/sec.~~
■ ~~600 bits/sec.~~		■ ~~19200 bits/sec.~~
■ ~~1200 bits/sec.~~		■ ~~38400 bits/sec.~~
		■ ~~56000 bits/sec.~~
		■ ~~64000 bits/sec.~~

4. LINK LAYER

Link Transmission Procedure:	**Address Field of the Link:**
■ ~~Balanced Transmision~~	■ ~~Not Present (Balanced Transmission Only)~~
■ ~~Unbalanced Transmission~~	■ ~~One Octet~~
	■ ~~Two Octets~~
	■ ~~Structured~~
	■ ~~Unstructured~~
Frame Length (maximum length, number of octets): Not selectable in companion IEC 60870-5-104 standard	

D

When using an unbalanced link layer, the following ADSU types are returned in class 2 messages (low priority) with the indicated causes of transmission:

- ■ ~~The standard assignment of ADSUs to class 2 messages is used as follows~~:
- ■ ~~A special assignment of ADSUs to class 2 messages is used as follows~~:

5. APPLICATION LAYER

Transmission Mode for Application Data:
Mode 1 (least significant octet first), as defined in Clause 4.10 of IEC 60870-5-4, is used exclusively in this companion stanadard.

Common Address of ADSU:

- ■ ~~One Octet~~
- ☒ Two Octets

Information Object Address:

- ■ ~~One Octet~~
- ■ ~~Two Octets~~
- ☒ Three Octets
- ☒ Structured
- ☒ Unstructured

D

Cause of Transmission:

- ■ ~~One Octet~~
- ☒ Two Octets (with originator address). Originator address is set to zero if not used.

Maximum Length of APDU: 253 (the maximum length may be reduced by the system.

Selection of standard ASDUs:

For the following lists, the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

Process information in monitor direction

☒ <1> := Single-point information	M_SP_NA_1
■ ~~<2> := Single-point information with time tag~~	~~M_SP_TA_1~~
☐ <3> := Double-point information	M_DP_NA_1
■ ~~<4> := Double-point information with time tag~~	~~M_DP_TA_1~~
☐ <5> := Step position information	M_ST_NA_1
■ ~~<6> := Step position information with time tag~~	~~M_ST_TA_1~~
☐ <7> := Bitstring of 32 bits	M_BO_NA_1
■ ~~<8> := Bitstring of 32 bits with time tag~~	~~M_BO_TA_1~~
☐ <9> := Measured value, normalized value	M_ME_NA_1
■ ~~<10> := Measured value, normalized value with time tag~~	~~M_NE_TA_1~~
☐ <11> := Measured value, scaled value	M_ME_NB_1
■ ~~<12> := Measured value, scaled value with time tag~~	~~M_NE_TB_1~~
☒ <13> := Measured value, short floating point value	M_ME_NC_1
■ ~~<14> := Measured value, short floating point value with time tag~~	~~M_NE_TC_1~~
☒ <15> := Integrated totals	M_IT_NA_1
■ ~~<16> := Integrated totals with time tag~~	~~M_IT_TA_1~~
■ ~~<17> := Event of protection equipment with time tag~~	~~M_EP_TA_1~~
■ ~~<18> := Packed start events of protection equipment with time tag~~	~~M_EP_TB_1~~
■ ~~<19> := Packed output circuit information of protection equipment with time tag~~	~~M_EP_TC_1~~
☐ <20> := Packed single-point information with status change detection	M_SP_NA_1

☐ <21> := Measured value, normalized value without quantity descriptor	M_ME_ND_1
☒ <30> := Single-point information with time tag CP56Time2a	M_SP_TB_1
☐ <31> := Double-point information wiht time tag CP56Time2a	M_DP_TB_1
☐ <32> := Step position information with time tag CP56Time2a	M_ST_TB_1
☐ <33> := Bitstring of 32 bits with time tag CP56Time2a	M_BO_TB_1
☐ <34> := Measured value, normalized value with time tag CP56Time2a	M_ME_TD_1
☐ <35> := Measured value, scaled value with time tag CP56Time2a	M_ME_TE_1
☐ <36> := Measured value, short floating point value with time tag CP56Time2a	M_ME_TF_1
☒ <37> := Integrated totals with time tag CP56Time2a	M_IT_TB_1
☐ <38> := Event of protection equipment with time tag CP56Time2a	M_EP_TD_1
☐ <39> := Packed start events of protection equipment with time tag CP56Time2a	M_EP_TE_1
☐ <40> := Packed output circuit information of protection equipment with time tag CP56Time2a	M_EP_TF_1

Either the ASDUs of the set <2>, <4>, <6>, <8>, <10>, <12>, <14>, <16>, <17>, <18>, and <19> or of the set <30> to <40> are used.

Process information in control direction

☒ <45> := Single command	C_SC_NA_1
☐ <46> := Double command	C_DC_NA_1
☐ <47> := Regulating step command	C_RC_NA_1
☐ <48> := Set point command, normalized value	C_SE_NA_1
☐ <49> := Set point command, scaled value	C_SE_NB_1
☐ <50> := Set point command, short floating point value	C_SE_NC_1
☐ <51> := Bitstring of 32 bits	C_BO_NA_1
☒ <58> := Single command with time tag CP56Time2a	C_SC_TA_1
☐ <59> := Double command with time tag CP56Time2a	C_DC_TA_1
☐ <60> := Regulating step command with time tag CP56Time2a	C_RC_TA_1
☐ <61> := Set point command, normalized value with time tag CP56Time2a	C_SE_TA_1
☐ <62> := Set point command, scaled value with time tag CP56Time2a	C_SE_TB_1
☐ <63> := Set point command, short floating point value with time tag CP56Time2a	C_SE_TC_1
☐ <64> := Bitstring of 32 bits with time tag CP56Time2a	C_BO_TA_1

Either the ASDUs of the set <45> to <51> or of the set <58> to <64> are used.

System information in monitor direction

☒ <70> := End of initialization	M_EI_NA_1

System information in control direction

☒ <100> := Interrogation command	C_IC_NA_1
☒ <101> := Counter interrogation command	C_CI_NA_1
☒ <102> := Read command	C_RD_NA_1
☒ <103> := Clock synchronization command (see Clause 7.6 in standard)	C_CS_NA_1
■ ~~<104> := Test command~~	~~C_TS_NA_1~~
☒ <105> := Reset process command	C_RP_NA_1
■ <106> := Delay acquisition command	C_CD_NA_1
☒ <107> := Test command with time tag CP56Time2a	C_TS_TA_1

Parameter in control direction

- ☐ <110> := Parameter of measured value, normalized value — PE_ME_NA_1
- ☐ <111> := Parameter of measured value, scaled value — PE_ME_NB_1
- ☒ <112> := Parameter of measured value, short floating point value — PE_ME_NC_1
- ☐ <113> := Parameter activation — PE_AC_NA_1

File transfer

- ☐ <120> := File Ready — F_FR_NA_1
- ☐ <121> := Section Ready — F_SR_NA_1
- ☐ <122> := Call directory, select file, call file, call section — F_SC_NA_1
- ☐ <123> := Last section, last segment — F_LS_NA_1
- ☐ <124> := Ack file, ack section — F_AF_NA_1
- ☐ <125> := Segment — F_SG_NA_1
- ☐ <126> := Directory (blank or X, available only in monitor [standard] direction) — C_CD_NA_1

D

Type identifier and cause of transmission assignments
(station-specific parameters)

In the following table:

- Shaded boxes are not required.
- Black boxes are not permitted in this companion standard.
- Blank boxes indicate functions or ASDU not used.
- '**X**' if only used in the standard direction

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																		
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<1>	M_SP_NA_1			X		X						X	X		X					
<2>	M_SP_TA_1																			
<3>	M_DP_NA_1																			
<4>	M_DP_TA_1																			
<5>	M_ST_NA_1																			
<6>	M_ST_TA_1																			
<7>	M_BO_NA_1																			
<8>	M_BO_TA_1																			

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																		
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<9>	M_ME_NA_1																			
<10>	M_ME_TA_1																			
<11>	M_ME_NB_1																			
<12>	M_ME_TB_1																			
<13>	M_ME_NC_1	X		X		X									X					
<14>	M_ME_TC_1																			
<15>	M_IT_NA_1			X												X				
<16>	M_IT_TA_1																			
<17>	M_EP_TA_1																			
<18>	M_EP_TB_1																			
<19>	M_EP_TC_1																			
<20>	M_PS_NA_1																			
<21>	M_ME_ND_1																			
<30>	M_SP_TB_1			X								X	X							
<31>	M_DP_TB_1																			
<32>	M_ST_TB_1																			
<33>	M_BO_TB_1																			
<34>	M_ME_TD_1																			
<35>	M_ME_TE_1																			
<36>	M_ME_TF_1																			
<37>	M_IT_TB_1			X												X				
<38>	M_EP_TD_1																			
<39>	M_EP_TE_1																			
<40>	M_EP_TF_1																			
<45>	C_SC_NA_1						X	X	X	X	X									
<46>	C_DC_NA_1																			
<47>	C_RC_NA_1																			
<48>	C_SE_NA_1																			
<49>	C_SE_NB_1																			

D

TYPE IDENTIFICATION		CAUSE OF TRANSMISSION																		
		PERIODIC, CYCLIC	BACKGROUND SCAN	SPONTANEOUS	INITIALIZED	REQUEST OR REQUESTED	ACTIVATION	ACTIVATION CONFIRMATION	DEACTIVATION	DEACTIVATION CONFIRMATION	ACTIVATION TERMINATION	RETURN INFO CAUSED BY LOCAL CMD	FILE TRANSFER	INTERROGATED BY GROUP <NUMBER>	REQUEST BY GROUP <N> COUNTER REQ	UNKNOWN TYPE IDENTIFICATION	UNKNOWN CAUSE OF TRANSMISSION	UNKNOWN COMMON ADDRESS OF ADSU	UNKNOWN INFORMATION OBJECT ADDR	UNKNOWN INFORMATION OBJECT ADDR
NO.	MNEMONIC	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<50>	C_SE_NC_1																			
<51>	C_BO_NA_1																			
<58>	C_SC_TA_1						X	X	X	X	X									
<59>	C_DC_TA_1																			
<60>	C_RC_TA_1																			
<61>	C_SE_TA_1																			
<62>	C_SE_TB_1																			
<63>	C_SE_TC_1																			
<64>	C_BO_TA_1																			
<70>	M_EI_NA_1*)				X															
<100>	C_IC_NA_1						X	X	X	X	X									
<101>	C_CI_NA_1						X	X			X									
<102>	C_RD_NA_1					X														
<103>	C_CS_NA_1			X			X	X												
<104>	C_TS_NA_1																			
<105>	C_RP_NA_1						X	X												
<106>	C_CD_NA_1																			
<107>	C_TS_TA_1																			
<110>	P_ME_NA_1																			
<111>	P_ME_NB_1																			
<112>	P_ME_NC_1						X	X							X					
<113>	P_AC_NA_1																			
<120>	F_FR_NA_1																			
<121>	F_SR_NA_1																			
<122>	F_SC_NA_1																			
<123>	F_LS_NA_1																			
<124>	F_AF_NA_1																			
<125>	F_SG_NA_1																			
<126>	F_DR_TA_1*)																			

6. BASIC APPLICATION FUNCTIONS

Station Initialization:

☒ Remote initialization

Cyclic Data Transmission:

☒ Cyclic data transmission

Read Procedure:

☒ Read procedure

Spontaneous Transmission:

☒ Spontaneous transmission

Double transmission of information objects with cause of transmission spontaneous:

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

☐ Single point information: M_SP_NA_1, M_SP_TA_1, M_SP_TB_1, and M_PS_NA_1

☐ Double point information: M_DP_NA_1, M_DP_TA_1, and M_DP_TB_1

☐ Step position information: M_ST_NA_1, M_ST_TA_1, and M_ST_TB_1

☐ Bitstring of 32 bits: M_BO_NA_1, M_BO_TA_1, and M_BO_TB_1 (if defined for a specific project)

☐ Measured value, normalized value: M_ME_NA_1, M_ME_TA_1, M_ME_ND_1, and M_ME_TD_1

☐ Measured value, scaled value: M_ME_NB_1, M_ME_TB_1, and M_ME_TE_1

☐ Measured value, short floating point number: M_ME_NC_1, M_ME_TC_1, and M_ME_TF_1

Station interrogation:

☒ Global

☒ Group 1	☒ Group 5	☒ Group 9	☒ Group 13
☒ Group 2	☒ Group 6	☒ Group 10	☒ Group 14
☒ Group 3	☒ Group 7	☒ Group 11	☒ Group 15
☒ Group 4	☒ Group 8	☒ Group 12	☒ Group 16

Clock synchronization:

☒ Clock synchronization (optional, see Clause 7.6)

Command transmission:

☒ Direct command transmission

☐ Direct setpoint command transmission

☒ Select and execute command

☐ Select and execute setpoint command

☒ C_SE ACTTERM used

☒ No additional definition

☒ Short pulse duration (duration determined by a system parameter in the outstation)

☒ Long pulse duration (duration determined by a system parameter in the outstation)

☒ Persistent output

☒ Supervision of maximum delay in command direction of commands and setpoint commands

Maximum allowable delay of commands and setpoint commands: **10 s**

Transmission of integrated totals:

- ☒ Mode A: Local freeze with spontaneous transmission
- ☒ Mode B: Local freeze with counter interrogation
- ☒ Mode C: Freeze and transmit by counter-interrogation commands
- ☒ Mode D: Freeze by counter-interrogation command, frozen values reported simultaneously

- ☒ Counter read
- ☒ Counter freeze without reset
- ☒ Counter freeze with reset
- ☒ Counter reset

- ☒ General request counter
- ☒ Request counter group 1
- ☒ Request counter group 2
- ☒ Request counter group 3
- ☒ Request counter group 4

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Parameter loading:

- ☒ Threshold value
- ☐ Smoothing factor
- ☐ Low limit for transmission of measured values
- ☐ High limit for transmission of measured values

Parameter activation:

- ☐ Activation/deactivation of persistent cyclic or periodic transmission of the addressed object

Test procedure:

- ☐ Test procedure

File transfer:

File transfer in monitor direction:

- ☐ Transparent file
- ☐ Transmission of disturbance data of protection equipment
- ☐ Transmission of sequences of events
- ☐ Transmission of sequences of recorded analog values

File transfer in control direction:

- ☐ Transparent file

Background scan:

- ☐ Background scan

Acquisition of transmission delay:

- ■ ~~Acquisition of transmission delay~~

Definition of time outs:

PARAMETER	DEFAULT VALUE	REMARKS	SELECTED VALUE
t_0	30 s	Timeout of connection establishment	120 s
t_1	15 s	Timeout of send or test APDUs	15 s
t_2	10 s	Timeout for acknowlegements in case of no data messages $t_2 < t_1$	10 s
t_3	20 s	Timeout for sending test frames in case of a long idle state	20 s

Maximum range of values for all time outs: 1 to 255 s, accuracy 1 s

Maximum number of outstanding I-format APDUs *k* and latest acknowledge APDUs (*w*):

PARAMETER	DEFAULT VALUE	REMARKS	SELECTED VALUE
k	12 APDUs	Maximum difference receive sequence number to send state variable	12 APDUs
w	8 APDUs	Latest acknowledge after receiving *w* I-format APDUs	8 APDUs

Maximum range of values *k*: 1 to 32767 ($2^{15} - 1$) APDUs, accuracy 1 APDU

Maximum range of values *w*: 1 to 32767 APDUs, accuracy 1 APDU
Recommendation: *w* should not exceed two-thirds of *k*.

Portnumber:

PARAMETER	VALUE	REMARKS
Portnumber	2404	In all cases

RFC 2200 suite:

RFC 2200 is an official Internet Standard which describes the state of standardization of protocols used in the Internet as determined by the Internet Architecture Board (IAB). It offers a broad spectrum of actual standards used in the Internet. The suitable selection of documents from RFC 2200 defined in this standard for given projects has to be chosen by the user of this standard.

- ☒ Ethernet 802.3
- ☐ Serial X.21 interface
- ☐ Other selection(s) from RFC 2200 (list below if selected)

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D.1.2 POINT LIST

D

Table D–1: IEC 60870-5-104 POINTS (Sheet 1 of 3)

POINT	DESCRIPTION	UNITS
M_ME_NC_1 Points		
2000	SRC 1 Phase A Current RMS	A
2001	SRC 1 Phase B Current RMS	A
2002	SRC 1 Phase C Current RMS	A
2003	SRC 1 Neutral Current RMS	A
2004	SRC 1 Phase A Current Magnitude	A
2005	SRC 1 Phase A Current Angle	degrees
2006	SRC 1 Phase B Current Magnitude	A
2007	SRC 1 Phase B Current Angle	degrees
2008	SRC 1 Phase C Current Magnitude	A
2009	SRC 1 Phase C Current Angle	degrees
2010	SRC 1 Neutral Current Magnitude	A
2011	SRC 1 Neutral Current Angle	degrees
2012	SRC 1 Ground Current RMS	A
2013	SRC 1 Ground Current Magnitude	A
2014	SRC 1 Ground Current Angle	degrees
2015	SRC 1 Zero Sequence Current Magnitude	A
2016	SRC 1 Zero Sequence Current Angle	degrees
2017	SRC 1 Positive Seq Current Magnitude	A
2018	SRC 1 Positive Sequence Current Angle	degrees
2019	SRC 1 Negative Seq Current Magnitude	A
2020	SRC 1 Negative Sequence Current Angle	degrees
2021	SRC 1 Differential Gnd Current Magnitude	A
2022	SRC 1 Differential Ground Current Angle	degrees
2023	SRC 1 Phase AG Voltage RMS	V
2024	SRC 1 Phase BG Voltage RMS	V
2025	SRC 1 Phase CG Voltage RMS	V
2026	SRC 1 Phase AG Voltage Magnitude	V
2027	SRC 1 Phase AG Voltage Angle	degrees
2028	SRC 1 Phase BG Voltage Magnitude	V
2029	SRC 1 Phase BG Voltage Angle	degrees
2030	SRC 1 Phase CG Voltage Magnitude	V
2031	SRC 1 Phase CG Voltage Angle	degrees
2032	SRC 1 Phase AB Voltage RMS	V
2033	SRC 1 Phase BC Voltage RMS	V
2034	SRC 1 Phase CA Voltage RMS	V
2035	SRC 1 Phase AB Voltage Magnitude	V
2036	SRC 1 Phase AB Voltage Angle	degrees
2037	SRC 1 Phase BC Voltage Magnitude	V
2038	SRC 1 Phase BC Voltage Angle	degrees
2039	SRC 1 Phase CA Voltage Magnitude	V
2040	SRC 1 Phase CA Voltage Angle	degrees
2041	SRC 1 Auxiliary Voltage RMS	V
2042	SRC 1 Auxiliary Voltage Magnitude	V
2043	SRC 1 Auxiliary Voltage Angle	degrees
2044	SRC 1 Zero Sequence Voltage Magnitude	V

Table D–1: IEC 60870-5-104 POINTS (Sheet 2 of 3)

POINT	DESCRIPTION	UNITS
2045	SRC 1 Zero Sequence Voltage Angle	degrees
2046	SRC 1 Positive Seq Voltage Magnitude	V
2047	SRC 1 Positive Sequence Voltage Angle	degrees
2048	SRC 1 Negative Seq Voltage Magnitude	V
2049	SRC 1 Negative Sequence Voltage Angle	degrees
2050	SRC 1 Three Phase Real Power	W
2051	SRC 1 Phase A Real Power	W
2052	SRC 1 Phase B Real Power	W
2053	SRC 1 Phase C Real Power	W
2054	SRC 1 Three Phase Reactive Power	var
2055	SRC 1 Phase A Reactive Power	var
2056	SRC 1 Phase B Reactive Power	var
2057	SRC 1 Phase C Reactive Power	var
2058	SRC 1 Three Phase Apparent Power	VA
2059	SRC 1 Phase A Apparent Power	VA
2060	SRC 1 Phase B Apparent Power	VA
2061	SRC 1 Phase C Apparent Power	VA
2062	SRC 1 Three Phase Power Factor	none
2063	SRC 1 Phase A Power Factor	none
2064	SRC 1 Phase B Power Factor	none
2065	SRC 1 Phase C Power Factor	none
2066	SRC 1 Frequency	Hz
2067	Breaker 1 Arcing Amp Phase A	kA2-cyc
2068	Breaker 1 Arcing Amp Phase B	kA2-cyc
2069	Breaker 1 Arcing Amp Phase C	kA2-cyc
2070	Breaker 2 Arcing Amp Phase A	kA2-cyc
2071	Breaker 2 Arcing Amp Phase B	kA2-cyc
2072	Breaker 2 Arcing Amp Phase C	kA2-cyc
2073	Synchrocheck 1 Delta Voltage	V
2074	Synchrocheck 1 Delta Frequency	Hz
2075	Synchrocheck 1 Delta Phase	degrees
2076	Synchrocheck 2 Delta Voltage	V
2077	Synchrocheck 2 Delta Frequency	Hz
2078	Synchrocheck 2 Delta Phase	degrees
2079	Tracking Frequency	Hz
2080	FlexElement 1 Actual	none
2081	FlexElement 2 Actual	none
2082	FlexElement 3 Actual	none
2083	FlexElement 4 Actual	none
2084	FlexElement 5 Actual	none
2085	FlexElement 6 Actual	none
2086	FlexElement 7 Actual	none
2087	FlexElement 8 Actual	none
2088	FlexElement 9 Actual	none
2089	FlexElement 10 Actual	none
2090	FlexElement 11 Actual	none

Table D–1: IEC 60870-5-104 POINTS (Sheet 3 of 3)

POINT	DESCRIPTION	UNITS
2091	FlexElement 12 Actual	none
2092	FlexElement 13 Actual	none
2093	FlexElement 14 Actual	none
2094	FlexElement 15 Actual	none
2095	FlexElement 16 Actual	none
2096	Current Setting Group	none
P_ME_NC_1 Points		
5000 - 5096	Threshold values for M_ME_NC_1 points	-
M_SP_NA_1 Points		
100 - 115	Virtual Input States[0]	-
116 - 131	Virtual Input States[1]	-
132 - 147	Virtual Output States[0]	-
148 - 163	Virtual Output States[1]	-
164 - 179	Virtual Output States[2]	-
180 - 195	Virtual Output States[3]	-
196 - 211	Contact Input States[0]	-
212 - 227	Contact Input States[1]	-
228 - 243	Contact Input States[2]	-
244 - 259	Contact Input States[3]	-
260 - 275	Contact Input States[4]	-
276 - 291	Contact Input States[5]	-
292 - 307	Contact Output States[0]	-
308 - 323	Contact Output States[1]	-
324 - 339	Contact Output States[2]	-
340 - 355	Contact Output States[3]	-
356 - 371	Remote Input x States[0]	-
372 - 387	Remote Input x States[1]	-
388 - 403	Remote Device x States	-
404 - 419	LED Column x State[0]	-
420 - 435	LED Column x State[1]	-
C_SC_NA_1 Points		
1100 - 1115	Virtual Input States[0] - No Select Required	-
1116 - 1131	Virtual Input States[1] - Select Required	-
M_IT_NA_1 Points		
Point	Description	-
4000	Digital Counter 1 Value	-
4001	Digital Counter 2 Value	-
4002	Digital Counter 3 Value	-
4003	Digital Counter 4 Value	-
4004	Digital Counter 5 Value	-
4005	Digital Counter 6 Value	-
4006	Digital Counter 7 Value	-
4007	Digital Counter 8 Value	-

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D

E.1.1 DNP V3.00 DEVICE PROFILE

The following table provides a “Device Profile Document” in the standard format defined in the DNP 3.0 Subset Definitions Document.

Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 1 of 3)

<table>
<tr><td colspan="2">(Also see the IMPLEMENTATION TABLE in the following section)</td></tr>
<tr><td colspan="2">Vendor Name: General Electric Power Management</td></tr>
<tr><td colspan="2">Device Name: UR Series Relay</td></tr>
<tr><td>Highest DNP Level Supported:
For Requests: Level 2
For Responses: Level 2</td><td>Device Function:
❐ Master
☒ Slave</td></tr>
<tr><td colspan="2">Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):
Binary Inputs (Object 1)
Binary Input Changes (Object 2)
Binary Outputs (Object 10)
Binary Counters (Object 20)
Frozen Counters (Object 21)
Counter Change Event (Object 22)
Frozen Counter Event (Object 23)
Analog Inputs (Object 30)
Analog Input Changes (Object 32)
Analog Deadbands (Object 34)</td></tr>
<tr><td>Maximum Data Link Frame Size (octets):
Transmitted: 292
Received: 292</td><td>Maximum Application Fragment Size (octets):
Transmitted: 240
Received: 2048</td></tr>
<tr><td>Maximum Data Link Re-tries:
❐ None
☒ Fixed at 2
❐ Configurable</td><td>Maximum Application Layer Re-tries:
☒ None
❐ Configurable</td></tr>
<tr><td colspan="2">Requires Data Link Layer Confirmation:
☒ Never
❐ Always
❐ Sometimes
❐ Configurable</td></tr>
</table>

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Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 2 of 3)

Requires Application Layer Confirmation:

☐ Never
☐ Always
☒ When reporting Event Data
☒ When sending multi-fragment responses
☐ Sometimes
☐ Configurable

Timeouts while waiting for:

Data Link Confirm:	☐ None	☒ **Fixed at 3 s**	☐ Variable	☐ Configurable
Complete Appl. Fragment:	☒ **None**	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm:	☐ None	☒ **Fixed at 4 s**	☐ Variable	☐ Configurable
Complete Appl. Response:	☒ **None**	☐ Fixed at ____	☐ Variable	☐ Configurable

Others:

Transmission Delay:	**No intentional delay**
Inter-character Timeout:	**50 ms**
Need Time Delay:	**Configurable (default = 24 hrs.)**
Select/Operate Arm Timeout:	**10 s**
Binary input change scanning period:	**8 times per power system cycle**
Packed binary change process period:	**1 s**
Analog input change scanning period:	**500 ms**
Counter change scanning period:	**500 ms**
Frozen counter event scanning period:	**500 ms**
Unsolicited response notification delay:	**500 ms**
Unsolicited response retry delay	**configurable 0 to 60 sec.**

Sends/Executes Control Operations:

WRITE Binary Outputs	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE – NO ACK	☐ Never	☒ **Always**	☐ Sometimes	☐ Configurable

Count > 1	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Pulse Off	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Latch On	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable
Latch Off	☐ Never	☐ Always	☒ **Sometimes**	☐ Configurable

Queue	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ **Never**	☐ Always	☐ Sometimes	☐ Configurable

Explanation of 'Sometimes': Object 12 points are mapped to UR Virtual Inputs. The persistence of Virtual Inputs is determined by the **VIRTUAL INPUT X TYPE** settings. Both "Pulse On" and "Latch On" operations perform the same function in the UR; that is, the appropriate Virtual Input is put into the "On" state. If the Virtual Input is set to "Self-Reset", it will reset after one pass of FlexLogic™. The On/Off times and Count value are ignored. "Pulse Off" and "Latch Off" operations put the appropriate Virtual Input into the "Off" state. "Trip" and "Close" operations both put the appropriate Virtual Input into the "On" state.

Table E–1: DNP V3.00 DEVICE PROFILE (Sheet 3 of 3)

Reports Binary Input Change Events when no specific variation requested: ☐ Never ☒ **Only time-tagged** ☐ Only non-time-tagged ☐ Configurable	**Reports time-tagged Binary Input Change Events when no specific variation requested:** ☐ Never ☒ Binary Input Change With Time ☐ Binary Input Change With Relative Time ☐ Configurable (attach explanation)
Sends Unsolicited Responses: ☐ **Never** ☒ Configurable ☐ Only certain objects ☐ Sometimes (attach explanation) ☒ ENABLE/DISABLE unsolicited Function codes supported	**Sends Static Data in Unsolicited Responses:** ☒ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) ☒ **Default Object: 20** **Default Variation: 1** ☒ **Point-by-point list attached**	**Counters Roll Over at:** ☐ No Counters Reported ☐ Configurable (attach explanation) ☒ **16 Bits (Counter 8)** ☒ **32 Bits (Counters 0 to 7, 9)** ☐ Other Value: _____ ☒ **Point-by-point list attached**
Sends Multi-Fragment Responses: ☒ **Yes** ☐ No	

E

E.2.1 IMPLEMENTATION TABLE

The following table identifies the variations, function codes, and qualifiers supported by the UR in both request messages and in response messages. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01. Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

Table E–2: IMPLEMENTATION TABLE (Sheet 1 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
1	0	Binary Input (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	Binary Input	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	Binary Input with Status *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
2	0	Binary Input Change (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	Binary Input Change without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	2	Binary Input Change with Time *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response 130 (unsol. resp.)	17, 28 (index)
10	0	Binary Output Status (Variation 0 is used to request default variation)	1 (read)	00, 01(start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	2	Binary Output Status *(default – see Note 1)*	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
12	1	Control Relay Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	echo of request
20	0	Binary Counter (Variation 0 is used to request default variation)	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01(start-stop) 06(no range, or all) 07, 08(limited qty) 17, 28(index)		
	1	32-Bit Binary Counter *(default – see Note 1)*	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

Table E–2: IMPLEMENTATION TABLE (Sheet 2 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	**VARIATION NO.**	**DESCRIPTION**	**FUNCTION CODES (DEC)**	**QUALIFIER CODES (HEX)**	**FUNCTION CODES (DEC)**	**QUALIFIER CODES (HEX)**
20 con't	2	16-Bit Binary Counter	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	5	32-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	6	16-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
21	0	Frozen Counter (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	32-Bit Frozen Counter *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	16-Bit Frozen Counter	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	9	32-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	10	16-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
22	0	Counter Change Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Counter Change Event *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	32-Bit Counter Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
23	0	Frozen Counter Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Frozen Counter Event *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	32-Bit Frozen Counter Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

Table E–2: IMPLEMENTATION TABLE (Sheet 3 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	**VARIATION NO.**	**DESCRIPTION**	**FUNCTION CODES (DEC)**	**QUALIFIER CODES (HEX)**	**FUNCTION CODES (DEC)**	**QUALIFIER CODES (HEX)**
30	0	Analog Input (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	32-Bit Analog Input *(default – see Note 1)*	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	2	16-Bit Analog Input	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	3	32-Bit Analog Input without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	4	16-Bit Analog Input without Flag	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	5	short floating point	1 (read) 22 (assign class)	00, 01 (start-stop) 06(no range, or all) 07, 08(limited qty) 17, 28(index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
32	0	Analog Change Event (Variation 0 is used to request default variation)	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
	1	32-Bit Analog Change Event without Time *(default – see Note 1)*	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	2	16-Bit Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	3	32-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	4	16-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	5	short floating point Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
	7	short floating point Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
34	0	Analog Input Reporting Deadband (Variation 0 is used to request default variation)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)		
	1	16-bit Analog Input Reporting Deadband (default – see Note 1)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
			2 (write)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)		

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

E

Table E–2: IMPLEMENTATION TABLE (Sheet 4 of 4)

OBJECT			REQUEST		RESPONSE	
OBJECT NO.	VARIATION NO.	DESCRIPTION	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)	FUNCTION CODES (DEC)	QUALIFIER CODES (HEX)
34 con't	2	32-bit Analog Input Reporting Deadband (default – see Note 1)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
			2 (write)	00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)		
	3	Short floating point Analog Input Reporting Deadband	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
50	0	Time and Date	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
	1	Time and Date (default – see Note 1)	1 (read) 2 (write)	00, 01 (start-stop) 06 (no range, or all) 07 (limited qty=1) 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index) *(see Note 2)*
52	2	Time Delay Fine			129 (response)	07 (limited qty) (qty = 1)
60	0	Class 0, 1, 2, and 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all)		
	1	Class 0 Data	1 (read) 22 (assign class)	06 (no range, or all)		
	2	Class 1 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
	3	Class 2 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
	4	Class 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty)		
80	1	Internal Indications	2 (write)	00 (start-stop) (index must =7)		
---		No Object (function code only) *see Note 3*	13 (cold restart)			
---		No Object (function code only)	14 (warm restart)			
---		No Object (function code only)	23 (delay meas.)			

Note 1: A Default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Type 30 (Analog Input) data is limited to data that is actually possible to be used in the UR, based on the product order code. For example, Signal Source data from source numbers that cannot be used is not included. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the UR is not restarted, but the DNP process is restarted.

E

E.3.1 BINARY INPUT POINTS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

BINARY INPUT POINTS

Static (Steady-State) Object Number: **1**

Change Event Object Number: **2**

Request Function Codes supported: **1 (read), 22 (assign class)**

Static Variation reported when variation 0 requested: **2 (Binary Input with status)**

Change Event Variation reported when variation 0 requested: **2 (Binary Input Change with Time)**

Change Event Scan Rate: **8 times per power system cycle**

Change Event Buffer Size: **1000**

Table E–3: BINARY INPUTS (Sheet 1 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
0	Virtual Input 1	2
1	Virtual Input 2	2
2	Virtual Input 3	2
3	Virtual Input 4	2
4	Virtual Input 5	2
5	Virtual Input 6	2
6	Virtual Input 7	2
7	Virtual Input 8	2
8	Virtual Input 9	2
9	Virtual Input 10	2
10	Virtual Input 11	2
11	Virtual Input 12	2
12	Virtual Input 13	2
13	Virtual Input 14	2
14	Virtual Input 15	2
15	Virtual Input 16	2
16	Virtual Input 17	2
17	Virtual Input 18	2
18	Virtual Input 19	2
19	Virtual Input 20	2
20	Virtual Input 21	2
21	Virtual Input 22	2
22	Virtual Input 23	2
23	Virtual Input 24	2
24	Virtual Input 25	2
25	Virtual Input 26	2
26	Virtual Input 27	2
27	Virtual Input 28	2
28	Virtual Input 29	2
29	Virtual Input 30	2
30	Virtual Input 31	2
31	Virtual Input 32	2

Table E–3: BINARY INPUTS (Sheet 2 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
32	Virtual Output 1	2
33	Virtual Output 2	2
34	Virtual Output 3	2
35	Virtual Output 4	2
36	Virtual Output 5	2
37	Virtual Output 6	2
38	Virtual Output 7	2
39	Virtual Output 8	2
40	Virtual Output 9	2
41	Virtual Output 10	2
42	Virtual Output 11	2
43	Virtual Output 12	2
44	Virtual Output 13	2
45	Virtual Output 14	2
46	Virtual Output 15	2
47	Virtual Output 16	2
48	Virtual Output 17	2
49	Virtual Output 18	2
50	Virtual Output 19	2
51	Virtual Output 20	2
52	Virtual Output 21	2
53	Virtual Output 22	2
54	Virtual Output 23	2
55	Virtual Output 24	2
56	Virtual Output 25	2
57	Virtual Output 26	2
58	Virtual Output 27	2
59	Virtual Output 28	2
60	Virtual Output 29	2
61	Virtual Output 30	2
62	Virtual Output 31	2
63	Virtual Output 32	2

Table E–3: BINARY INPUTS (Sheet 3 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
64	Virtual Output 33	2
65	Virtual Output 34	2
66	Virtual Output 35	2
67	Virtual Output 36	2
68	Virtual Output 37	2
69	Virtual Output 38	2
70	Virtual Output 39	2
71	Virtual Output 40	2
72	Virtual Output 41	2
73	Virtual Output 42	2
74	Virtual Output 43	2
75	Virtual Output 44	2
76	Virtual Output 45	2
77	Virtual Output 46	2
78	Virtual Output 47	2
79	Virtual Output 48	2
80	Virtual Output 49	2
81	Virtual Output 50	2
82	Virtual Output 51	2
83	Virtual Output 52	2
84	Virtual Output 53	2
85	Virtual Output 54	2
86	Virtual Output 55	2
87	Virtual Output 56	2
88	Virtual Output 57	2
89	Virtual Output 58	2
90	Virtual Output 59	2
91	Virtual Output 60	2
92	Virtual Output 61	2
93	Virtual Output 62	2
94	Virtual Output 63	2
95	Virtual Output 64	2
96	Contact Input 1	1
97	Contact Input 2	1
98	Contact Input 3	1
99	Contact Input 4	1
100	Contact Input 5	1
101	Contact Input 6	1
102	Contact Input 7	1
103	Contact Input 8	1
104	Contact Input 9	1
105	Contact Input 10	1
106	Contact Input 11	1
107	Contact Input 12	1
108	Contact Input 13	1
109	Contact Input 14	1
110	Contact Input 15	1
111	Contact Input 16	1
112	Contact Input 17	1
113	Contact Input 18	1
114	Contact Input 19	1

Table E–3: BINARY INPUTS (Sheet 4 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
115	Contact Input 20	1
116	Contact Input 21	1
117	Contact Input 22	1
118	Contact Input 23	1
119	Contact Input 24	1
120	Contact Input 25	1
121	Contact Input 26	1
122	Contact Input 27	1
123	Contact Input 28	1
124	Contact Input 29	1
125	Contact Input 30	1
126	Contact Input 31	1
127	Contact Input 32	1
128	Contact Input 33	1
129	Contact Input 34	1
130	Contact Input 35	1
131	Contact Input 36	1
132	Contact Input 37	1
133	Contact Input 38	1
134	Contact Input 39	1
135	Contact Input 40	1
136	Contact Input 41	1
137	Contact Input 42	1
138	Contact Input 43	1
139	Contact Input 44	1
140	Contact Input 45	1
141	Contact Input 46	1
142	Contact Input 47	1
143	Contact Input 48	1
144	Contact Input 49	1
145	Contact Input 50	1
146	Contact Input 51	1
147	Contact Input 52	1
148	Contact Input 53	1
149	Contact Input 54	1
150	Contact Input 55	1
151	Contact Input 56	1
152	Contact Input 57	1
153	Contact Input 58	1
154	Contact Input 59	1
155	Contact Input 60	1
156	Contact Input 61	1
157	Contact Input 62	1
158	Contact Input 63	1
159	Contact Input 64	1
160	Contact Input 65	1
161	Contact Input 66	1
162	Contact Input 67	1
163	Contact Input 68	1
164	Contact Input 69	1
165	Contact Input 70	1

Table E–3: BINARY INPUTS (Sheet 5 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
166	Contact Input 71	1
167	Contact Input 72	1
168	Contact Input 73	1
169	Contact Input 74	1
170	Contact Input 75	1
171	Contact Input 76	1
172	Contact Input 77	1
173	Contact Input 78	1
174	Contact Input 79	1
175	Contact Input 80	1
176	Contact Input 81	1
177	Contact Input 82	1
178	Contact Input 83	1
179	Contact Input 84	1
180	Contact Input 85	1
181	Contact Input 86	1
182	Contact Input 87	1
183	Contact Input 88	1
184	Contact Input 89	1
185	Contact Input 90	1
186	Contact Input 91	1
187	Contact Input 92	1
188	Contact Input 93	1
189	Contact Input 94	1
190	Contact Input 95	1
191	Contact Input 96	1
192	Contact Output 1	1
193	Contact Output 2	1
194	Contact Output 3	1
195	Contact Output 4	1
196	Contact Output 5	1
197	Contact Output 6	1
198	Contact Output 7	1
199	Contact Output 8	1
200	Contact Output 9	1
201	Contact Output 10	1
202	Contact Output 11	1
203	Contact Output 12	1
204	Contact Output 13	1
205	Contact Output 14	1
206	Contact Output 15	1
207	Contact Output 16	1
208	Contact Output 17	1
209	Contact Output 18	1
210	Contact Output 19	1
211	Contact Output 20	1
212	Contact Output 21	1
213	Contact Output 22	1
214	Contact Output 23	1
215	Contact Output 24	1
216	Contact Output 25	1

Table E–3: BINARY INPUTS (Sheet 6 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
217	Contact Output 26	1
218	Contact Output 27	1
219	Contact Output 28	1
220	Contact Output 29	1
221	Contact Output 30	1
222	Contact Output 31	1
223	Contact Output 32	1
224	Contact Output 33	1
225	Contact Output 34	1
226	Contact Output 35	1
227	Contact Output 36	1
228	Contact Output 37	1
229	Contact Output 38	1
230	Contact Output 39	1
231	Contact Output 40	1
232	Contact Output 41	1
233	Contact Output 42	1
234	Contact Output 43	1
235	Contact Output 44	1
236	Contact Output 45	1
237	Contact Output 46	1
238	Contact Output 47	1
239	Contact Output 48	1
240	Contact Output 49	1
241	Contact Output 50	1
242	Contact Output 51	1
243	Contact Output 52	1
244	Contact Output 53	1
245	Contact Output 54	1
246	Contact Output 55	1
247	Contact Output 56	1
248	Contact Output 57	1
249	Contact Output 58	1
250	Contact Output 59	1
251	Contact Output 60	1
252	Contact Output 61	1
253	Contact Output 62	1
254	Contact Output 63	1
255	Contact Output 64	1
256	Remote Input 1	1
257	Remote Input 2	1
258	Remote Input 3	1
259	Remote Input 4	1
260	Remote Input 5	1
261	Remote Input 6	1
262	Remote Input 7	1
263	Remote Input 8	1
264	Remote Input 9	1
265	Remote Input 10	1
266	Remote Input 11	1
267	Remote Input 12	1

Table E–3: BINARY INPUTS (Sheet 7 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
268	Remote Input 13	1
269	Remote Input 14	1
270	Remote Input 15	1
271	Remote Input 16	1
272	Remote Input 17	1
273	Remote Input 18	1
274	Remote Input 19	1
275	Remote Input 20	1
276	Remote Input 21	1
277	Remote Input 22	1
278	Remote Input 23	1
279	Remote Input 24	1
280	Remote Input 25	1
281	Remote Input 26	1
282	Remote Input 27	1
283	Remote Input 28	1
284	Remote Input 29	1
285	Remote Input 30	1
286	Remote Input 31	1
287	Remote Input 32	1
288	Remote Device 1	1
289	Remote Device 2	1
290	Remote Device 3	1
291	Remote Device 4	1
292	Remote Device 5	1
293	Remote Device 6	1
294	Remote Device 7	1
295	Remote Device 8	1
296	Remote Device 9	1
297	Remote Device 10	1
298	Remote Device 11	1
299	Remote Device 12	1
300	Remote Device 13	1
301	Remote Device 14	1
302	Remote Device 15	1
303	Remote Device 16	1
304	PHASE IOC1 Element OP	1
305	PHASE IOC2 Element OP	1
320	PHASE TOC1 Element OP	1
321	PHASE TOC2 Element OP	1
328	PH DIR1 Element OP	1
329	PH DIR2 Element OP	1
336	NEUTRAL IOC1 Element OP	1
337	NEUTRAL IOC2 Element OP	1
352	NEUTRAL TOC1 Element OP	1
353	NEUTRAL TOC2 Element OP	1
360	NTRL DIR OC1 Element OP	1
361	NTRL DIR OC2 Element OP	1
364	NEG SEQ DIR OC1 Elem. OP	1
365	NEG SEQ DIR OC2 Elem OP	1
368	GROUND IOC1 Element OP	1

Table E–3: BINARY INPUTS (Sheet 8 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
369	GROUND IOC2 Element OP	1
384	GROUND TOC1 Element OP	1
385	GROUND TOC2 Element OP	1
400	NEG SEQ IOC1 Element OP	1
401	NEG SEQ IOC2 Element OP	1
416	NEG SEQ TOC1 Element OP	1
417	NEG SEQ TOC2 Element OP	1
444	AUX UV1 Element OP	1
448	PHASE UV1 Element OP	1
449	PHASE UV2 Element OP	1
452	AUX OV1 Element OP	1
456	PHASE OV1 Element OP	1
460	NEUTRAL OV1 Element OP	1
464	PH DIST Z1 Element OP	1
465	PH DIST Z2 Element OP	1
466	PH DIST Z3 Element OP	1
467	PH DIST Z4 Element OP	1
472	LINE PICKUP Element OP	1
480	GND DIST Z1 Element OP	1
481	GND DIST Z2 Element OP	1
482	GND DIST Z3 Element OP	1
483	GND DIST Z4 Element OP	1
484	LOAD ENCHR Element OP	1
488	DUTT Element OP	1
489	PUTT Element OP	1
490	POTT Element OP	1
491	HYBRID POTT Element OP	1
492	BLOCK SCHEME Element OP	1
494	POWER SWING Element OP	1
528	SRC1 VT FUSE FAIL Elem OP	1
529	SRC2 VT FUSE FAIL Elem OP	1
530	SRC3 VT FUSE FAIL Elem OP	1
531	SRC4 VT FUSE FAIL Elem OP	1
532	SRC5 VT FUSE FAIL Elem OP	1
533	SRC6 VT FUSE FAIL Elem OP	1
536	SRC1 50DD Element OP	1
537	SRC2 50DD Element OP	1
538	SRC3 50DD Element OP	1
539	SRC4 50DD Element OP	1
540	SRC5 50DD Element OP	1
541	SRC6 50DD Element OP	1
548	50DD Element OP	1
554	STUB BUS Element OP	1
576	BREAKER 1 Element OP	1
577	BREAKER 2 Element OP	1
584	BKR FAIL 1 Element OP	1
585	BKR FAIL 2 Element OP	1
592	BKR ARC 1 Element OP	1
593	BKR ARC 2 Element OP	1
608	AR 1 Element OP	1
609	AR 2 Element OP	1

Table E–3: BINARY INPUTS (Sheet 9 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
610	AR 3 Element OP	1
611	AR 4 Element OP	1
612	AR 5 Element OP	1
613	AR 6 Element OP	1
616	SYNC 1 Element OP	1
617	SYNC 2 Element OP	1
640	SETTING GROUP Element OP	1
641	RESET Element OP	1
704	FLEXELEMENT 1 Element OP	1
705	FLEXELEMENT 2 Element OP	1
706	FLEXELEMENT 3 Element OP	1
707	FLEXELEMENT 4 Element OP	1
708	FLEXELEMENT 5 Element OP	1
709	FLEXELEMENT 6 Element OP	1
710	FLEXELEMENT 7 Element OP	1
711	FLEXELEMENT 8 Element OP	1
816	DIG ELEM 1 Element OP	1
817	DIG ELEM 2 Element OP	1
818	DIG ELEM 3 Element OP	1
819	DIG ELEM 4 Element OP	1
820	DIG ELEM 5 Element OP	1
821	DIG ELEM 6 Element OP	1
822	DIG ELEM 7 Element OP	1
823	DIG ELEM 8 Element OP	1
824	DIG ELEM 9 Element OP	1
825	DIG ELEM 10 Element OP	1
826	DIG ELEM 11 Element OP	1
827	DIG ELEM 12 Element OP	1
828	DIG ELEM 13 Element OP	1
829	DIG ELEM 14 Element OP	1
830	DIG ELEM 15 Element OP	1
831	DIG ELEM 16 Element OP	1
848	COUNTER 1 Element OP	1
849	COUNTER 2 Element OP	1
850	COUNTER 3 Element OP	1
851	COUNTER 4 Element OP	1
852	COUNTER 5 Element OP	1
853	COUNTER 6 Element OP	1
854	COUNTER 7 Element OP	1
855	COUNTER 8 Element OP	1
864	LED State 1 (IN SERVICE)	1
865	LED State 2 (TROUBLE)	1
866	LED State 3 (TEST MODE)	1
867	LED State 4 (TRIP)	1
868	LED State 5 (ALARM)	1
869	LED State 6(PICKUP)	1
880	LED State 9 (VOLTAGE)	1
881	LED State 10 (CURRENT)	1
882	LED State 11 (FREQUENCY)	1
883	LED State 12 (OTHER)	1
884	LED State 13 (PHASE A)	1

Table E–3: BINARY INPUTS (Sheet 10 of 10)

POINT INDEX	NAME/DESCRIPTION	CHANGE EVENT CLASS (1/2/3/NONE)
885	LED State 14 (PHASE B)	1
886	LED State 15 (PHASE C)	1
887	LED State 16 (NTL/GROUND)	1
899	BATTERY FAIL	1
900	PRI ETHERNET FAIL	1
901	SEC ETHERNET FAIL	1
902	EPROM DATA ERROR	1
903	SRAM DATA ERROR	1
904	PROGRAM MEMORY	1
905	WATCHDOG ERROR	1
906	LOW ON MEMORY	1
907	REMOTE DEVICE OFF	1
910	Any Major Error	1
911	Any Minor Error	1
912	Any Self-Tests	1
913	IRIG-B FAILURE	1
914	DSP ERROR	1
915	Not Used	
916	NO DSP INTERUPTS	1
917	UNIT NOT CALIBRATED	1
921	PROTOTYPE FIRMWARE	1
922	FLEXLOGIC ERR TOKEN	1
923	EQUIPMENT MISMATCH	1
925	UNIT NOT PROGRAMMED	1
926	SYSTEM EXCEPTION	1

E.3.2 BINARY OUTPUT AND CONTROL RELAY OUTPUT

Supported Control Relay Output Block fields: Pulse On, Pulse Off, Latch On, Latch Off, Paired Trip, Paired Close.

BINARY OUTPUT STATUS POINTS
Object Number: **10**
Request Function Codes supported: **1 (read)**
Default Variation reported when variation 0 requested: **2 (Binary Output Status)**
CONTROL RELAY OUTPUT BLOCKS
Object Number: **12**
Request Function Codes supported: **3 (select), 4 (operate), 5 (direct operate),6 (direct operate, noack)**

Table E–4: BINARY/CONTROL OUTPUT POINT LIST

POINT INDEX	NAME/DESCRIPTION
0	Virtual Input 1
1	Virtual Input 2
2	Virtual Input 3
3	Virtual Input 4
4	Virtual Input 5
5	Virtual Input 6
6	Virtual Input 7
7	Virtual Input 8
8	Virtual Input 9
9	Virtual Input 10
10	Virtual Input 11
11	Virtual Input 12
12	Virtual Input 13
13	Virtual Input 14
14	Virtual Input 15
15	Virtual Input 16
16	Virtual Input 17
17	Virtual Input 18
18	Virtual Input 19
19	Virtual Input 20
20	Virtual Input 21
21	Virtual Input 22
22	Virtual Input 23
23	Virtual Input 24
24	Virtual Input 25
25	Virtual Input 26
26	Virtual Input 27
27	Virtual Input 28
28	Virtual Input 29
29	Virtual Input 30
30	Virtual Input 31
31	Virtual Input 32

E.3.3 COUNTERS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

BINARY COUNTERS

Static (Steady-State) Object Number: **20**

Change Event Object Number: **22**

Request Function Codes supported: **1 (read), 7 (freeze), 8 (freeze noack), 9 (freeze and clear), 10 (freeze and clear, noack), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Binary Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Counter Change Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

FROZEN COUNTERS

Static (Steady-State) Object Number: **21**

Change Event Object Number: **23**

Request Function Codes supported: **1 (read)**

Static Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

Table E–5: BINARY and FROZEN COUNTERS

POINT INDEX	NAME/DESCRIPTION
0	Digital Counter 1
1	Digital Counter 2
2	Digital Counter 3
3	Digital Counter 4
4	Digital Counter 5
5	Digital Counter 6
6	Digital Counter 7
7	Digital Counter 8
8	Oscillography Trigger Count
9	Events Since Last Clear

Note that a counter freeze command has no meaning for counters 8 and 9.

E.3.4 ANALOG INPUTS

The following table lists Analog Inputs (Object 30). It is important to note that 16-bit and 32-bit variations of Analog Inputs are transmitted through DNP as signed numbers. Even for analog input points that are not valid as negative values, the maximum positive representation is 32767. This is a DNP requirement.

The deadbands for all Analog Input points are in the same units as the Analog Input quantity. For example, an Analog Input quantity measured in volts has a corresponding deadband in units of volts. This is in conformance with DNP Technical Bulletin 9809-001 Analog Input Reporting Deadband. Relay settings are available to set default deadband values according to data type. Deadbands for individual Analog Input Points can be set using DNP Object 34.

When using the UR in DNP systems with limited memory, the ANALOG INPUT POINTS LIST below may be replaced with a user-definable list. This user-definable list uses the same settings as the Modbus User Map and can be configured with the MODBUS USER MAP settings. When used with DNP, each entry in the Modbus User Map represents the starting Modbus address of a data item available as a DNP Analog Input point. To enable use of the Modbus User Map for DNP Analog Input points, set the **USER MAP FOR DNP ANALOGS** setting to Enabled (this setting is in the **PRODUCT SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP PROTOCOL** menu). The new DNP Analog points list can be checked via the "DNP Analog Input Points List" webpage, accessible from the "Device Information menu" webpage.

NOTE: After changing the **USER MAP FOR DNP ANALOGS** setting, the relay must be powered off and then back on for the setting to take effect.

Only Source 1 data points are shown in the following table. If the **NUMBER OF SOURCES IN ANALOG LIST** setting is increased, data points for subsequent sources will be added to the list immediately following the Source 1 data points.

Units for Analog Input points are as follows:

- Current: A
- Voltage: V
- Real Power: W
- Reactive Power: var
- Apparent Power: VA
- Energy Wh, varh
- Frequency: Hz
- Angle: degrees
- Ohm Input: Ohms
- RTD Input: degrees C

Static (Steady-State) Object Number: **30**

Change Event Object Number: **32**

Request Function Codes supported: **1 (read), 2 (write, deadbands only), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Analog Input)**

Change Event Variation reported when variation 0 requested: **1 (Analog Change Event w/o Time)**

Change Event Scan Rate: defaults to **500 ms.**

Change Event Buffer Size: **800**

Default Class for all Points: **1**

Table E–6: ANALOG INPUT POINTS (Sheet 1 of 4)

POINT	DESCRIPTION
0	SRC 1 Phase A Current RMS
1	SRC 1 Phase B Current RMS
2	SRC 1 Phase C Current RMS
3	SRC 1 Neutral Current RMS
4	SRC 1 Phase A Current Magnitude

Table E–6: ANALOG INPUT POINTS (Sheet 2 of 4)

POINT	DESCRIPTION
5	SRC 1 Phase A Current Angle
6	SRC 1 Phase B Current Magnitude
7	SRC 1 Phase B Current Angle
8	SRC 1 Phase C Current Magnitude
9	SRC 1 Phase C Current Angle

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Table E–6: ANALOG INPUT POINTS (Sheet 3 of 4)

POINT	DESCRIPTION
10	SRC 1 Neutral Current Magnitude
11	SRC 1 Neutral Current Angle
12	SRC 1 Ground Current RMS
13	SRC 1 Ground Current Magnitude
14	SRC 1 Ground Current Angle
15	SRC 1 Zero Sequence Current Magnitude
16	SRC 1 Zero Sequence Current Angle
17	SRC 1 Positive Sequence Current Magnitude
18	SRC 1 Positive Sequence Current Angle
19	SRC 1 Negative Sequence Current Magnitude
20	SRC 1 Negative Sequence Current Angle
21	SRC 1 Differential Ground Current Magnitude
22	SRC 1 Differential Ground Current Angle
23	SRC 1 Phase AG Voltage RMS
24	SRC 1 Phase BG Voltage RMS
25	SRC 1 Phase CG Voltage RMS
26	SRC 1 Phase AG Voltage Magnitude
27	SRC 1 Phase AG Voltage Angle
28	SRC 1 Phase BG Voltage Magnitude
29	SRC 1 Phase BG Voltage Angle
30	SRC 1 Phase CG Voltage Magnitude
31	SRC 1 Phase CG Voltage Angle
32	SRC 1 Phase AB Voltage RMS
33	SRC 1 Phase BC Voltage RMS
34	SRC 1 Phase CA Voltage RMS
35	SRC 1 Phase AB Voltage Magnitude
36	SRC 1 Phase AB Voltage Angle
37	SRC 1 Phase BC Voltage Magnitude
38	SRC 1 Phase BC Voltage Angle
39	SRC 1 Phase CA Voltage Magnitude
40	SRC 1 Phase CA Voltage Angle
41	SRC 1 Auxiliary Voltage RMS
42	SRC 1 Auxiliary Voltage Magnitude
43	SRC 1 Auxiliary Voltage Angle
44	SRC 1 Zero Sequence Voltage Magnitude
45	SRC 1 Zero Sequence Voltage Angle
46	SRC 1 Positive Sequence Voltage Magnitude
47	SRC 1 Positive Sequence Voltage Angle
48	SRC 1 Negative Sequence Voltage Magnitude
49	SRC 1 Negative Sequence Voltage Angle
50	SRC 1 Three Phase Real Power
51	SRC 1 Phase A Real Power
52	SRC 1 Phase B Real Power
53	SRC 1 Phase C Real Power
54	SRC 1 Three Phase Reactive Power
55	SRC 1 Phase A Reactive Power
56	SRC 1 Phase B Reactive Power

Table E–6: ANALOG INPUT POINTS (Sheet 4 of 4)

POINT	DESCRIPTION
57	SRC 1 Phase C Reactive Power
58	SRC 1 Three Phase Apparent Power
59	SRC 1 Phase A Apparent Power
60	SRC 1 Phase B Apparent Power
61	SRC 1 Phase C Apparent Power
62	SRC 1 Three Phase Power Factor
63	SRC 1 Phase A Power Factor
64	SRC 1 Phase B Power Factor
65	SRC 1 Phase C Power Factor
66	SRC 1 Frequency
67	Breaker 1 Arcing Amp Phase A
68	Breaker 1 Arcing Amp Phase B
69	Breaker 1 Arcing Amp Phase C
70	Breaker 2 Arcing Amp Phase A
71	Breaker 2 Arcing Amp Phase B
72	Breaker 2 Arcing Amp Phase C
73	Synchrocheck 1 Delta Voltage
74	Synchrocheck 1 Delta Frequency
75	Synchrocheck 1 Delta Phase
76	Synchrocheck 2 Delta Voltage
77	Synchrocheck 2 Delta Frequency
78	Synchrocheck 2 Delta Phase
79	Tracking Frequency
80	FlexElement 1 Actual
81	FlexElement 2 Actual
82	FlexElement 3 Actual
83	FlexElement 4 Actual
84	FlexElement 5 Actual
85	FlexElement 6 Actual
86	FlexElement 7 Actual
87	FlexElement 8 Actual
88	FlexElement 9 Actual
89	FlexElement 10 Actual
90	FlexElement 11 Actual
91	FlexElement 12 Actual
92	FlexElement 13 Actual
93	FlexElement 14 Actual
94	FlexElement 15 Actual
95	FlexElement 16 Actual
96	Current Setting Group

F.1.1 REVISION HISTORY

Table F–1: REVISION HISTORY

MANUAL P/N	D60 REVISION	RELEASE DATE	ECO
1601-0089-0.1	1.5X (BETA)	23 August 1999	N/A
1601-0089-A1	2.0X	17 December 1999	N/A
1601-0089-A2	2.0X	14 January 2000	URD-001
1601-0089-A3	2.2X	12 May 2000	URD-002
1601-0089-A4	2.2X	14 June 2000	URD-003
1601-0089-A4a	2.2X	28 June 2000	URD-003a
1601-0089-B1	2.4X	08 September 2000	URD-004
1601-0089-B2	2.4X	03 November 2000	URD-005
1601-0089-B3	2.6X	08 March 2001	URD-006
1601-0089-B4	2.8X	27 September 2001	URD-007
1601-0089-B5	2.9X	03 December 2001	URD-008
1601-0089-B6	2.9X	07 January 2002	URD-009
1601-0089-B7	2.9X	15 March 2002	URD-010

F.1.2 CHANGES TO D60 MANUAL

Table F–2: MAJOR UPDATES FOR D60 MANUAL REVISION B7

PAGES (B5)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B6 to B7
5-119	Add	Added BKR ΦA, ΦB, and ΦC OPEN settings and description to TRIP OUTPUT section
10-28	Update	Updated CONTROL ELEMENTS table to reflect changes to TRIP OUTPUT settings

Table F–3: MAJOR UPDATES FOR D60 MANUAL REVISION B6

PAGES (B5)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B5 to B6
2-2	Update	Updated DEVICE NUMBERS AND FUNCTIONS table to include Negative Sequence Overvoltage
2-8	Add	Added specifications for NEGATIVE SEQUENCE OVERVOLTAGE
5-36	Add	Added FlexLogic™ operands for Negative Sequence Overvoltage
5-112	Update	Updated VOLTAGE ELEMENTS section
5-115	Add	Added NEGATIVE SEQUENCE VOLTAGE section

Table F–4: MAJOR UPDATES FOR D60 MANUAL REVISION B5

PAGES (B4)	CHANGE	DESCRIPTION
Title	Update	Manual part number from B4 to B5
2-1	Update	Updated SINGLE LINE DIAGRAM to 837709AE
2-2	Update	Updated OTHER DEVICE FUNCTIONS table to include IEC 60870-5-104 communications
2-8	Update	Updated AUTORECLOSURE specifications
5-24	Update	Updated description for POWER SYSTEM settings
5-34	Update	Updated FLEXLOGIC™ OPERANDS table to reflect new 2.9X operands
5-53	Update	Updated FLEXLOGIC™ EQUATION EDITOR section
5-54	Update	Updated PHASE DISTANCE section to reflect updates to settings and scheme logic
5-61	Update	Updated GROUND DISTANCE section to reflect updates to settings and scheme logic
5-103	Update	Updated BREAKER FAILURE section to reflect Auxiliary UV/OV and Neutral OV elements
5-123	Update	Updated AUTORECLOSE section to reflect updates to settings and scheme logic
5-138	Update	Updated PILOT SCHEMES section to reflect updates to settings and scheme logic
8-14	Add	Added SINGLE POLE TRIPPING theory of operation section
10-	Update	Chapter 10: COMMISSIONING updated to reflect settings changes for revision 2.9X firmware
B-11	Update	MODBUS MEMORY MAP updated for version 2.9X firmware
D-1	Add	Added IEC 60870-5-104 INTEROPERABILITY DOCUMENT section
E-1	Update	Updated DNP 3.0 DEVICE PROFILE DOCUMENT table
E-4	Update	Updated DNP 3.0 IMPLEMENTATION table

F.2.1 LIST OF FIGURES

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F.2.2 LIST OF TABLES

F.3.1 STANDARD ABBREVIATIONS

A.................... ampere
AC .... alternating current
A/D .... analog to digital
AE .... accidental energization
AE .... application entity
AMP .... ampere
ANSI............... American National Standards Institute
AR .... automatic reclosure
AUTO .... automatic
AUX................ auxiliary
AVG................ average

BER................ bit error rate
BF................... breaker fail
BFI.................. breaker failure initiate
BKR................ breaker
BLK .... block
BLKG.............. blocking
BPNT.............. breakpoint of a characteristic

CAP................ capacitor
CC .... coupling capacitor
CCVT .... coupling capacitor voltage transformer
CFG................ configure / configurable
.CFG............... file name extension for oscillography files
CHK................ check
CHNL .... channel
CLS .... close
CLSD.............. closed
CMND .... command
CMPRSN........ comparison
CO.................. contact output
COM............... communication
COMM............ communications
COMP .... compensated
CONN............. connection
CO-ORD......... coordination
CPU................ central processing unit
CRT, CRNT .... current
CT .... current transformer
CVT .... capacitive voltage transformer

D/A .... digital to analog
DC (dc)........... direct current
DD .... disturbance detector
DFLT .... default
DGNST........... diagnostics
DI.................... digital input
DIFF .... differential
DIR .... directional
DISCREP .... discrepancy
DIST .... distance
DMD .... demand
DPO .... dropout
DSP................ digital signal processor
DTT .... direct transfer trip
DUTT.............. direct under-reaching transfer trip

EPRI............... Electric Power Research Institute
.EVT .... file name extension for event recorder files
EXT .... extension

F..................... field
FAIL................ failure
FD .... fault detector
FDH................ fault detector high-set
FDL .... fault detector low-set
FLA................. full load current
FO .... fiber optic
FREQ .... frequency
FSK .... frequency-shift keying
FWD............... forward

G .... generator
GE.................. General Electric
GND .... ground
GNTR............. generator
GOOSE...........general object oriented substation event

HARM ....harmonic / harmonics
HGF ....high-impedance ground fault (CT)
HIZ ....high-impedance & arcing ground
HMI ....human-machine interface
HYB ....hybrid

I.......................instantaneous
I_0...................zero sequence current
I_1...................positive sequence current
I_2...................negative sequence current
IA ....phase A current
IAB ....phase A minus B current
IB ....phase B current
IBC..................phase B minus C current
IC ....phase C current
ICA..................phase C minus A current
ID ....identification
IEEE................Institute of Electrical & Electronic Engineers
IG ....ground (not residual) current
Igd...................differential ground current
IN ....CT residual current (3Io) or input
INC SEQ ....incomplete sequence
INIT ....initiate
INST................instantaneous
INV..................inverse
I/O ....input/output
IOC ....instantaneous overcurrent
IOV..................instantaneous overvoltage
IRIG ....inter-range instrumentation group
IUV..................instantaneous undervoltage

K0 ....zero sequence current compensation
kA....................kiloAmpere
kV....................kiloVolt

LED.................light emitting diode
LEO.................line end open
LOOP..............loopback
LPU.................line pickup
LRA.................locked-rotor current
LTC ....load tap-changer

M.....................machine
mA ....milliAmpere
MAN................manual / manually
MMI.................man machine interface
MMS ....Manufacturing Message Specification
MSG................message
MTA ....maximum torque angle
MTR ....motor
MVA ....MegaVolt-Ampere (total 3-phase)
MVA_A............MegaVolt-Ampere (phase A)
MVA_B............MegaVolt-Ampere (phase B)
MVA_C............MegaVolt-Ampere (phase C)
MVAR..............MegaVar (total 3-phase)
MVAR_A ....MegaVar (phase A)
MVAR_B ....MegaVar (phase B)
MVAR_C ....MegaVar (phase C)
MVARH ....MegaVar-Hour
MW ....MegaWatt (total 3-phase)
MW_A ....MegaWatt (phase A)
MW_B ....MegaWatt (phase B)
MW_C ....MegaWatt (phase C)
MWH...............MegaWatt-Hour

N ....neutral
N/A, n/a...........not applicable
NEG ....negative
NMPLT............nameplate
NOM ....nominal
NTR ....neutral

O.....................over
OC, O/C ....overcurrent
O/P, Op ....output
OP...................operate

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OPER .... operate
OPERATG...... operating
O/S .... operating system
OSB................ out-of-step blocking
OUT................ output
OV .... overvoltage
OVERFREQ ... overfrequency
OVLD .... overload

P..................... phase
PC .... phase comparison, personal computer
PCNT .... percent
PF................... power factor (total 3-phase)
PF_A .... power factor (phase A)
PF_B .... power factor (phase B)
PF_C .... power factor (phase C)
PHS................ phase
PKP .... pickup
PLC .... power line carrier
POS................ positive
POTT.............. permissive over-reaching transfer trip
PRESS .... pressure
PROT .... protection
PSEL .... presentation selector
pu .... per unit
PUIB............... pickup current block
PUIT .... pickup current trip
PUTT .... permissive under-reaching transfer trip
PWM .... pulse width modulated
PWR............... power

R..................... rate, reverse
REM .... remote
REV................ reverse
RI.................... reclose initiate
RIP .... reclose in progress
ROD .... remote open detector
RST .... reset
RSTR .... restrained
RTD................ resistance temperature detector
RTU................ remote terminal unit
RX (Rx) .... receive, receiver

s .... second
S..................... sensitive
SAT .... CT saturation
SBO................ select before operate
SEL .... select / selector / selection
SENS .... sensitive
SEQ................ sequence
SIR .... source impedance ratio
SRC................ source
SSB .... single side band
SSEL .... session selector
STATS .... statistics
SUPN .... supervision
SUPV .... supervise / supervision
SV .... supervision
SYNCHCHK... synchrocheck

T..................... time, transformer
TC .... thermal capacity
TD MULT........ time dial multiplier
TEMP............. temperature
THD .... total harmonic distortion
TOC .... time overcurrent
TOV................ time overvoltage
TRANS........... transient
TRANSF .... transfer
TSEL.............. transport selector
TUC .... time undercurrent
TUV................ time undervoltage
TX (Tx)........... transmit, transmitter

U .... under
UC.................. undercurrent
UCA .... Utility Communications Architecture
UNBAL .... unbalance
UR.................. universal relay
.URS .... file name extension for settings files
UV.................. undervoltage

V/Hz .... Volts per Hertz
V_0 .... zero sequence voltage
V_1 .... positive sequence voltage
V_2 .... negative sequence voltage
VA .... phase A voltage
VAB .... phase A to B voltage
VAG................ phase A to ground voltage
VARH .... var-hour voltage
VB .... phase B voltage
VBA................ phase B to A voltage
VBG .... phase B to ground voltage
VC.................. phase C voltage
VCA .... phase C to A voltage
VCG .... phase C to ground voltage
VF .... variable frequency
VIBR .... vibration
VT .... voltage transformer
VTFF.............. voltage transformer fuse failure
VTLOS .... voltage transformer loss of signal

WDG .... winding
WH................. Watt-hour
w/ opt .... with option
WRT............... with respect to

X .... reactance
XDUCER........ transducer
XFMR............. transformer

Z..................... impedance

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F.4.1 GE POWER MANAGEMENT WARRANTY

GE POWER MANAGEMENT RELAY WARRANTY

General Electric Power Management Inc. (GE Power Management) warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Power Management will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Power Management authorized factory outlet.

GE Power Management is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to GE Power Management Standard Conditions of Sale.

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