7SR224 Recloser Controller

Overcurrent Relay

Document Release History

This document is issue **2010/09**. The list of revisions up to and including this issue is:

2008/03	First issue
2008/06	Second issue
2009/04	Third issue
2009/09	Fourth issue
2010/04	Fifth issue
2010/05	Sixth Issue. Document formatted due to rebrand
2010/09	Seventh issue. Addition of IEC60870-5-101 communication protocol.

Software Revision History

2008/03	2435H80011R2d-1a	First Release
2008/06	2435H80011R3d-2b	Second Release. Loss Of Voltage
2008/10	2435H80011R4-3	Third Release. Single/Triple Autoreclose function
2009/09	2435H80011R4c-3b	Fourth Release. Maintenance Release
2010/04	2435H80011R4d-4	Fifth Release. Check Synchronising function
2010/09	2435H80011R4f-4b	IEC60870-5-101 communication protocol

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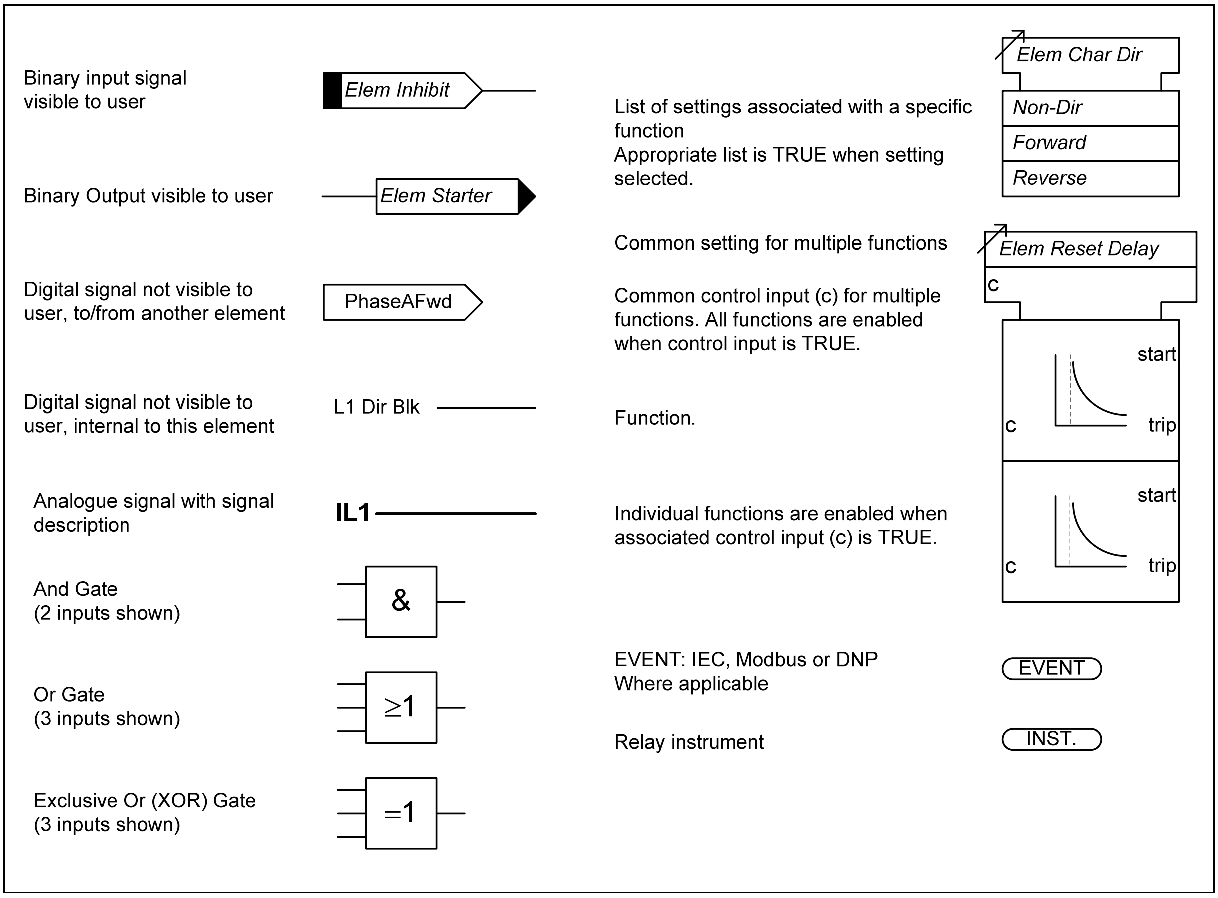
Symbols and Nomenclature

The following notational and formatting conventions are used within the remainder of this document:

1. Setting Menu Location MAIN MENU>SUB-MENU
2. **Setting:** *Elem name -Setting*
3. Setting value: value
4. **Alternatives:** [1st] [2nd] [3rd]



Section 1: Introduction

This manual is applicable to the following relays:

7SR224 Directional Overcurrent and Directional Earth Fault Recloser Control Relay

The 7SR224 relay integrates the protection and control elements required to provide a complete recloser control relay.

The 'Ordering Options' Tables summarise the features available in each model

General Safety Precautions

1.1 Current Transformer Circuits

The secondary circuit of a live CT must not be open circuited. Non-observance of this precaution can result in injury to personnel or damage to equipment.

1.2 External Resistors

Where external resistors are fitted to relays, these may present a danger of electric shock or burns, if touched.

1.3 Fibre Optic Communication

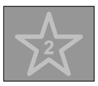
Where fibre optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

1.4 Front Cover

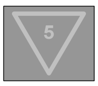
The front cover provides additional securing of the relay element within the case. The relay cover should be in place during normal operating conditions.

1.5 Front Fascia

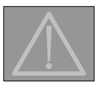
For safety reasons the following symbols are displayed on the fascia

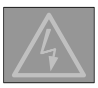


Dielectric Test Voltage 2kV



Impulse Test Above 5kV


Caution: Refer to Equipment Documentation


Caution: Risk of Electric Shock

Reyrolle
RECLOSER CONTROLLER (Directional Overcurrent)

	1	2	3	4	5	6	7		8	9	10	11	12		13	14	15	16
ORDER-No.:	N	A	A	N	N	N	N	-	N	A	A	N	N	-	N	A	A	N
ORDER-No.:	7	S	R	2	2	4		-	2					-	0			

Protection Product Family (5)

Overcurrent - Directional	2	

Relay Type (6)

Recloser	4	

Case, I/O and Fascia [1] (7)

		14	15
E10 case, 4 CT, 6 VT, 13 Binary Inputs / 14 Binary Outputs, 8 LEDs + 12 keys	1	D	A
E10 case, 4 CT, 4 VT, 13 Binary Inputs / 14 Binary Outputs, 8 LEDs + 12 keys	2	C	
E10 case, 4 CT, 4 VT, 23 Binary Inputs / 22 Binary Outputs, 8 LEDs + 12 keys	3	C	
E10 case, 4 CT, 4 VT, 33 Binary Inputs / 14 Binary Outputs, 8 LEDs + 12 keys	4	C	
E10 case, 4 CT, 6 VT, 23 Binary Inputs / 22 Binary Outputs, 8 LEDs + 12 keys	5	D	A
E12 case, 4 CT, 4 VT, 33 Binary Inputs / 14 Binary Outputs, 16 LEDs + 12 keys	6	C E	 A
E12 case, 4 CT, 4 VT, 33 Binary Inputs / 30 Binary Outputs, 16 LEDs + 12 keys	7	C E	 A
E12 case, 4 CT, 4 VT, 43 Binary Inputs / 22 Binary Outputs, 16 LEDs + 12 keys	8	C E	 A

Measuring Input (8)

1/5 A, 63.5/110V	2

Auxiliary Nominal Voltage (9)

30 to 220V DC, binary input threshold 19V DC 22W	A
30 to 220V DC, binary input threshold 88V DC 22W	B

Region Specific Functions (10)

Region World, 50/60Hz, language English, Reyrolle fascia	A
Region World, 50/60Hz, language English, Siemens fascia	B
Region USA, 60/50Hz, language English - US (ANSI) (language changeable), Siemens fascia	C

Communication Interface (11)

		12
Standard version - included in all models, USB front port, RS485 rear port	1	0-3
Standard version - plus additional rear F/O ST connectors (x2) and IRIG-B	2	0-3
Standard version - plus additional rear RS485 and IRIG-B	3	0-3
Standard version - plus additional rear RS232 and IRIG-B	4	0-3

Protocol (12)

	11	
IEC 60870-5-103	1-4	0
IEC 60870-5-103 and Modbus RTU (user selectable setting)	1-4	1
IEC 60870-5-103 and Modbus RTU and DNP 3.0 (user selectable setting)	1-4	2
IEC 60870-5-103 and IEC60870-5-101 and Modbus RTU (user selectable setting)	1-4	3

Spare (13)

	0

Protection Function Packages (14)

		7		15
Standard version - included in all models		2-4,6-8	C	
27/59	Under/overvoltage			
27/59	Under/overvoltage, Sag/swell			
37	Undercurrent			
46BC	Broken conductor/load unbalance			
46NPS	Negative phase sequence overcurrent			
47NPS	Negative phase sequence overvoltage			
49	Thermal overload			
50BF	Circuit breaker fail			
51V	Voltage dependent overcurrent			
59N	Neutral voltage displacement			
60CTS	CT supervision			
60VTS	VT supervision			
67/50	Directional instantaneous phase fault overcurrent			
67/50G	Directional instantaneous earth fault			
67/51	Directional time delayed phase fault overcurrent			
67/51G	Directional time delayed earth fault			
67/50HIZ	Directional instantaneous sensitive earth fault			
67/51HIZ	Directional time delayed sensitive earth fault			
74TC	Trip circuit supervision			
74BF	Circuit breaker close fail			
79	Autoreclose			
81	Under/overfrequency			
81HBL2	Inrush restraint			
86	Lockout			
	Battery and capacitor test			
	Cold load pickup			
	Programmable logic			
Standard version - plus		1,5	D	A
27/59	Under/overvoltage			
60VTS	VT supervision			
	Loop automation by loss of voltage			
Standard version - plus		6-8	E	A
	Single/triple pole autoreclose			

Additional Functionality (15)

	Description	7	14	Code
No additional functionality				A
25	Synchronising, synchronising check	2-4,6-8	C	D

Settings File (16)

Standard settings and standard labels for Siemens Recloser	0

[1] 4CT is configured as 3PF + EF/SEF (user selectable setting).
NB: For updates to the MLFB structure see drawing C53207-A422-X1-1D-7695

Table 1-1 7SR224 Ordering Options

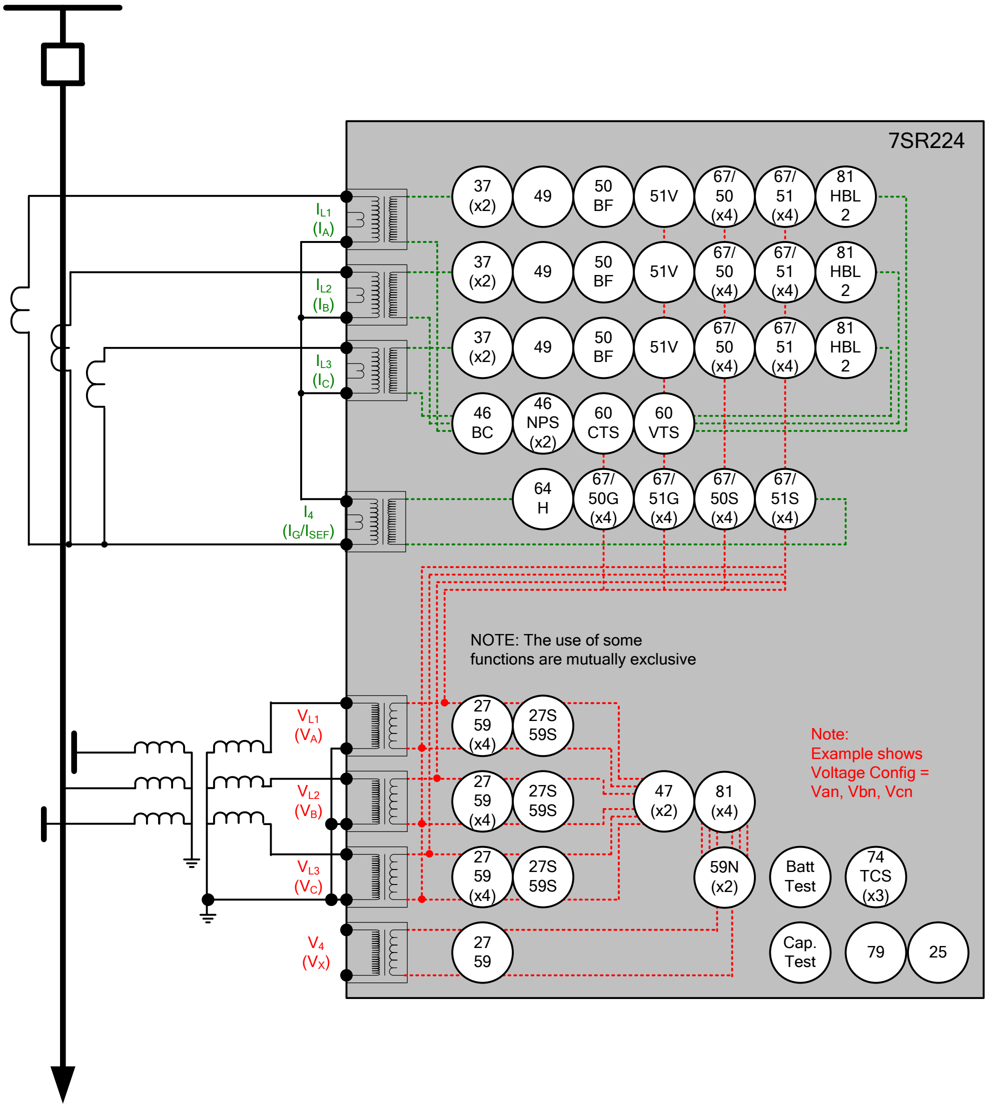


Figure 1.5-1 Functional Diagram of 7SR224 Relay Showing Possible External Connections

Section 2: Hardware Description

2.1 General

The structure of the relay is based upon the Multi-function hardware platform. The relays are supplied in a size E10 or E12 case (where 1 x E = width of approx. 26mm). The hardware design provides commonality between products and components across the Multi-function range of relays.

Relay	Current Inputs	Voltage Inputs	Binary Inputs	Output Relays	LEDs	Function Keys	Case
7SR2241	4	6	13	14	8	12	E10
7SR2242	4	4	13	14	8	12	E10
7SR2243	4	4	23	22	8	12	E10
7SR2244	4	4	33	14	8	12	E10
7SR2245	4	6	23	22	8	12	E10
7SR2246	4	4	33	14	16	12	E12
7SR2247	4	4	33	30	16	12	E12
7SR2248	4	4	43	22	16	12	E12

Table 2-1 Summary of Controller Relay Configurations

Relays are assembled from the following modules:

1) Front Fascia with three fixed function LEDs, Function Keys and ordering options of configurable LEDs.

2) Processor module.

3) Analogue Input module - 4 x Current + 4 or 6 x Voltage.

4) Power Supply (PSU) and Basic Binary Input (BI) and Binary Output (BO).

5) Binary Input/Output Module.

6) Data Comms module (optional)

2.2 Case

The relays are housed in cases designed to fit directly into standard panel racks. The case has a width of 260mm (E10), 312mm (E12) and a height of 177 mm (4U). The required panel depth for wiring clearance is 242 mm and 287mm to accommodate the bending radius of fibre optic data communications cables if fitted.

The complete relay assembly is withdrawable from the front of the case. Shorting contacts on the rear connection block in the case ensure that the CT circuits remain short-circuited when the relay is removed.

External connections to the rear terminal block are made via M4 screws. Each terminal can accept two 4mm crimps.

Located at the top rear of the case is a screw clamp earthing point, this must be connected to the main panel earth.

2.3 Front Cover

With the transparent front cover in place the user only has access to the READ DOWN ▼ and **TEST/RESET►** buttons, via blue push buttons, allowing all areas of the menu system to be viewed, but preventing setting changes and control actions. The only ‘action’ that is permitted is to reset the Fault Data display, latched binary outputs and LEDs by using the **TEST/RESET** ► button. The front cover is used to secure the relay assembly in the case.

2.4 Power Supply Unit (PSU)

The relay PSU can be directly connected to any dc supply via a suitably rated fuse from 30V dc to 220V dc.

In the event of the supply voltage level falling below the relay minimum operate level the PSU will automatically switch itself off and latch out – this prevents any PSU overload conditions occurring. The PSU is reset by switching the auxiliary supply off and on.

2.5 Operator Interface/ Fascia

The operator interface is designed to provide a user-friendly method of controlling, entering settings and retrieving data from the relay.

Figure 2.5-1 7SR224 with 12 Function Keys and 3 + 8 LEDs in E10 Case

NOTE: Transparent cover with pushbuttons not shown

The fascia is an integral part of the relay. Handles are located at each side of the relay which allow it to be withdrawn from the relay case.

Relay Information

Above the LCD three labels are provided, these provide the following information:

1) Product name and order code.

2) Nominal current rating, rated frequency, voltage rating, auxiliary dc supply rating, binary input supply rating, configuration and serial number.

3) Blank label for user defined information.

A ‘template’ is available to allow users to create and print customised labels.

Liquid Crystal Display (LCD)

A 4 line by 20-character liquid crystal display indicates settings, instrumentation, fault data and control commands.

To conserve power the display backlighting is extinguished when no buttons are pressed for a user defined period. A setting within the “SYSTEM CONFIG” menu allows the timeout to be adjusted from 1 to 60 minutes and “Off” (backlight permanently on). After an hour the display is completely de-activated. Pressing any key will re-activate the display.

The LCD contrast can be adjusted using a flat blade screwdriver to turn the screw located below the contrast symbol ◑. Turning the screw clockwise increases the contrast, anti-clockwise reduces the contrast.

‘PROTECTION HEALTHY’ LED

This green LED is steadily illuminated to indicate that DC voltage has been applied to the relay power supply and that the relay is operating correctly. If the internal relay watchdog detects an internal fault then this LED will continuously flash.

‘PICKUP’ LED

This yellow LED is illuminated to indicate that a user selectable function(s) has picked up. The LED will self reset after the initiating condition has been removed.

Functions are assigned to the PICKUP LED in the OUTPUT CONFIG>PICKUP CONFIG menu.

‘TRIP’ LED

This red LED is steadily illuminated to indicate that a user selectable function has operated to trip the circuit breaker. Functions are assigned to the ‘Trip’ LED using the OUTPUT CONFIG>Trip Contacts setting.

Operation of the LED is latched and can be reset by either pressing the TEST/RESET► button, energising a suitably programmed binary input, or, by sending an appropriate command over the data communications channel(s).

Indication LEDs

Relays have either 8 or 16 user programmable LED indicators. Each LED can be programmed to be illuminated as either green, yellow or red. Where an LED is programmed to be lit both red and green it will illuminate yellow.

Functions are assigned to the LEDs in the OUTPUT CONFIG>OUTPUT MATRIX menu.

Each LED can be labelled by withdrawing the relay and inserting a label strip into the pocket behind the front fascia. A ‘template’ is available to allow users to create and print customised legends.

Each LED can be user programmed as hand or self –resetting. Hand reset LEDs can be reset by either pressing the TEST/RESET► button, energising a suitably programmed binary input, or, by sending an appropriate command over the data communications channel(s).

The status of hand reset LEDs is maintained by a back up storage capacitor in the event of an interruption to the d.c. supply voltage.

Standard Keys

The relay is supplied as standard with five navigation / control pushbuttons and 12 programmable function keys. The navigation / control buttons are used to navigate the menu structure and control relay functions. They are labelled:

▲	Increases a setting or moves up menu.
▼	Decreases a setting or moves down menu.
TEST/RESET►	Moves right, can be used to reset selected functionality and for LED test (at relay identifier screen).
ENTER	Used to initiate and accept settings changes.
CANCEL.	Used to cancel settings changes and/or move up the menu structure by one level per press.

NOTE: All settings and configuration of LEDs, BI, BO and function keys can be accessed and set by the user using these keys. Alternatively configuration/settings files can be loaded into the relay using ‘Reydisp’.

Function Keys/ LEDs

The 12 programmable function keys can be configured by the user to initiate selected functions from the Control menu (INPUT CONFIG > FUNCTION KEY MATRIX).

Each programmable function key has an associated LED. These can be programmed as hand or self reset and can be illuminated as green, yellow or red (OUTPUT CONFIG > LED CONFIG).

Function keys can be used with Quick Logic.

2.6 Current Inputs

Four current inputs are provided on the Analogue Input module. Terminals are available for both 1A and 5A inputs.

Current is sampled at 1600Hz for both 50Hz and 60Hz system frequencies. Protection and monitoring functions of the relay use either the Fundamental Frequency RMS or the True RMS value of current appropriate to the individual function.

The waveform recorder samples and displays current input waveforms at 32 samples per cycle (1600Hz).

2.7 Voltage Inputs

Four voltage inputs are provided on the Analogue Input module.

Voltage is sampled at 32 samples per cycle (1600Hz) both 50Hz and 60Hz system frequencies. Protection and monitoring functions of the relay use fundamental frequency voltage measurement.

The waveform recorder samples and displays voltage input waveforms at 32 samples per cycle (1600Hz).

NB: The Relay has a flat frequency response measuring harmonic currents up to and including the 50th Harmonic but does not measure the content at the aliasing frequencies i.e. 800 Hz (16^{th} harmonic) + 1600 Hz (32^{nd} harmonic) + 2400 Hz (48^{th} harmonic).

2.8 Binary Inputs

The binary inputs are operated from a suitably rated dc supply.

Relays are fitted with 13, 33 or 43 binary inputs (BI) depending on the variant. The user can assign any binary input to any of the available functions (INPUT CONFIG > INPUT MATRIX).

The Power Supply module includes the relay basic I/O incorporating 3 x BI and 6 x BO.

Pick-up (PU) and drop-off (DO) time delays are associated with each binary input. Where no pick-up time delay has been applied the input may pick up due to induced ac voltage on the wiring connections (e.g. cross site wiring). The default pick-up time of 20ms provides ac immunity. Each input can be programmed independently.

Each input may be logically inverted to facilitate integration of the relay within the user scheme. When inverted the relay indicates that the BI is energised when no d.c. is applied. Inversion occurs before the PU & DO time delay, see fig. 2.8-1.

Each input may be mapped to any front Fascia indication LED and/or to any Binary output contact and can also be used with the internal user programmable logic. This allows the relay to provide panel indications and alarms.

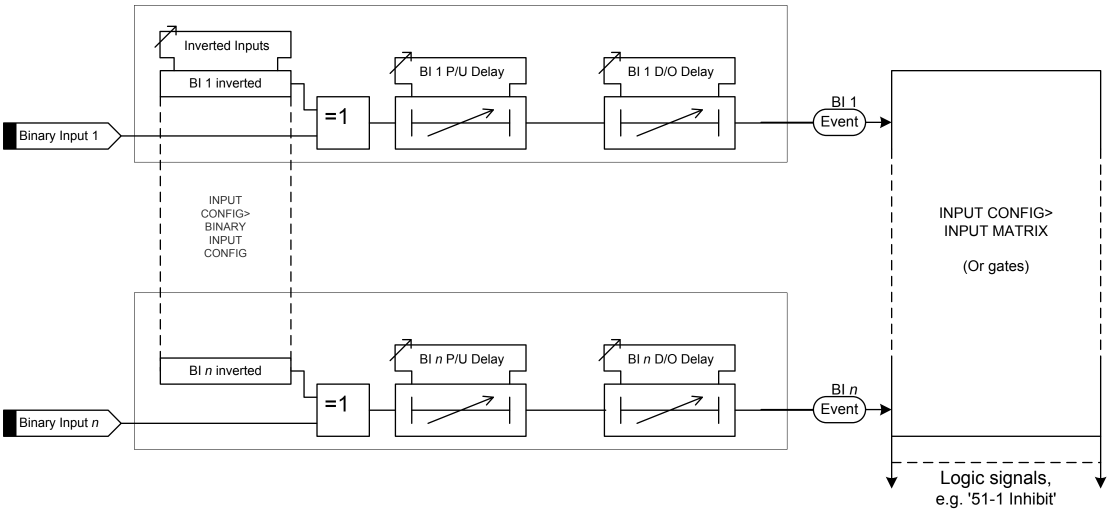


Figure 2.8-1 Binary Input Logic

2.9 Binary Outputs (Output Relays)

Relays are fitted with 14, 22 or 30 binary outputs. All outputs are fully user configurable and can be programmed to operate from any or all of the available functions.

The Power Supply module includes the relay basic I/O. The module includes six binary outputs each fitted with 1 contact – providing in total 1 x normally closed (NC), 2 x change-over (CO) and 3 x normally open (NO) contacts.

In the default mode of operation binary outputs are self reset and remain energised for a user configurable minimum time of up to 60 seconds. If required, outputs can be programmed to operate as ‘hand reset’. Alternatively, outputs can be programmed as ‘Pulsed’ outputs. When operated, these outputs will reset automatically after a delay of the minimum operating time.

The binary outputs can be used to operate the trip coils of the circuit breaker directly where the trip coil current does not exceed the 'make and carry' contact rating. The circuit breaker auxiliary contacts or other in-series auxiliary device must be used to break the trip coil current.

When the relay is withdrawn from the case all normally closed contacts will be open circuited. This should be considered in the design of the control and protection circuitry.

Notes on Pulsed Outputs

When operated, the output will reset after a user configurable time of up to 60 seconds regardless of the initiating condition.

Notes on Self Reset Outputs

Self reset operation has a minimum reset time of 100ms

With a failed breaker condition the relay may remain operated until current flow is interrupted by an upstream device. The relay will then reset and attempt to interrupt trip coil current flowing through an output contact. Where this level is above the break rating of the output contact an auxiliary relay with heavy-duty contacts should be utilised.in the primary system

Notes on Hand Reset Outputs

Hand reset outputs can be reset by either pressing the **TEST/RESET►** button, by energising a suitably programmed binary input, or, by sending an appropriate command over the data communications channel(s).

On loss of the auxiliary supply hand-reset outputs will reset. When the auxiliary supply is re-established the binary output will remain in the reset state unless the initiating condition is still present.

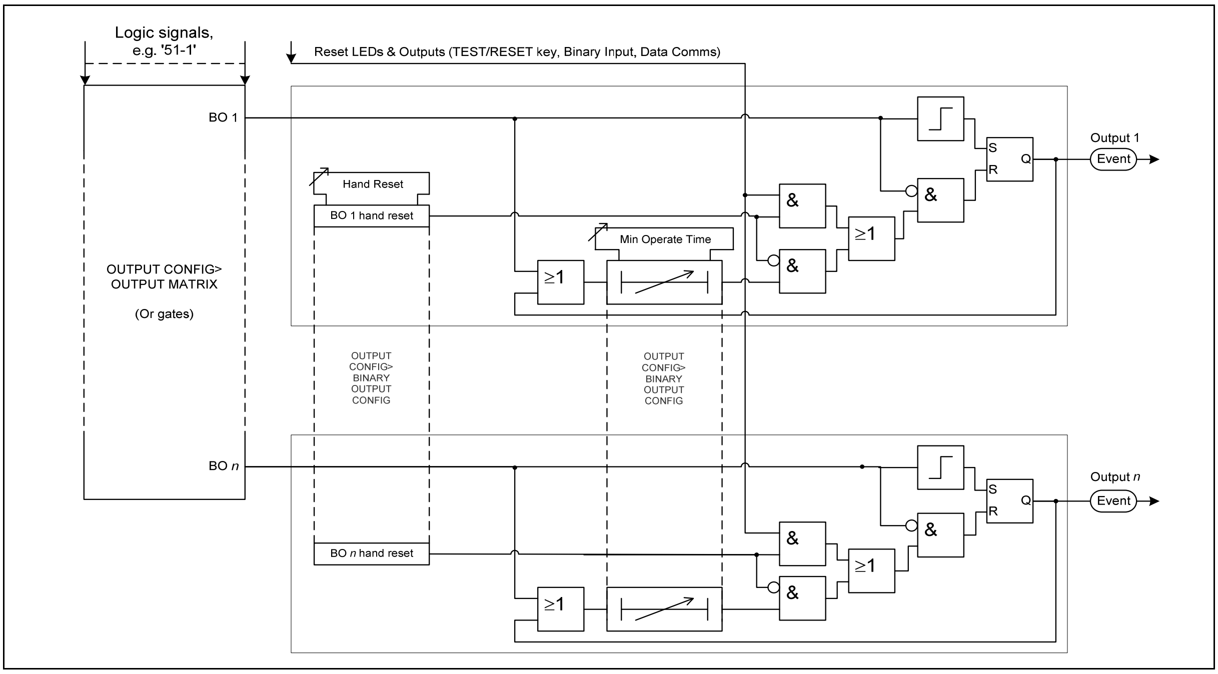


Figure 2.9-1 Binary Output Logic

2.10 Virtual Input/Outputs

The relays have 16 virtual input/outputs, these are internal logic states. Virtual I/O is assigned in the same way as physical Binary Inputs and Binary Outputs. Virtual I/O is mapped from within the INPUT CONFIG > INPUT MATRIX and OUTPUT CONFIG > OUTPUT MATRIX menus.

2.11 Self Monitoring Of The Controller

The relay incorporates a number of self-monitoring features. Each of these features can initiate a controlled reset recovery sequence.

Supervision includes a power supply watchdog, code execution watchdog, memory checks by checksum and processor/ADC health checks. When all checks indicate the relay is operating correctly the ‘Protection Healthy’ LED is illuminated.

If an internal failure is detected, a message will be displayed; also an event will be generated and stored. The relay will reset in an attempt to rectify the failure. This will result in de-energisation of any binary output mapped to ‘protection healthy’ and flashing of the protection healthy LED. If a successful reset is achieved by the relay the LED and output contact will revert back to normal operational mode, and the relay will restart.

2.11.1 Protection Healthy/Defective

When the relay has an auxiliary DC supply and it has successfully passed its self-checking procedure then the front facia Protection Healthy LED is turned on.

A normally open contact can be mapped via the binary output matrix to provide an external protection healthy signal.

A normally closed contact can be mapped via the binary output matrix to provide an external protection defective signal. With the ‘Protection Healthy’ this contact is open. When the auxiliary DC supply is not applied to the relay or a problem is detected within the relay then this output contact closes to provide external indication.

A shorting contact in the case at positions 25-26 of the PSU module can be used to provide an external indication when the relay is withdrawn.

2.12 Battery And Capacitor Test Facility Of The Recloser

The quiescent battery voltage V_{AUX} is constantly monitored to ensure that the charging system is connected and operating correctly. The capacitor voltage is monitored externally by the Switch Unit Driver and Monitor. The healthy condition of the capacitor is indicated to the Controller by the state of two binary signals. These signals are constantly monitored and used to provide alarms and operation blocking for quiescent capacitor voltage levels which are out of limits.

Battery and capacitor tests are initiated at user set intervals - typically once per week/month. The condition and state of the Recloser battery and Recloser capacitor are assessed; any unhealthy states are identified and can be alarmed. Battery and capacitor tests are not carried out at the same time. The battery test is initiated first to avoid any possible interaction with the capacitor test which is performed 30 minutes afterwards.

Section 3: Protection Functions

3.1 Current Protection: Phase Overcurrent (67, 51, 50)

All phase overcurrent elements have a common setting to measure either fundamental frequency RMS or True RMS current:

True RMS current: ***51/50 Measurement* = RMS**

Fundamental Frequency RMS current: ***51/50 Measurement* = Fundamental**

3.1.1 Directional Control of Overcurrent Protection (67)

The directional element produces forward and reverse outputs for use with overcurrent elements. These outputs can then be mapped as controls to each shaped and instantaneous over-current element.

If a protection element is set as non-directional then it will operate independently of the output of the directional detector. However, if a protection element is programmed for forward directional mode then operation will occur only for a fault lying within the forward operate zone. Conversely, if a protection element is programmed for reverse directional mode then operation will occur only for a fault lying within the reverse operate zone. Typically the forward direction is defined as being ‘away’ from the busbar or towards the protected zone.

The Characteristic angle is the phase angle by which the polarising voltage must be adjusted such that the directional detector gives maximum sensitivity in the forward operate zone when the current is in phase with it. The reverse operate zone is the mirror image of the forward zone.

Voltage polarisation is achieved for the phase-fault elements using the quadrature voltage i.e. at unity power factor I leads V by 90°. Each phase current is compared to the voltage between the other two phases, i.e for normal phase sequence 1-2-3:

$I_{L1} \sim V_{23}$ $I_{L2} \sim V_{31}$ $I_{L3} \sim V_{12}$

When the device is applied to reverse sequence networks, i.e. 1-3-2, the polarizing is corrected automatically by the *Gn Phase* Rotation setting in the *CT/VT Configl menu.*

The characteristic angle can be user programmed to any angle between -95° and +95° using the ***67 Char Angle*** setting. The voltage is the reference phasor (V_{ref}) and the ***67 Char Angle*** setting is added to this to adjust the forward and reverse zones.

The centre of the forward zone is set by (V_{ref} Angle + ***67 Char Angle***) and should be set to correspond with I_{fault} Angle for maximum sensitivity i.e.

For fault current of -60° (I lagging V by 60°) a ***67 Char Angle*** of **+30°** is required for maximum sensitivity (i.e. due to quadrature connection 90° - 60° = 30°).

OR

For fault current of -45° (I lagging V by 45°) a ***67 Char Angle*** of **+45°** is required for maximum sensitivity (i.e. due to quadrature connection 90° - 45° = 45°).

Two-out-of-three Gate

When the ***67 2-Out-Of-3 Logic*** setting is set to **Enabled**, the directional elements will only operate for the majority direction, e.g. if I_{L1} and I_{L3} are detected as forward flowing currents and I_{L2} is detected as reverse current flow, phases L1 and L3 will operate forwards, while phase L2 will be inhibited.

Minimum Polarising Voltage

The ***67 Minimum Voltage*** setting defines the minimum polarising voltage level. Where the measured polarising voltage is below this level no directional output is given and operation of protection elements set as directional will be inhibited. This prevents mal-operation under fuse failure/MCB tripped conditions where noise voltages can be present.

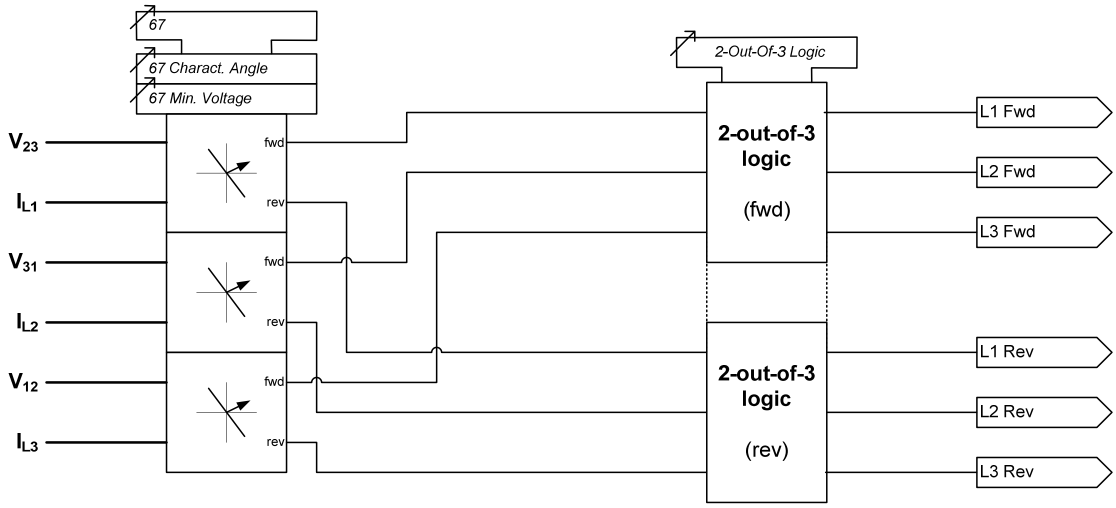


Figure 3.1-1 Logic Diagram: Directional Overcurrent Element (67)

3.1.2 Instantaneous Overcurrent Protection (50)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

Each instantaneous element (50-n) has independent settings. ***50-n Setting*** for pick-up current and ***50-n Delay*** follower time delay. The instantaneous elements have transient free operation.

For the directional elements the direction of operation can be set using ***50-n Dir. Control*** setting. Directional logic is provided independently for each 50-n element.

Operation of the instantaneous overcurrent elements can be inhibited from:

Inhibit 50-n	A binary or virtual input, or function key.
***79 P/F Inst Trips:* 50-n**	When ‘delayed’ trips only are allowed in the autoreclose sequence (***79 P/F Prot’n Trip n* = Delayed**).
***50-n Inrush Action:* Inhibit**	Operation of the inrush current detector function.
***50-n VTS Action:* Inhibit**	Operation of the VT Supervision function.

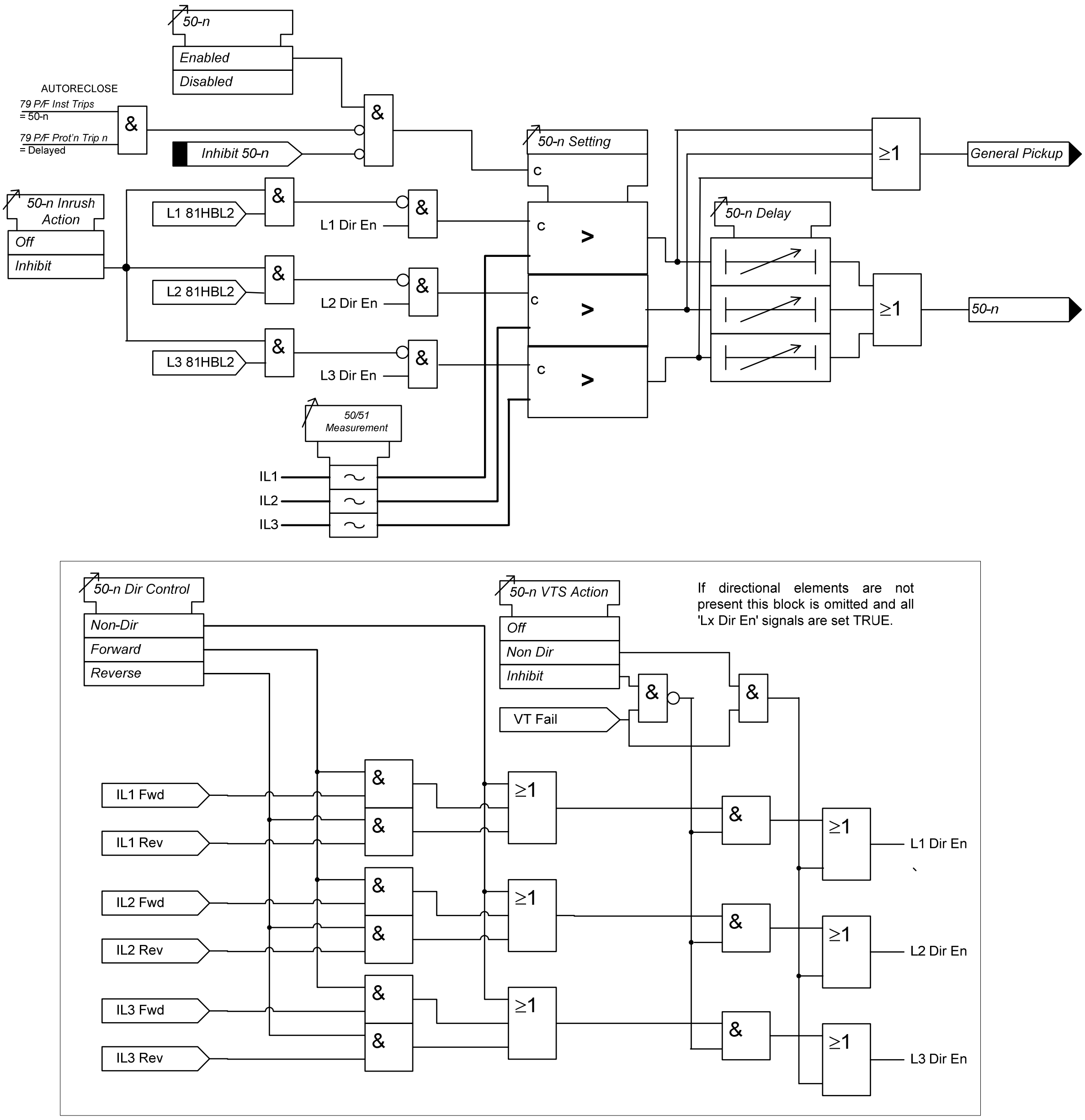


Figure 3.1-2 Logic Diagram: Instantaneous Over-current Element

3.1.3 Time Delayed Overcurrent Protection (51)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

51-n Setting sets the pick-up current level. Where the voltage controlled overcurrent function (51VCO) is used a multiplier is applied to this setting where the voltage drops below the setting ***VCO Setting***, see section 3.2.

A number of shaped characteristics are provided. An inverse definite minimum time (IDMT) characteristic is selected from IEC, ANSI or manufacturer specific curves using ***51-n Char***. A time multiplier is applied to the characteristic curves using the ***51-n Time Mult*** setting. Alternatively, a definite time lag delay (DTL) can be chosen using ***51-n Char***. When Delay (DTL) is selected the time multiplier is not applied and the ***51-n Delay (DTL)*** setting is used instead. The full list of operating curves is given in section 2 – 'Settings, Configuration and Instruments Guide'. Operating curve characteristics are illustrated in section 3 – 'Performance Specification'.

The ***51-n Reset*** setting can apply a **definite time delayed** reset**,** or when configured as an ANSI characteristic an **ANSI (DECAYING)** reset. If ANSI (DECAYING) reset is selected for an IEC characteristic, the reset will be instantaneous. The reset mode is significant where the characteristic has reset before issuing a trip output – see 'Applications Guide'.

A minimum operate time for the characteristic can be set using ***51-n Min. Operate Time*** setting.

A fixed additional operate time can be added to the characteristic using ***51-n Follower DTL*** setting.

For the directional elements the direction of operation can be set using ***51-n Dir. Control*** setting. Directional logic is provided independently for each 51-n element.

Operation of the time delayed overcurrent elements can be inhibited from:

Inhibit 51-n	A binary or virtual input, or function key
79 P/F Inst Trips: **51-n**	When 'delayed' trips only are allowed in the autoreclose sequence (***79 P/F Prot'n Trip n*** **= Delayed**).
51c	Activation of the cold load settings (see section 3.7).
51-n Inrush Action: **Inhibit**	Operation of the inrush current detector function.
51-n VTSAction: **Inhibit**	Operation of the VT Supervision function.

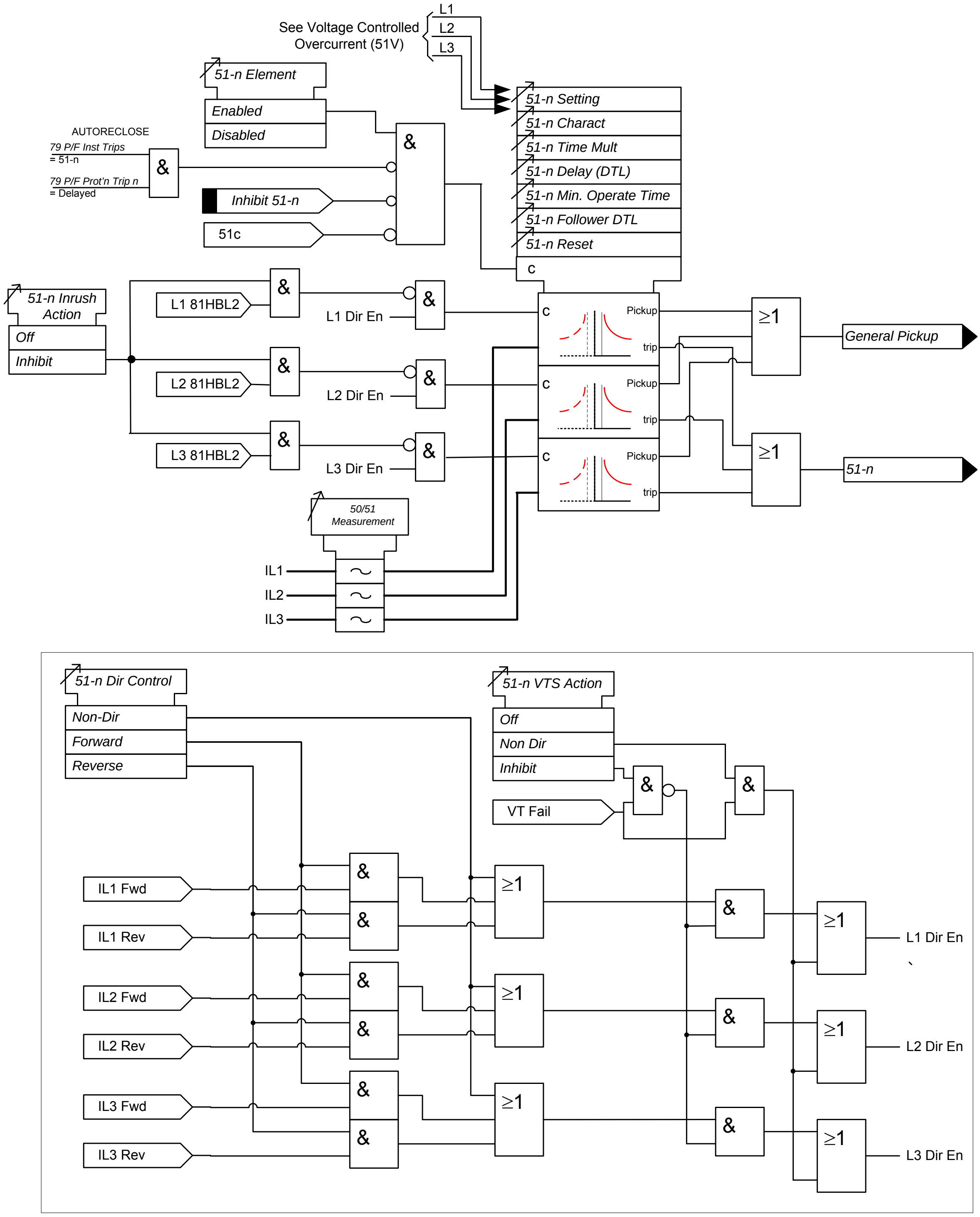


Figure 3.1-3 Logic Diagram: Time Delayed Overcurrent Element

3.2 Current Protection: Voltage Controlled OC (51V)

Each shaped overcurrent element ***51-n Setting*** can be independently controlled by the level of measured (control) input voltage.

For applied voltages above ***VCO Setting*** the 51-n element operates in accordance with its normal current setting (see 3.1.3). For input Ph-Ph control voltages below ***VCO Setting*** a multiplier (***51-n Multiplier***) is applied to reduce the 51-n pickup current setting.

51-n Multiplier is applied to each phase independently when its control phase-phase voltage falls below ***VCO Setting.*** The voltage levels used for each phase over-current element are shown in the table below. Relays with a Ph-N connection automatically calculate the correct Ph-Ph control voltage.

Current Element	**Control Voltage**
I_{L1}	V_{12}
I_{L2}	V_{23}
I_{L3}	V_{31}

The Voltage Controlled Overcurrent function (51V) can be inhibited from:

VCO VTSAction: **Inhibit** Operation of the VT Supervision function.

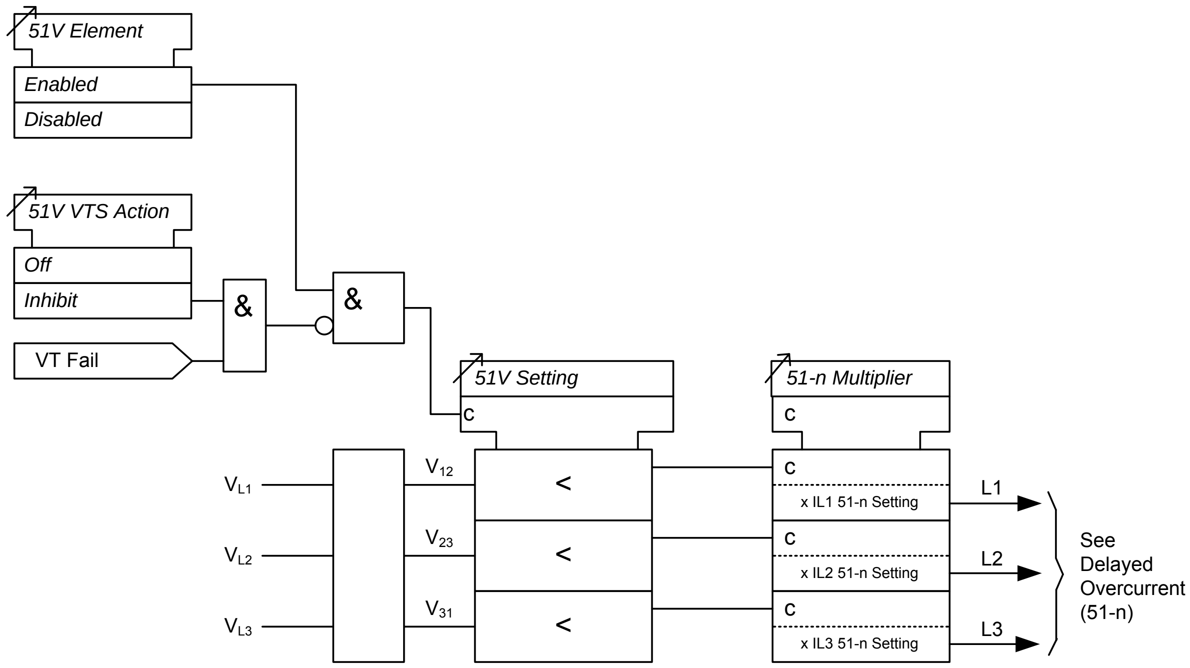


Figure 3.2-1 Logic Diagram: Voltage Controlled Overcurrent Protection

3.3 Current Protection: Measured EF (67G, 51G, 50G)

The earth current is measured directly via a dedicated current analogue input.

All measured earth fault elements have a common setting to measure either fundamental frequency RMS, True RMS current or the derived sum current:

True RMS current: ***51/50 Measurement*** **= RMS**

Fundamental Frequency RMS current: ***51/50 Measurement*** **= Fundamental**

Additionally these elements can be selected to operate on a Fundamental Frequency current which is calculated from the sum of the phase currents, i.e. a Derived quantity. This option should only be used when the fourth current input is required for connection of a Core Balance Current Transformer to achieve very low earth fault sensitivity using the 50/51SEF elements.

51/50 Measurement **= Calculated**

3.3.1 Directional Control of Measured Earth Fault Protection (67G)

The directional element produces forward and reverse outputs for use with measured earth fault elements. These outputs can be mapped as controls to each shaped and instantaneous element.

If a protection element is set as non-directional then it will operate independently of the output of the directional detector. However, if a protection element is programmed for forward directional mode then operation will occur only for a fault lying within the forward operate zone. Conversely, if a protection element is programmed for reverse directional mode then operation will occur only for a fault lying within the reverse operate zone. Typically the forward direction is defined as being ‘away’ from the busbar or towards the protected zone.

The Characteristic angle is the phase angle by which the polarising voltage must be adjusted such that the directional detector gives maximum sensitivity in the forward operate zone when the current is in phase with it. The reverse operate zone is the mirror image of the forward zone.

The measured directional earth fault elements use zero phase sequence (ZPS) polarising.

Voltage polarisation is achieved for the earth-fault elements by comparison of the appropriate current with its equivalent voltage:

$I_0 \sim V_0$

The characteristic angle can be user programmed to any angle between -95° and +95° using the ***67G Char Angle*** setting. The voltage is the reference phasor (V_{ref}) and the ***67G Char Angle*** setting is added to this to adjust the forward and reverse zones.

The centre of the forward zone is set by (V_{ref} Angle + ***67G Char Angle***) and should be set to correspond with I_{fault} Angle for maximum sensitivity e.g.

For fault current of -15° (I lagging V by 15°) a ***67G Char Angle*** of **-15°** is required for maximum sensitivity, OR

For fault current of -45° (I lagging V by 45°) a ***67G Char Angle*** of **-45°** is required for maximum sensitivity.

Minimum Polarising Voltage

The ***67G Minimum Voltage*** setting defines the minimum polarising voltage level. Where the measured polarising voltage is below this level no directional output is given and. Operation of protection elements set as directional will be inhibited. This prevents mal-operation under fuse failure/MCB tripped conditions where noise voltages can be present.

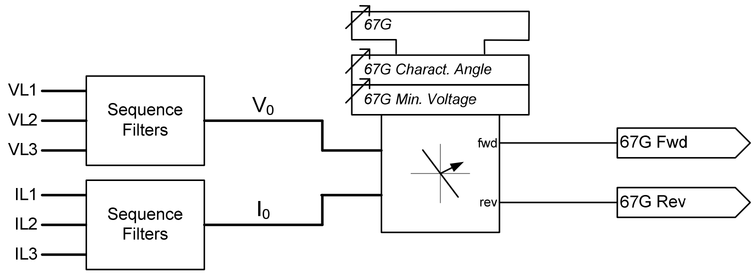


Figure 3.3-1 Logic Diagram: Measured Directional Earth Fault Protection

3.3.2 Instantaneous Measured Earth Fault Protection (50G)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

Each instantaneous element has independent settings for pick-up current ***50G-n Setting*** and a follower time delay ***50G-n Delay***. The instantaneous elements have transient free operation.

For the directional elements the direction of operation can be set using ***50G-n Dir. Control*** setting. Directional logic is provided independently for each 50G-n element.

Operation of the instantaneous measured earth fault elements can be inhibited from:

Inhibit 50G-n	A binary or virtual input, or function key
79 E/F Inst Trips: **50G-n**	When ‘delayed’ trips only are allowed in the autoreclose sequence (***79 E/F Prot’n Trip n*** = **Delayed**).
50G-n Inrush Action: **Inhibit**	Operation of the current inrush detector function.
50G-n VTSAction: **Inhibit**	Operation of the VT Supervision function.

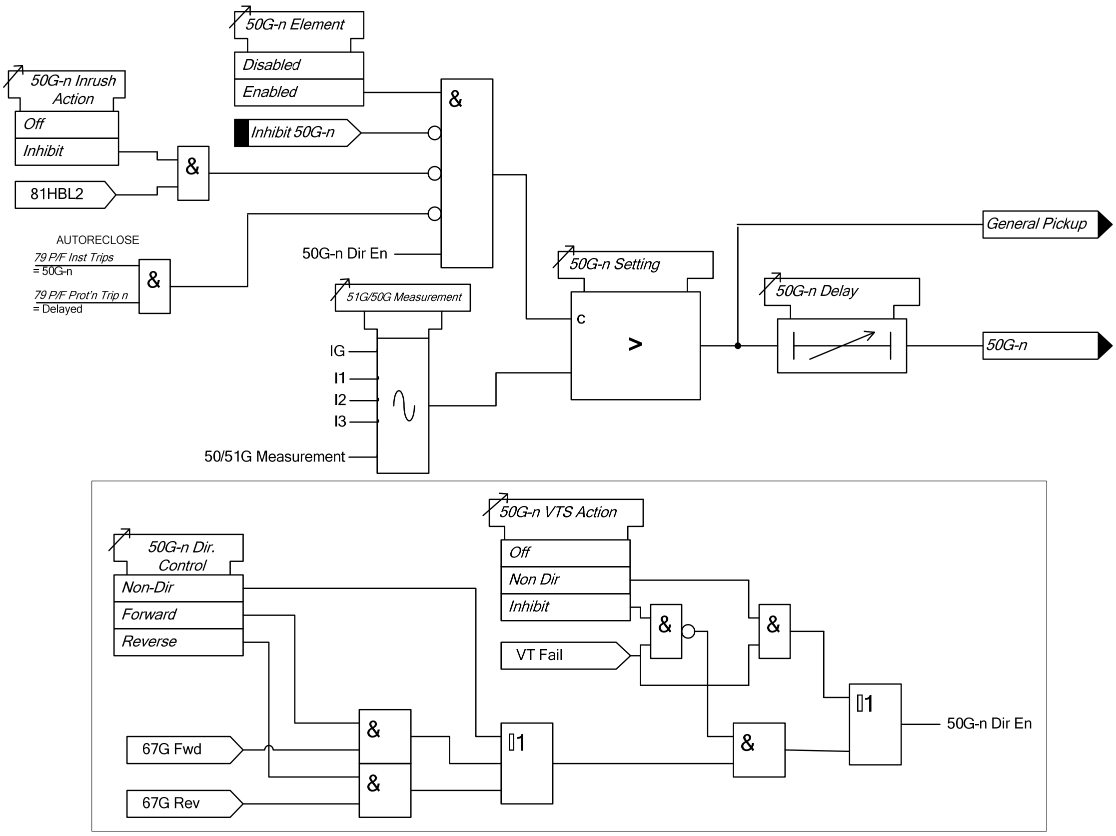


Figure 3.3-2 Logic Diagram: Measured Instantaneous Earth-fault Element

3.3.3 Time Delayed Measured Earth Fault Protection (51G)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

51G-n Setting sets the pick-up current level.

A number of shaped characteristics are provided. An inverse definite minimum time (IDMT) characteristic is selected from IEC and ANSI curves using ***51G-n Char***. A time multiplier is applied to the characteristic curves using the ***51G-n Time Mult*** setting. Alternatively, a definite time lag (DTL) can be chosen using ***51G-n Char***. When DTL is selected the time multiplier is not applied and the ***51G-n Delay (DTL)*** setting is used instead. The full list of operating curves is given in section 2 – 'Settings, Configuration and Instruments Guide'. Operating curve characteristics are illustrated in section 3 – 'Performance Specification'.

The ***51G-n Reset*** setting can apply a **definite time delayed** reset**,** or when configured as an ANSI characteristic an **ANSI (DECAYING)** reset. If ANSI (DECAYING) is selected for an IEC characteristic, the reset will be instantaneous. The reset mode is significant where the characteristic has reset before issuing a trip output – see 'Applications Guide'.

A minimum operate time for the characteristic can be set using ***51G-n Min. Operate Time*** setting.

A fixed additional operate time can be added to the characteristic using ***51G-n Follower DTL*** setting.

For the directional elements the direction of operation can be set using ***51G-n Dir. Control*** setting. Directional logic is provided independently for each 51G-n element.

Operation of the time delayed measured earth fault elements can be inhibited from:

Inhibit 51G-n	A binary or virtual input, or function key
79 E/F Inst Trips: **51G-n**	When 'delayed' trips only are allowed in the autoreclose sequence (***79 E/F Prot'n Trip n*** = **Delayed**).
51G-n Inrush Action: **Inhibit**	Operation of the inrush current detector function.
51G-n VTSAction: **Inhibit**	Operation of the VT Supervision function.

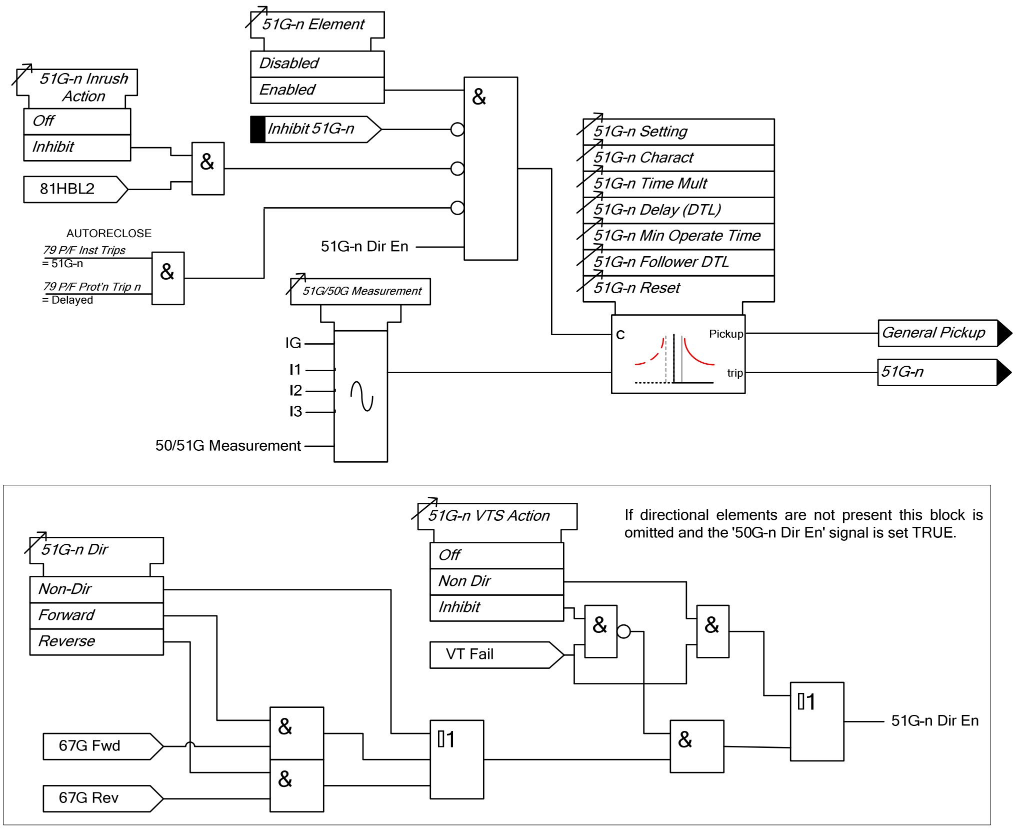


Figure 3.3-3 Logic Diagram: Measured Time Delayed Earth Fault Element (51G)

3.4 Current Protection: Sensitive EF (67SEF, 51SEF, 50SEF)

Current for the Sensitive Earth Fault (SEF) elements is measured directly via a dedicated current analogue input. SEF elements measure the fundamental frequency RMS current.

3.4.1 Directional Control of Sensitive Earth Fault Protection (67SEF)

The directional element produces forward and reverse outputs for use with SEF elements. These outputs can be mapped as controls to each shaped and instantaneous element.

If a protection element is set as non-directional then it will operate independently of the output of the directional detector. However, if a protection element is programmed for forward directional mode then operation will occur only for a fault lying within the forward operate zone. Conversely, if a protection element is programmed for reverse directional mode then operation will occur only for a fault lying within the reverse operate zone. Typically the forward direction is defined as being ‘away’ from the busbar or towards the protected zone.

The Characteristic angle is the phase angle by which the polarising voltage must be adjusted such that the directional detector gives maximum sensitivity in the forward operate zone when the current is in phase with it. The reverse operate zone is the mirror image of the forward zone.

The directional sensitive earth fault elements use zero phase sequence (ZPS) polarising.

Voltage polarisation is achieved for the earth-fault elements by comparison of the appropriate current with its equivalent voltage:

$I_0 \sim V_0$

The characteristic angle can be user programmed to any angle between -95° and +95° using the ***67SEF Char Angle*** setting. The voltage is the reference phasor (V_{ref}) and the ***67SEF Char Angle*** setting is added to this to adjust the forward and reverse zones.

The centre of the forward zone is set by (V_{ref} Angle + ***67SEF Char Angle***) and should be set to correspond with I_{fault} Angle for maximum sensitivity i.e.

For fault current of -15° (I lagging V by 15°) a ***67SEF Char Angle*** of **-15°** is required for maximum sensitivity.

OR

For fault current of -45° (I lagging V by 45°) a ***67SEF Char Angle*** of **-45°** is required for maximum sensitivity.

For application of 67SEF protection to networks with compensation (Peterson) coils fitted, an additional setting, ***67SEF Compensated Networks*** is available which when set to Enabled will increase the directional boundary to closer to 90º to suit this application. This setting should be set to Disabled for application on networks with other earthing arrangements.

Minimum Polarising Voltage

The ***67SEF Minimum Voltage*** setting defines the minimum polarising voltage level. Where the measured polarising voltage is below this level no directional output is given and. Operation of protection elements set as directional will be inhibited. This prevents mal-operation under fuse failure/MCB tripped conditions where noise voltages can be present.

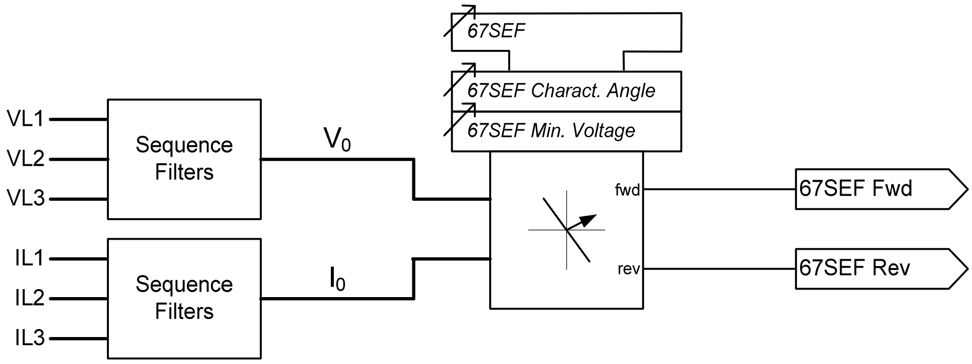


Figure 3.4-1 Logic Diagram: SEF Directional Element (67SEF)

3.4.2 Instantaneous Sensitive Earth Fault Protection (50SEF)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

Each instantaneous element has independent settings for pick-up current ***50SEF-n Setting*** and a follower time delay ***50SEF-n Delay***. The instantaneous elements have transient free operation.

For the directional elements the direction of operation can be set using ***50SEF-n Dir. Control*** setting. Directional logic is provided independently for each 50SEF-n element.

Operation of the instantaneous earth fault elements can be inhibited from:

Inhibit 50SEF-n	A binary or virtual input, or function key
79 SEF Inst Trips: **50SEF-n**	When 'delayed' trips only are allowed in the autoreclose sequence (***79 SEF Prot'n Trip n*** = **Delayed**).
50SEF-n VTSAction: **Inhibit**	Operation of the VT Supervision function.

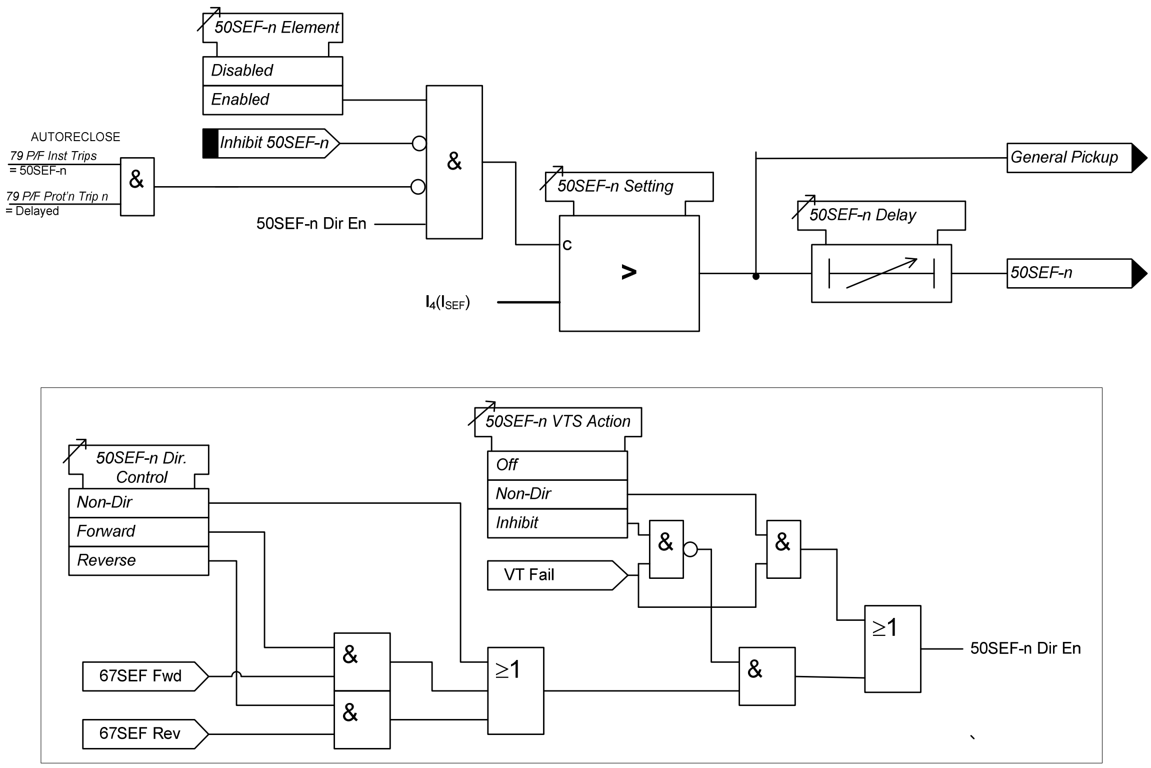


Figure 3.4-2 Logic Diagram: SEF Instantaneous Element

3.4.3 Time Delayed Sensitive Earth Fault Protection (51SEF)

Four elements are provided e.g. giving the option of using two elements set to forward and two to reverse.

51SEF-n Setting sets the pick-up current level.

A number of shaped characteristics are provided. An inverse definite minimum time (IDMT) characteristic is selected from IEC and ANSI curves using ***51SEF-n Char***. A time multiplier is applied to the characteristic curves using the ***51SEF-n Time Mult*** setting. Alternatively, a definite time lag (DTL) can be chosen using ***51SEF-n Char***. When DTL is selected the time multiplier is not applied and the ***51SEF-n Delay (DTL)*** setting is used instead.

The ***51SEF-n Reset*** setting can apply a **definite time delayed** reset**,** or when configured as an ANSI characteristic an **ANSI (DECAYING)** reset. If ANSI (DECAYING) reset is selected for an IEC characteristic, the reset will be instantaneous. The reset mode is significant where the characteristic has reset before issuing a trip output – see 'Applications Guide'.

A minimum operate time for the characteristic can be set using ***51SEF-n Min. Operate Time*** setting.

A fixed additional operate time can be added to the characteristic using ***51SEF-n Follower DTL*** setting.

For the directional elements the direction of operation can be set using ***51SEF-n Dir. Control*** setting. Directional logic is provided independently for each 51SEF-n element.

Operation of the time delayed earth fault elements can be inhibited from:

Inhibit 51SEF-n	A binary or virtual input, or function key
79 SEF Inst Trips: **51SEF-n**	When 'delayed' trips only are allowed in the autoreclose sequence (***79 SEF Prot'n Trip n*** = **Delayed**).
51SEF-n VTSAction: **Inhibit**	Operation of the VT Supervision function.

If the I_4 input is used for SEF, REF cannot be used.

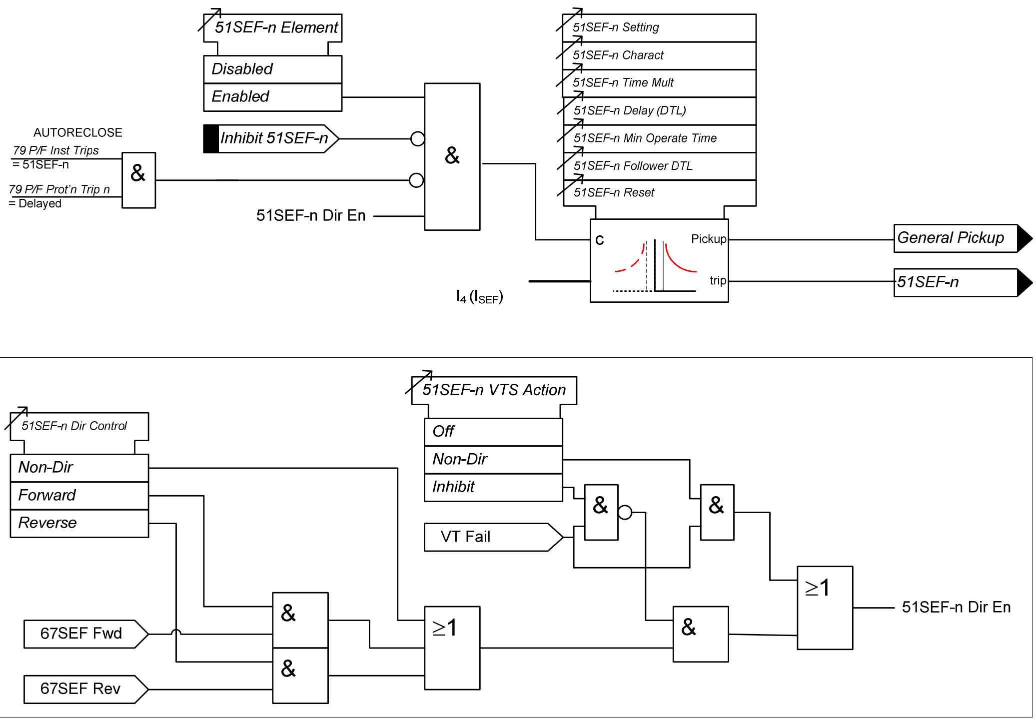


Figure 3.4-3 Logic Diagram: SEF Time Delayed Element (51SEF)

3.5 Current Protection: High Impedance Restricted EF (64H)

One high impedance Restricted Earth Fault (REF) element is provided.

The relay utilises fundamental current measurement values for this function.

The single phase current input is derived from the residual output of line/neutral CTs connected in parallel. An external stabilising resistor must be connected in series with this input to ensure that this element provides a high impedance path. If I_4 is utilised for this purpose, SEF protection cannot be used.

64H Current Setting sets the pick-up current level. An output is given after elapse of the ***64H Delay*** setting.

External components – a series stabilising resistor and a non-linear resistor – are used with this function. See 'Applications Guide' for advice in specifying suitable component values.

Operation of the high impedance element can be inhibited from:

Inhibit 64H	A binary or virtual input.

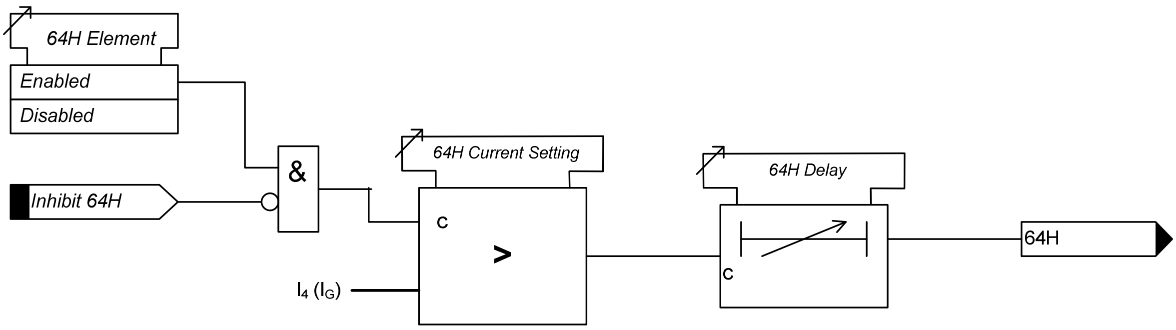


Figure 3.5-1 Logic Diagram: High Impedance REF (64H)

3.6 Current Protection: Cold Load (51c)

The setting of each shaped overcurrent element (51-n) can be inhibited and alternative 'cold load' settings (51c-n) can be applied for a period following circuit switch in.

The Cold Load settings are applied after the circuit breaker has been open for longer than the ***Pick-Up Time*** setting.

Following circuit breaker closure the 'cold load' overcurrent settings will revert to those defined in the Phase Overcurrent menu (51-n) after either elapse of the ***Drop-Off Time*** setting or when the measured current falls below the ***Reduced Current Level*** setting for a time in excess of ***Reduced Current Time*** setting.

During cold load settings conditions any directional settings applied in the Phase Overcurrent menu are still applicable.

A CB 'Don't Believe It' (DBI) condition is not acted on, causing the element to remain operating in accordance with the relevant 51-n settings. Where the ***Reduced Current*** setting is set to **OFF** reversion to 51-n settings will only occur at the end of the ***Drop-Off Time***. If any element is picked up on expiry of ***Drop-Off Time*** the relay will issue a trip and lockout.

If the circuit breaker is re-opened before expiry of the ***Drop-Off Time*** the drop-off timer is held but not reset. Resetting the timer for each trip could result in damaging levels of current flowing for a prolonged period during a rapid sequence of trips/closes.

Cold load trips use the same binary output(s) as the associated 51-n element.

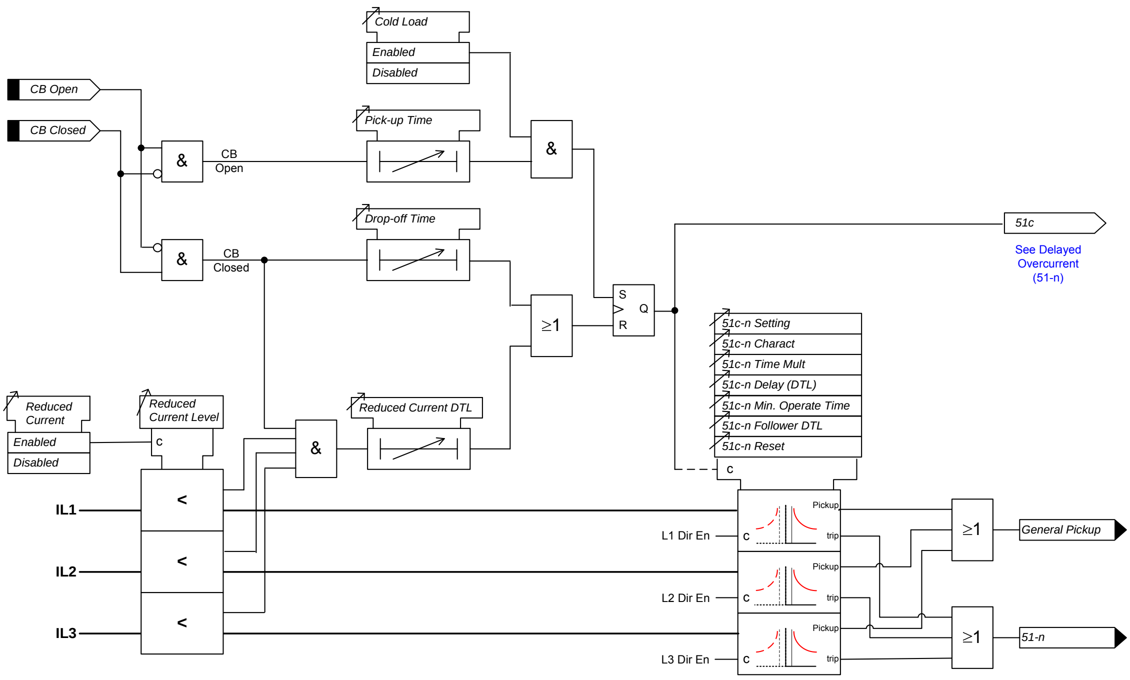


Figure 3.6-1 Logic Diagram: Cold Load Settings (51c)

3.7 Current Protection: Negative Phase Seq. OC (46NPS)

The negative sequence phase (NPS) component of current (I2) is derived from the three phase currents. It is a measure of the quantity of unbalanced current in the system.

When the device is applied to reverse sequence networks, i.e. 1-3-2, the NPS/PPS sequence is corrected automatically by the *Gn Phase* Rotation setting in the *CT/VT Configl menu.*

Two NPS current elements are provided – 46IT and 46DT.

The 46IT element can be configured to be either definite time lag (DTL) or inverse definite minimum time (IDMT),

46IT Setting sets the pick-up current level for the element.

A number of shaped characteristics are provided. An inverse definite minimum time (IDMT) characteristic is selected from IEC and ANSI curves using ***46IT Char***. A time multiplier is applied to the characteristic curves using the ***46IT Time Mult*** setting. Alternatively, a definite time lag delay (DTL) can be chosen using ***46ITChar***. When Delay (DTL) is selected the time multiplier is not applied and the ***46IT Delay (DTL)*** setting is used instead.

The ***46IT Reset*** setting can apply a, **definite time delayed** or **ANSI (DECAYING)** reset.

The 46DT element has a DTL characteristic. ***46DT Setting*** sets the pick-up current and ***46DT Delay*** the follower time delay.

Operation of the negative phase sequence overcurrent elements can be inhibited from:

Inhibit 46IT	A binary or virtual input.
Inhibit 46DT	A binary or virtual input.

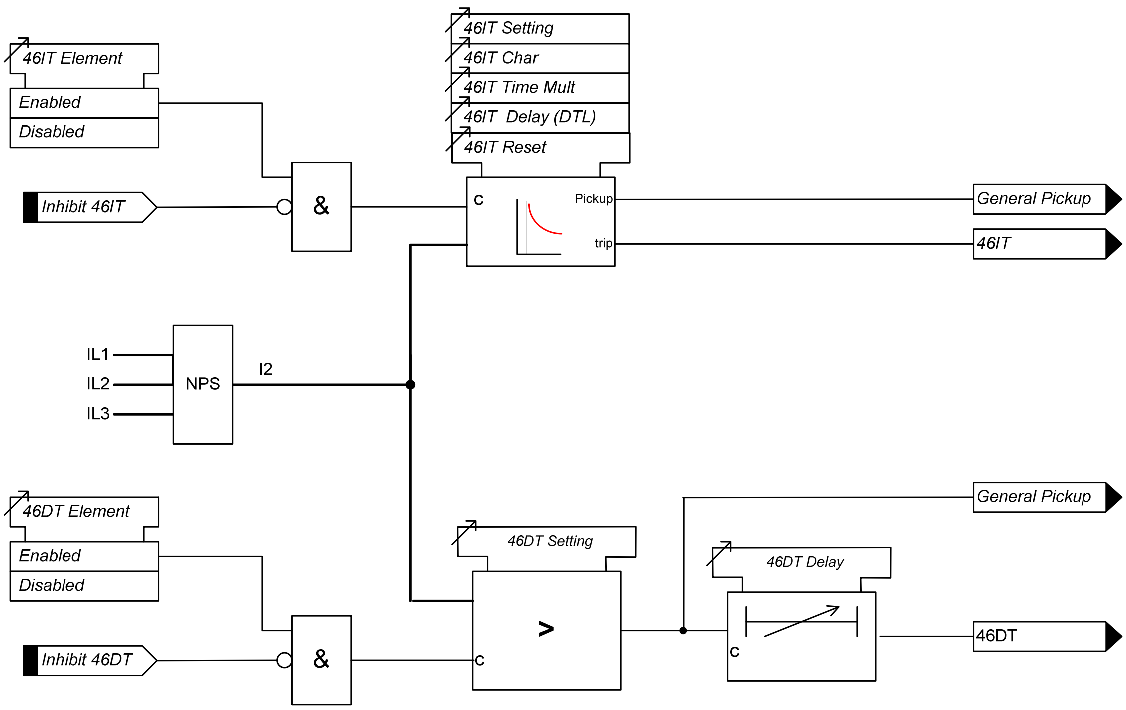


Figure 3.7-1 Logic Diagram: Negative Phase Sequence Overcurrent (46NPS)

3.8 Current Protection: Under-Current (37)

Two under-current elements are provided.

Each phase has an independent level detector and current-timing element. ***37-n Setting*** sets the pick-up current. An output is given after elapse of the ***37-n Delay*** setting.

Operation of the under-current elements can be inhibited from:

Inhibit 37-n A binary or virtual input.

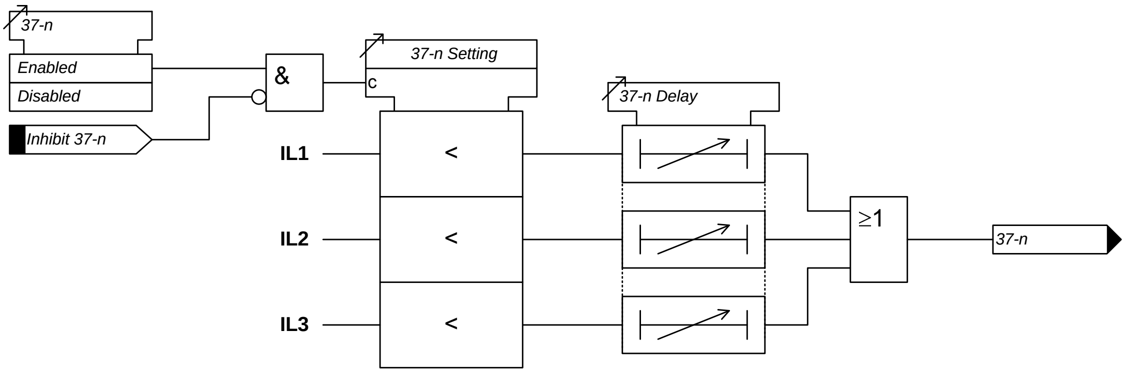


Figure 3.8-1 Logic Diagram: Undercurrent Detector (37)

3.9 Current Protection: Thermal Overload (49)

The relay provides a thermal overload suitable for the protection of static plant. Phase segregated elements are provided. The temperature of the protected equipment is not measured directly. Instead, thermal overload conditions are calculated using the measure True RMS current.

Should the current rise above the ***49 Overload Setting*** for a defined time an output signal will be initiated.

Operate Time (t):-

$$t = \tau \times \ln\left\{\frac{I^2 - I_P^2}{I^2 - (k \times I_B)^2}\right\}$$

Where

T = Time in minutes

τ = ***49 Time Constant*** setting (minutes)

In = Log Natural

I = measured current

I_P = Previous steady state current level

k = Constant

I_B = Basic current, typically the same as In

$k.I_B$ = ***49 Overload*** Setting (I_θ)

Additionally, an alarm can be given if the thermal state of the system exceeds a specified percentage of the protected equipment's thermal capacity ***49 Capacity Alarm*** setting.

For the heating curve:

$$\theta = \frac{I^2}{I_\theta^2} \cdot (1 - e^{-t/\tau}) \times 100\%$$

Where: θ = thermal state at time t

I = measured thermal current

I_θ = ***49 Overload*** setting (or $k.I_B$)

The final steady state thermal condition can be predicted for any steady state value of input current where t >τ,

$$\theta_F = \frac{I^2}{I_\theta^2} \times 100\%$$

Where: θ_F = final thermal state before disconnection of device

49 Overload Setting I_θ is expressed as a multiple of the relay nominal current and is equivalent to the factor $k.I_B$ as defined in the IEC255-8 thermal operating characteristics. It is the value of current above which 100% of thermal capacity will be reached after a period of time and it is therefore normally set slightly above the full load current of the protected device.

The thermal state may be reset from the fascia or externally via a binary input.

Thermal overload protection can be inhibited from:

Inhibit 49 A binary or virtual input.

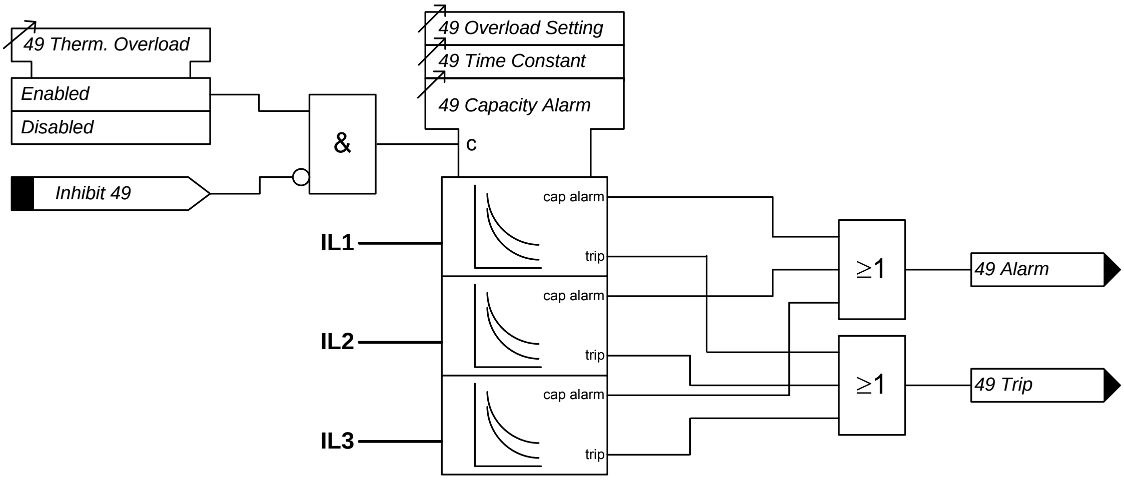


Figure 3.9-1 Logic Diagram: Thermal Overload Protection (49S)

3.10 Voltage Protection: Phase Under/Over Voltage (27/59)

In total five under/over voltage elements are provided. Four elements are provided for the 'Phase' Voltages and one for the 'Auxiliary' input voltage.

The relay utilises fundamental frequency RMS voltage for this function. All under/over voltage elements have a common setting to measure phase to phase **(Ph-Ph)** or phase to neutral **(Ph-N)** voltage using the ***Voltage Input Mode*** setting.

Voltage elements can be blocked if all phase voltages fall below the ***27/59 U/V Guard*** setting.

27/59-n (27/59-Vx) Setting sets the pick-up voltage level for the element.

The sense of the element (undervoltage or overvoltage) is set by the ***27/59-n Operation*** (***27/59-Vx Operation)*** setting.

The ***27/59-n O/P Phases*** setting determines whether the time delay is initiated for operation of any phase or only when all phases have detected the appropriate voltage condition. An output is given after elapse of the ***27/59-n Delay*** (***27/59-Vx Delay)*** setting.

The ***27/59-n Hysteresis*** (***27/59-Vx Hysteresis)*** setting allows the user to vary the pick-up/drop-off ratio for the element.

Operation of the under/over voltage elements can be inhibited from:

Inhibit 27/59-n	A binary or virtual input.
***27/59-n VTSInhibit:* Yes**	Operation of the VT Supervision function.
27/59-n U/V Guarded	Under voltage guard element.

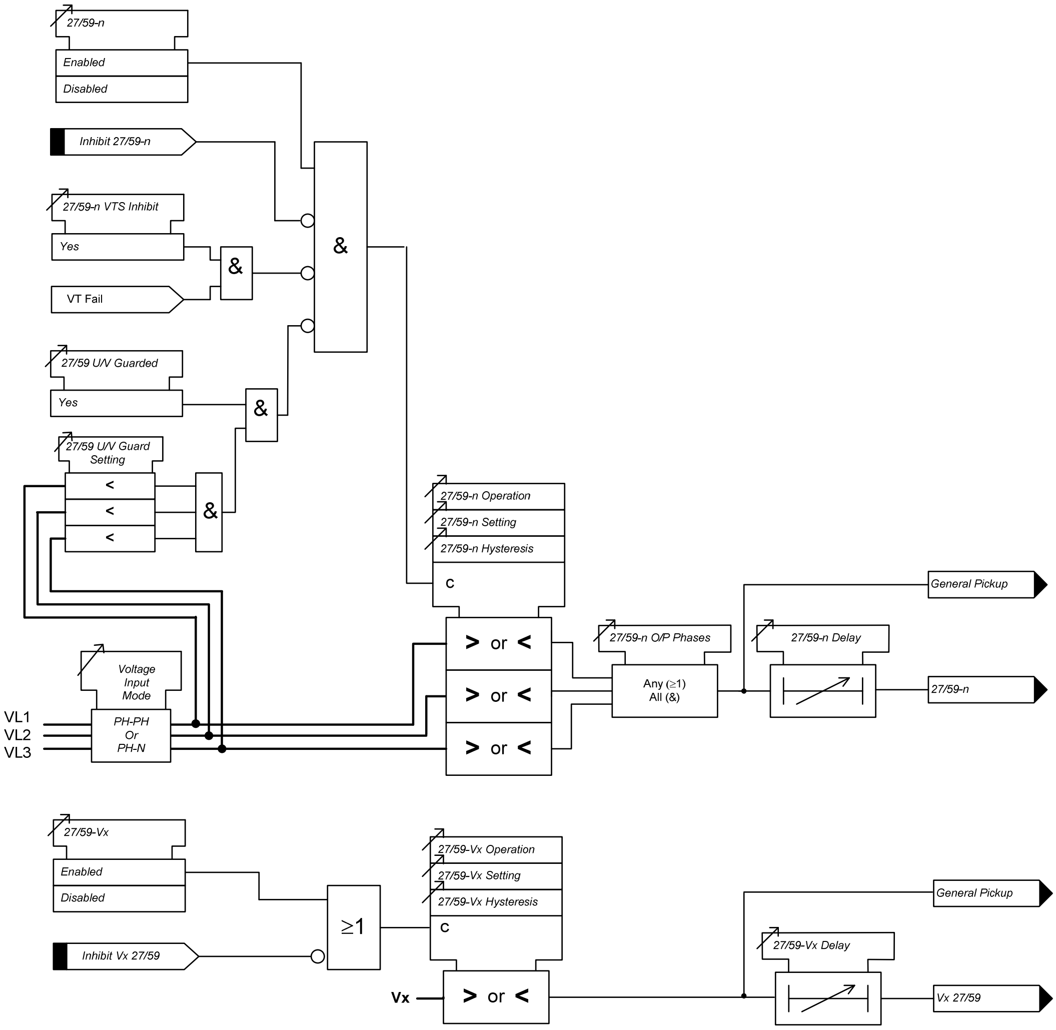


Figure 3.10-1 Logic Diagram: Under/Over Voltage Elements (27/59)

3.11 Voltage Protection: Negative Phase Sequence Overvoltage (47)

Negative phase sequence (NPS) voltage (V2) is a measure of the quantity of unbalanced voltage in the system. The relay derives the NPS voltage from the three input voltages (VL1, VL2 and VL3).

Two elements are provided.

47-n Setting sets the pick-up voltage level for the element.

The ***47-n Hysteresis*** setting allows the user to vary the pick-up/drop-off ratio for the element.

An output is given after elapse of the ***47-n Delay*** setting.

Operation of the negative phase sequence voltage elements can be inhibited from:

Inhibit 47-n A binary or virtual input.

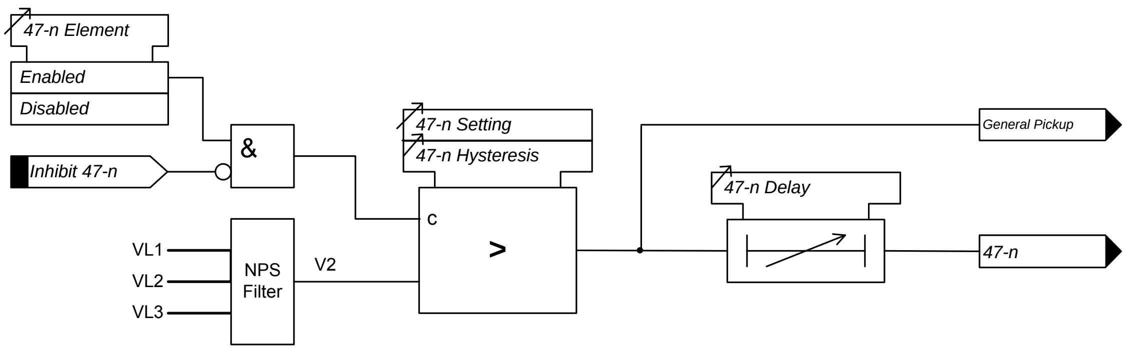


Figure 3.11-1 Logic Diagram: NPS Overvoltage Protection (47)

3.12 Voltage Protection: Neutral Overvoltage (59N)

Two Neutral Overvoltage (or Neutral Voltage Displacement) elements are provided.

59N Voltage Source setting selects the source of the residual voltage to be measured. The voltage is measured directly from the Vx input or derived from the line voltages where suitable VT connections are present. The relay utilises fundamental voltage measurement values for this function.

One of the elements can be configured to be either definite time lag (DTL) or inverse definite minimum time (IDMT),

59NIT Setting sets the pick-up voltage level ($3V_0$) for the element.

An inverse definite minimum time (IDMT) can be selected using ***59NIT Char***. A time multiplier is applied to the characteristic curves using the ***59NIT Time Mult*** setting (M):

$$t_{op} = \left[\frac{M}{\left[\frac{3Vo}{Vs}\right] - 1} \right] s$$

Alternatively, a definite time lag delay (DTL) can be chosen using ***59NITChar***. When Delay (DTL) is selected the time multiplier is not applied and the ***59NIT Delay (DTL)*** setting is used instead.

An instantaneous or definite time delayed reset can be applied using the ***59NIT Reset*** setting.

The second element has a DTL characteristic. ***59NDT Setting*** sets the pick-up voltage ($3V_0$) and ***59NDT Delay*** the follower time delay.

Operation of the neutral overvoltage elements can be inhibited from:

Inhibit 59NIT	A binary or virtual input.
Inhibit59NDT	A binary or virtual input.

It should be noted that neutral voltage displacement can only be applied to VT arrangements that allow zero sequence flux to flow in the core i.e. a 5-limb VT or 3 single phase VTs. The VT primary winding neutral must be earthed to allow the flow of zero sequence current.

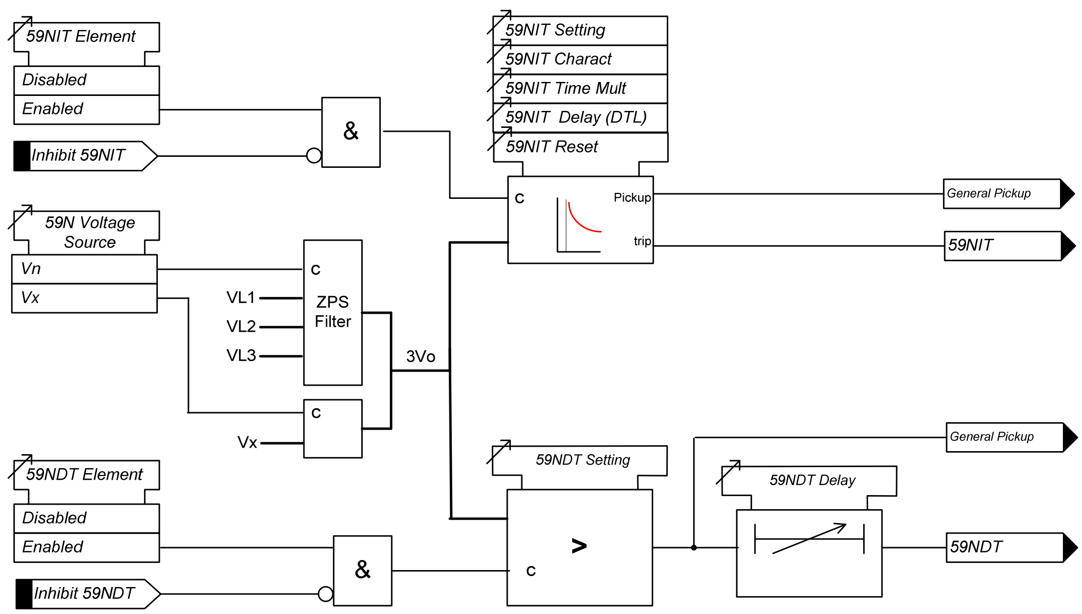


Figure 3.12-1 Logic Diagram: Neutral Overvoltage Element

3.13 Voltage Protection: Under/Over Frequency (81)

Four under/over frequency elements are provided.

The relay utilises fundamental voltage measurement values for this function. The frequency calculation is based on the highest input voltage derived from the voltage selection algorithm.

Frequency elements are blocked if all phase voltages fall below the ***81 U/V Guard*** setting.

The sense of the element (under-frequency or over-frequency) is set by the ***81-n Operation*** setting.

81-n Setting sets the pick-up voltage level for the element.

An output is given after elapse of the ***81-n Delay*** setting.

The ***81-n Hysteresis*** setting allows the user to vary the pick-up/drop-off ratio for the element.

Operation of the under/over voltage elements can be inhibited from:

Inhibit 81-n	A binary or virtual input.
81-n U/V Guarded	Under voltage guard element.

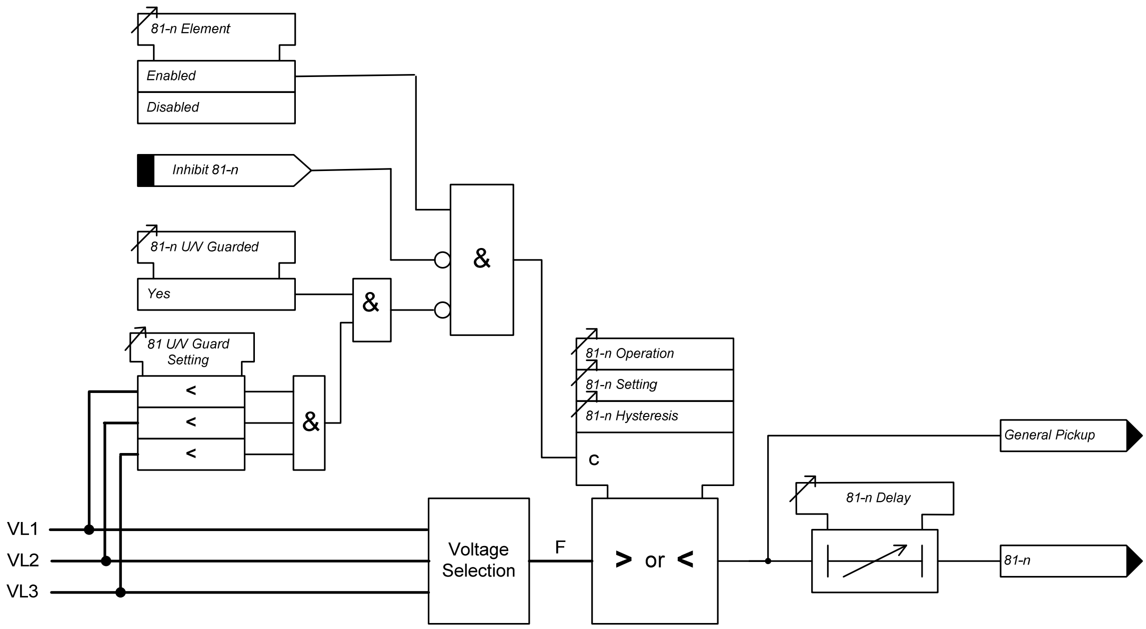


Figure 3.13-1 Logic Diagram: Under/Over Frequency Detector (81)

Section 4: Control & Logic Functions

4.1 Autoreclose (79)

4.1.1 Overview

A high proportion of faults on an Overhead Line (OHL) network are transient. These faults can be cleared and the network restored quickly by using Instantaneous (Fast) Protection trips followed by an automated sequence of CB reclosures after the line has been dead for a short time, this 'deadtime' allows the fault current arc to fully extinguish. Typically, this autoreclose (AR) sequence of Instantaneous Trip(s) and Reclose Delays (Dead times) followed by Delayed Trip(s) provides the automatic optimum method of clearing all types of fault i.e. both Transient and Permanent, as quickly as possible and achieving the desired outcome of keeping as much of the Network in-service as possible.

The AR function, therefore, has to: -

Control the type of Protection trip applied at each stage of a sequence

Control the Autoreclose of the Circuit Breaker to provide the necessary network Dead times, to allow time for Arc extinction

Co-ordinate its Protection and Autoreclose sequence with other fault clearing devices.

A typical sequence would be – 2 Instantaneous+1Delayed+HighSet Trips with 1 sec & 10 sec dead times.

The Autoreclose feature can be switched off if it is not required by the setting:

79 Autoreclose **ENABLE/DISABLE** (AUTORECLOSE CONFIG menu)

When the Autoreclose feature is enabled by the above setting, it may be switched in and out of service by a number of methods, these are:

A keypad change from the CONTROL MODE

Customer programmed function key (using Quick Logic)

Via the data communications channel(s),

From a ***79 OUT*** binary input. Note the ***79 OUT*** binary input has priority over the ***79 IN*** binary input - if both are raised the autoreclose will be Out of Service.

Knowledge of the CB position status is integral to the autoreclose functionality. CB auxiliary switches must be connected to ***CB Closed*** and ***CB Open*** binary inputs. A circuit breaker's service status is determined by its position i.e. from the binary inputs programmed ***CB Open*** and ***CB Closed***. The circuit breaker is defined as being in service when it is closed. The in service status has a drop-off delay of 2 sec, this delay is known as the circuit memory time. This functionality prevents autoreclosing when the line is normally de-energised, or normally open.

Autoreclose (AR) is started by a valid trip relay operation while the associated circuit breaker is in service.

The transition from AR started to deadtime initiation takes place when the CB has opened and the protection pickups have reset and the trip relay has reset. If check synchronising feature is included, the line or bus voltage must be detected as dead, unless the *Live Line Check* setting in the *Autoreclose Config* menu is set to *disabled*. If any of these do not occur within the ***79 Sequence Fail Timer*** setting the relay will Lockout. This prevents the AR being primed indefinitely. ***79 Sequence Fail Timer*** can be switched to **0** (= OFF).

Once an AR sequence has been initiated, up to 4 reclose operations can be attempted before the AR feature is locked-out. Number of recloses is determined by ***79 Num Shots***. Each reclosure (shot) is preceded by a time delay - ***79 Elem Deadtime n*** - giving transient faults time to clear. Separate dead-time settings are provided for each of the 4 recloses and for each of the four fault types – P/F, E/F, SEF and External.

Once a CB has reclosed and remained closed for a specified time period (the Reclaim time), the AR sequence is re-initialised and a Successful Close output issued. A single, common Reclaim time is used (***Reclaim Timer***).

When an autoreclose sequence does not result in a successful reclosure the relay goes to the lockout state.

Indications

The Instruments Menu includes the following meters relevant to the status of the Autoreclose and Manual Closing of the circuit breaker: -

Status of the AR sequence

AR Shot Count.

CB Open Countdown Timer

CB Close Countdown Timer

Inputs

External inputs to the recloser functionality are wired to the binary inputs. Functions which can be mapped to these binary inputs include: -

79 Out (edge triggered)

79 In (edge triggered)

CB Closed

CB Open

79 Ext Trip

79 Ext Pickup

79 Block Reclose

79 Lockout

79 Reset Lockout

Block Close CB

Close CB

79 Trip & Reclose

79 Trip & Lockout

79 Line Check

Hot Line In

Hot Line Out

Instantaneous Protection In/Out

Outputs

Outputs are fully programmable to either binary outputs or LEDs. Programmable outputs include: -

79 Out Of Service

79 In Service

79 In Progress

Sequence Fail

CB Close

79 Successful AR

79 Lockout

79 CloseOnFault

79 CB Close Fail

4.1.2 Autoreclose sequences

The CONTROL & LOGIC>AUTORECLOSE PROT'N and CONTROL & LOGIC>AUTORECLOSE CONFIG' menus, allow the user to set independent Protection and Autoreclose sequences for each type of fault i.e. Phase Fault (P/F), Earth Fault (E/F), Sensitive Earth Fault (SEF) or External Protections (EXTERN). Each Autoreclose sequence can be user set for up to four-shots i.e. five trips + four reclose sequence, with independently configurable type of Protection Trip, either Fast (**Inst**) or **Delayed** with associated ***Deadtime*** Delay time for each shot. The user has programming options for Autoreclose Sequences up to the maximum shot count i.e.:-

Inst or **Delayed** Trip 1 + (***DeadTime 1*: 0.1s-14400s**)

\+ **Inst** or **Delayed** Trip 2 + (***DeadTime 2:* 0.1s-14400s**)

\+ **Inst** or **Delayed** Trip 3 + (***DeadTime 3*: 0.1s-14400s**)

\+ **Inst** or **Delayed** Trip 4 + (***DeadTime 4*: 0.1s-14400s**)

\+ **Inst** or **Delayed** Trip 5 – Lockout.

The AR function recognizes developing faults and, as the shot count advances, automatically applies the correct type of Protection Trip and associated Dead time for that fault-type at that point in the sequence.

A typical sequence would consist of two **Inst** trips followed by at least one combined **Delayed** + HighSet (**HS**) Trip. This sequence enables transient faults to be cleared quickly by the **Inst** trip(s) and permanent fault to be cleared by the combined Delayed trip. The delayed trip must be 'graded' with other Recloser/CB's to ensure system discrimination is maintained, i.e. that as much of the system as possible is live after the fault is cleared.

A ***HS trips to lockout*** setting is provided such that when the number of operations of elements assigned as HS trips reach the setting the relay will go to lockout.

The number of Shots (Closes) is user programmable, note: - only one Shot Counter is used to advance the sequence, the Controller selects the next Protection characteristic/Dead time according to the type of the last Trip in the sequence e.g. PF, EF, SEF or EXTERNAL.

Reclose Dead Time

User programmable dead times are available for each protection trip operation.

The dead time is initiated when the trip output contact reset, the pickup is reset and the CB is open. Additionally, . if check synchronising feature is included, the line or bus voltage must be detected as dead, unless the *Live Line Check* setting in the *Autoreclose Config* menu is set to *disabled*.

The CB close output relay is energised after the dead time has elapsed.

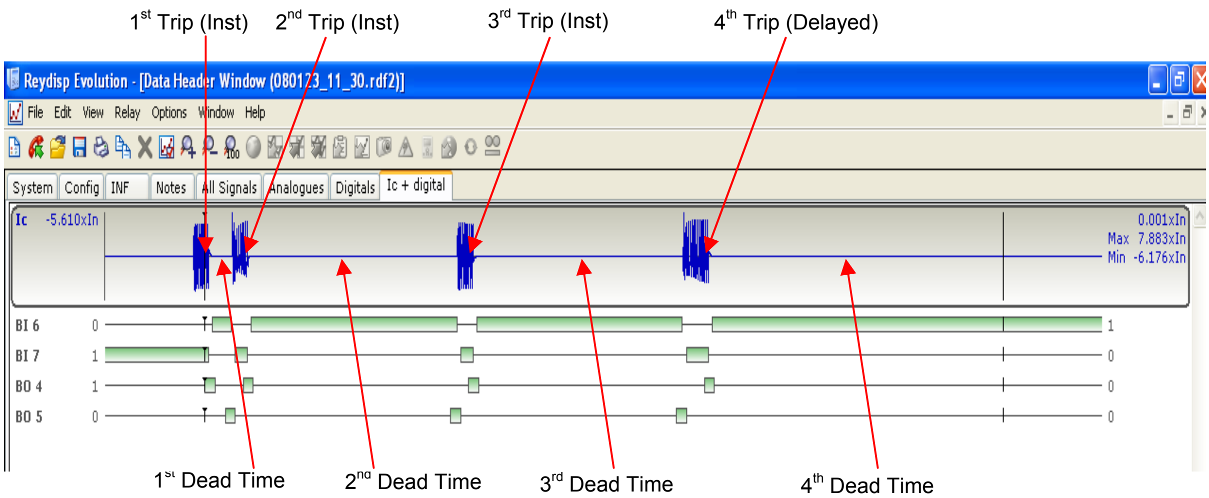


Figure 4.1-1 Typical Autoreclose Sequence with 3 Instantaneous and 1 Delayed trip

4.1.3 AUTORECLOSE PROT'N Menu

This menu presents the Overcurrent Protection elements available for each type of Fault i.e. P/F, E/F or SEF and allows the user to select those that are to be applied as **Inst trips**; those that are to be applied as **Delayed Trips**; and those that are to be applied as **HS Trips** (HighSet), as required by the selected sequence. There is no corresponding setting for External as the External protection type is not normally controlled by the Autoreclose Relay. The resultant configuration enables the Autoreclose function to correctly apply the required Protection for each shot in a sequence.

4.1.4 AUTORECLOSE CONFIG Menu

This menu allows the following settings to be made:-

79 Autoreclose **Enabled** turns ON all Autoreclose Functions.

79 Num Shots Sets the allowed number of Autoreclose attempts in a sequence.

79 Retry Enable **Enabled** configures the relay to perform further attempts to automatically Close the Circuit Breaker where the CB has initially failed to close in response to a Close command. If the first attempt fails the relay will wait for the ***79 Retry Interval*** to expire then attempt to Close the CB again.

79 Retry Attempts Sets the maximum number of retry attempts.

79 Retry Interval Sets the time delay between retry attempts.

79 Reclose Blocked Delay If the CB is not ready to receive a Close command or if system conditions are such that the CB should not be closed immediately e.g. a close-spring is not charged, then a Binary input mapped to **Reclose Block** can be raised and the Close pulse will not be issued but will be held-back. The ***79 Reclose Blocked Delay*** sets the time **Reclose Block** is allowed to be raised, if this time delay expires the Relay will go to Lockout. If Reclose Block is cleared, before this time expires, then the CB Close pulse will be issued at that point in time. Dead Time + Reclose Blocked Delay = Lockout.

79 Sequence Fail Timer Sets the time that AR start can be primed. Where this time expires before all the AR start signals are not received i.e. the CB has opened, protection pickups have reset and the trip relay has reset, the Relay goes to Lockout.

79 Minimum Lockout Delay Sets the time that the Relay's Lockout condition is maintained. After the last allowed Trip operation in a specific sequence the Circuit Breaker will be left locked-out in the open position and can only be closed by manual or remote SCADA operation. The ***79 Minimum Lockout Delay*** timer can be set to delay a too-fast manual close after lockout, this prevents an operator from manually closing onto the same fault too quickly and thus performing multiple sequences and possibly burning-out Plant.

79 Reset LO by Timer Set to **Enabled** this ensures that the Lockout condition is reset when the timer expires, Lockout indication will be cleared; otherwise, set to Disabled, the Lockout condition will be maintained until the CB is Closed by a Close command.

79 Sequence Co-Ord When set to **Enabled** the Relay will co-ordinate its sequence and shot count such that it automatically keeps in step with downstream devices as they advance through their sequence. The Relay detects that a pickup has operated but has dropped-off before its associated time delay has expired, it then increments its Shot count and advances to the next stage of the autoreclose sequence without issuing a trip, this is repeated as long as the fault is being cleared by the downstream device such that the Relay moves through the sequence bypassing the INST Trips and moving on to the Delayed Trip to maintain Grading margins.

79 Cold Load Action Set to Delayed will inhibit all instantaneous protection elements when Cold Load settings are being used.

79 Live Line Checking will set such that it will stop the autoreclose sequence before the Deadtime is started if neither the line nor bus voltages become dead following the trip. This can be used as a check that the remote end circuit breaker is tripped before proceeding with the sequence on a ring connected system. If this check is not required, the *79 Live Line Check* setting should be set to *disabled*.

79 Check Synchronising during the Deadtime will start the Check Synchronising before the completion of the deadtime if the dead state of the line or bus becomes live during the deadtime. This restoration of Live voltage state indicates that the remote end circuit breaker has reclosed and therefore it is not necessary to delay the CB close until the deadtime expires. This feature can be disabled if it is not required.

79 LO Line VT Fail will Lockout the autoreclose feature if the Line voltage is dead whilst the Bus voltage is live when the circuit breaker is closed.

79 LO Bus VT Fail will Lockout the autoreclose feature if the Bus voltage is dead whilst the Line voltage is live when the circuit breaker is closed.

Notes on the 'Lockout' State

The Lockout state can be reached for a number of reasons. Lockout will occur for the following: -

1. 79 Sequence Fail Timer**.**
2. **At the end of the** At the end of the *Reclaim timer* if the CB is in the open position.
3. A protection operates during the final Reclaim time.
4. If a Close Pulse is given and the CB fails to close.
5. The *79 Lockout* binary input is active.
6. At the end of the *79 Reclose Blocked Delay* due to presence of a persistent Block signal.
7. When the *79 Elem HS Trips to Lockout* count is reached.
8. **When the** 79 Elem Delayed Trips to Lockout **count is reached.**

Once lockout has occurred, an alarm (***79 Lockout***) is issued and all further Close commands, except manual close, are inhibited.

If the Lockout command is received while a Manual Close operation is in progress, the feature is immediately locked-out.

Once the Lockout condition has been reached, it will be maintained until reset. The following will reset lockout: -

1. By a Manual Close command, from fascia, comms or *Close CB* binary input.
2. By a *79 Reset Lockout* binary input, provided there is no signal present that will cause Lockout.
3. At the end of the *79 Minimum LO Delay* time setting if *79 Reset LO by Timer* is selected to ENABLED, provided there is no signal present which will cause Lockout.
4. Where Lockout was entered by an A/R Out signal during an Autoreclose sequence then a *79 In* signal must be received before Lockout can reset.
5. By the *CB Closed* binary input, provided there is no signal present which will cause Lockout.
6. The Lockout condition has a delayed drop-off of 2s.

4.1.5 P/F SHOTS sub-menu

This menu allows the Phase fault trip/reclose sequence to be parameterized:-

79 P/F Prot’n Trip1 The first protection Trip in the P/F sequence can be set to either **Inst** or **Delayed.**

79 P/F Deadtime 1 Sets the first Reclose Delay (Dead time) in the P/F sequence.

79 P/F Prot’n Trip2 The second protection Trip in the P/F sequence can be set to either **Inst** or **Delayed.**

79 P/F Deadtime 2 Sets the second Reclose Delay (Dead time) in the P/F sequence.

79 P/F Prot’n Trip3 The third protection Trip in the P/F sequence can be set to either **Inst** or **Delayed.**

79 P/F Deadtime 3 Sets the third Reclose Delay (Dead time) in the P/F sequence.

79 P/F Prot’n Trip 4 The fourth protection Trip in the P/F sequence can be set to either **Inst** or **Delayed.**

79 P/F Deadtime 4 Sets the fourth Reclose Delay (Dead time) in the P/F sequence.

79 P/F Prot’n Trip5 The fifth and last protection Trip in the P/F sequence can be set to either **Inst** or **Delayed.**

79 P/F HighSet Trips to Lockout Sets the number of allowed HighSet trips. The relay will go to Lockout on the last HighSet Trip. This function can be used to limit the duration and number of high current trips that the Circuit Breaker is required to perform, if the fault is permanent and close to the Circuit Breaker then there is no point in forcing a number of Delayed Trips before the Relay goes to Lockout – that sequence will be truncated.

79 P/F Delayed Trips to Lockout Sets the number of allowed Delayed trips, Relay will go to Lockout on the last Delayed Trip. This function limits the number of Delayed trips that the Relay can perform when the Instantaneous protection Elements are externally inhibited for system operating reasons - sequences are truncated.

4.1.6 E/F SHOTS sub-menu

This menu allows the Earth Fault trip/reclose sequence to be parameterized:-

As above but E/F settings.

4.1.7 SEF SHOTS sub-menu

This menu allows the Sensitive Earth trip/reclose sequence to be parameterized:-

As above but SEF Settings, Note: - SEF does not have HighSets

4.1.8 EXTERN SHOTS sub-menu

This menu allows the External Protection autoreclose sequence to be parameterized:-

79 P/F Prot'n Trip1 **Not Blocked/Blocked** - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's Trip Output.

79 P/F Deadtime 1 Sets the first Reclose Delay (Deadtime) for the External sequence.

79 P/F Prot'n Trip2 **Not Blocked/Blocked** - Blocked raises an output which can be mapped to a Binary Output to Block an External Protection's second Trip output.

79 P/F Deadtime 2 Sets the second Reclose Delay (Deadtime) in the External sequence.

79 P/F Prot'n Trip3 **Not Blocked/Blocked -** Blocked raises an output which can be mapped to a Binary output to Block an External Protection's third Trip Output.

79 P/F Deadtime 3 Sets the third Reclose Delay (Deadtime) in the External sequence.

79 P/F Prot'n Trip4 **Not Blocked/Blocked** - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's fourth Trip Output.

79 P/F Deadtime 4 Sets the fourth Reclose Delay (Deadtime) in the External sequence.

79 P/F Prot'n Trip5 **Not Blocked/Blocked** - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's fifth Trip Output.

79 P/F Extern Trips to Lockout - Sets the number of allowed External protection' trips, Relay will go to Lockout on the last Trip.

These settings allow the user to set-up a separate Autoreclose sequence for external protection(s) having a different sequence to P/F, E/F or SEF protections. The ***' Blocked '*** setting allows the Autoreclose sequence to raise an output at any point in the sequence to Block further Trips by the External Protection thus allowing the Overcurrent P/F or Earth Fault or SEF elements to apply Overcurrent Grading to clear the fault.

Other Protection Elements in the Relay can also be the cause of trips and it may be that Autoreclose is required; the External Autoreclose sequence can be applied for this purpose. By setting-up internal Quick Logic equation(s) the user can define and set what should occur when any one of these other elements operates.

Note: If the 'CB Total Trip Count' or the 'CB Frequent Ops Count' target is reached the relay will do one delayed tip and lockout*.

*NB: If Delayed Trips are not assigned in the AUTORECLOSE PROT'N menu the relay will not trip.

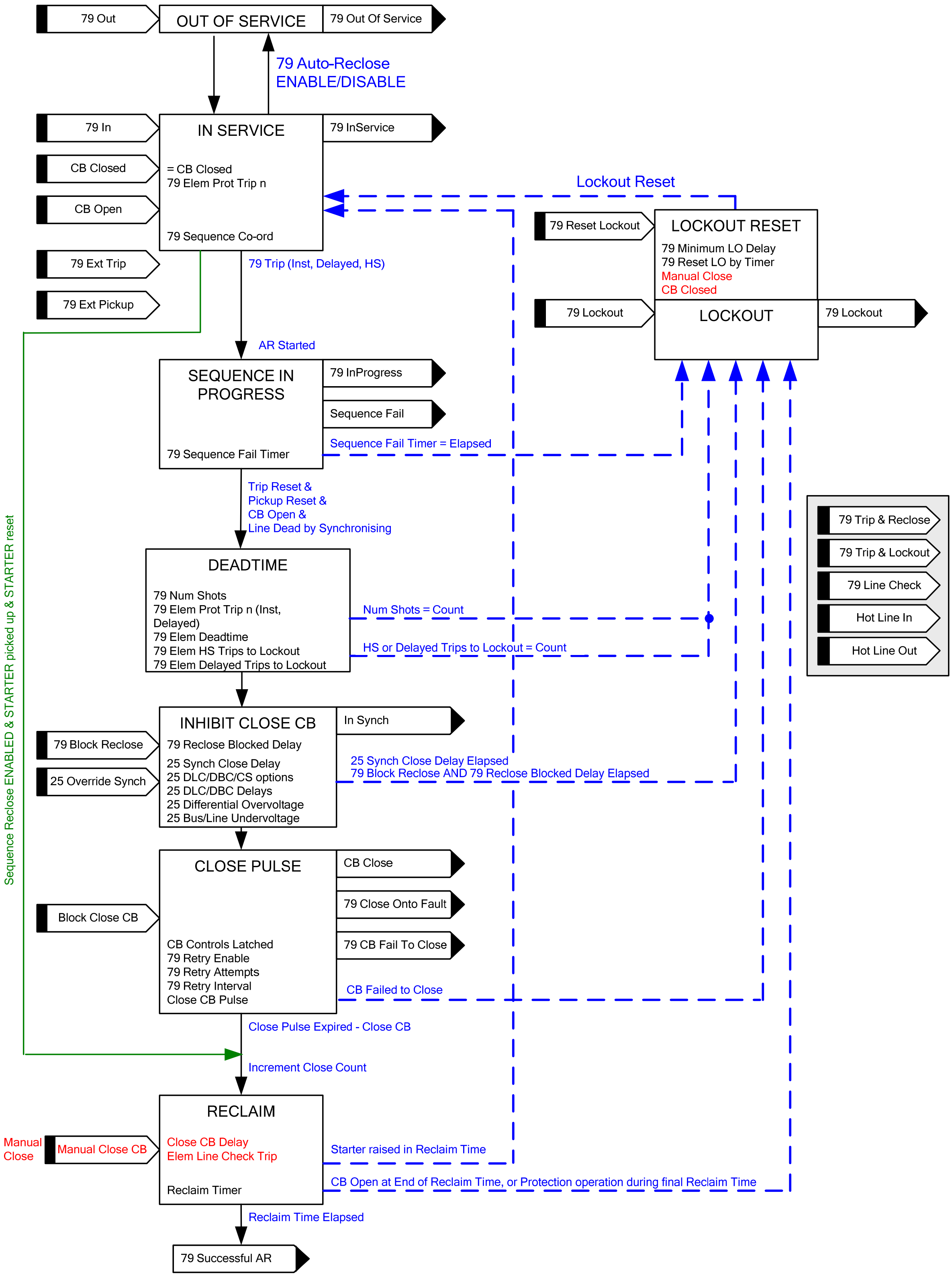


Figure 4.1-2 Basic Autoreclose Sequence Diagram

4.2 Manual Close

A Manual Close Command can be initiated in one of four ways: via a ***Close CB*** binary input, via the data communication Channel(s), from the relay CONTROL MODE menu or from the relay fascia function keys. It causes an instantaneous operation via ***79MC Close CB*** binary output, over-riding any autoreclose (AR) sequence in progress. When check syncronising is used, the manual close operation is performed using mode settings which are independent of those of the 79 autoreclose.

Repeated Manual Closes are avoided by checking for Positive edge triggers. Even if the Manual Close input is constantly energised the relay will only attempt one close.

A Manual Close will initiate ***Line Check*** if enabled. If a fault appears on the line during the Close Pulse or during the Reclaim Time with Line Check enabled, the relay will initiate a Trip and Lockout. This prevents a CB being repeatedly closed onto a faulted line. Where ***Line Check*** = **DELAYED** then instantaneous protection is inhibited until the reclaim time has elapsed.

Manual Close resets Lockout, if the conditions that set Lockout have reset i.e. there is no trip or Lockout input present.

Manual Close cannot proceed if there is a Lockout input present.

With the Autoreclose function set to Disabled the Manual Close control is still active.

4.3 Synchronising

The optional Synchronising function is used to check that the voltage conditions, measured by the voltage transformers on either side of the open circuit breaker, indicate that it is safe to close without risk of damage to the circuit breaker of disturbance to the system. The timing of closure, for charging lines which are dead following fault clearance, is controlled to co-ordinate with other devices.

The window of time in which voltage conditions must be met is applied as a setting or can be disabled such that an indefinite period is allowed.

4.3.1 Reclosure Modes

The Synchronising element can be set to allow the autoreclose sequence to proceed for various system voltage conditions. The voltage conditions selected must be met within the *Synch Close Window* time which is settable and starts at the end of the deadtime for autoreclose or the receipt of a Close CB command.

The voltage applied to the V_4 input is considered to be the BUSBAR voltage and the voltages applied to inputs V_1,V_2 & V_3 are the LINE voltage.

79 Dead Bar Charge, when set to Enabled, allows AR to proceed when the Busbar voltage is live and the Line is dead.

Manual Close DBC, when set to Enabled, allows MC to proceed when the Busbar voltage is live and the Line is dead.

79 Dead Line Charge, when set to Enabled, allows AR to proceed when the Line voltage is live and the Busbar is dead.

Manual Close DLC, when set to Enabled, allows MC to proceed when the Line voltage is live and the Busbar is dead.

79 Dead Line & Dead Bar Close, when set to Enabled, allows AR to proceed when the Line voltage and the Busbar voltage are dead.

Manual Close DLDB, when set to Enabled, allows MC to proceed when the Line voltage and the Busbar voltage are dead.

79Check Sync Close, when set to Enabled, allows AR to proceed when both the Line and Busbar are considered live AND other synchronising requirements are met.

Manual Close CS, when set to Enabled, allows MC to proceed when both the Line and Busbar are considered live AND other synchronising requirements are met.

79 Unconditional Close, when set to Enabled, allows AR to proceed regardless of the voltage condition of the Bus or Line.

Unconditional Manual Close, when set to Enabled, allows MC to proceed regardless of the voltage condition of the Bus or Line.

Separate Enable/Disable settings are thus provided for each option for Autoreclose and Manual Close.

4.3.2 Charge Delays

Separate delay settings are provided for Dead Line Charge and Dead Bus Charge closure. These are applied after the autoreclose Dead Time when voltage conditions are checked and met, at the Close Inhibit stage of the sequence. This feature effectively allows the dead time to be set differently for faults on each side of the recloser.

4.3.3 Voltage monitoring elements

The single phase voltage source used for synchronising can be selected as any phase to phase or phase to earth voltage for flexibility. The voltage is compared to the corresponding voltage from the three phase arrangement on the other side of the circuit breaker. Voltage settings are set as a percentage of the nominal voltage specified in the CT/VT Config menu.

Voltage detectors

Voltage detectors determine the status of the line or bus. If the voltages on either the line or bus are below a set threshold level they can be considered to be 'dead'. If the voltages are within a setting band around the nominal voltage they are classed as 'live'. Independent voltage detectors are provided for both line and bus.

If a voltage is in the dead band range then it will be classed as dead until it has reached the live band area. Similarly, if a voltage is live, it continues to be live until it has reached the dead band area. This effectively allows for variable amounts of hysteresis to be set. Figure 4.3-1 illustrates the voltage detector operation.

Note: the area between the dead and live zones is not indeterminate. When any voltage is applied to the relay it will ramp up the software RMS algorithm and always pass through the dead zone first.

A wide range is provided for live and dead voltage detector levels but the live and dead zones must not overlap.

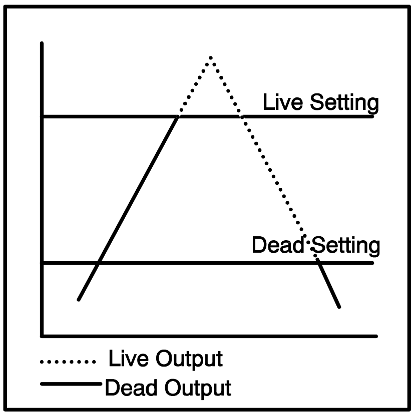


Figure 4.3-1 Voltage Detector Operation

Under-voltage detectors

The under-voltage detectors, if enabled, can block a close output command if either the line voltage or the bus voltage is below the under-voltage setting value. Both line and bus have their own independent settings.

Differential voltage detectors

The differential voltage detector, if enabled, can block a close output command if the difference between the line and bus voltages is greater than the differential voltage setting value.

4.3.4 Sync Override Logic

For certain switching operations, a means of bypassing the Check Synchronisation function is provided. This is provided by separate binary inputs for 79 Override Sync and Man Override Sync.

4.3.5 Check Synchronising Mode

The *MOS On/Off* input is provided to bypass the voltage and synchronising checks to provide an emergency close function. Similarly, check synchronising can be overridden by the *79 OS On/Off* input during autoreclose. *MOS On/Off* can be set by binary inputs, Control commands and the function keys.

For the relay to issue a Check Sync Close the following conditions have to be met :

The Line and Bus voltages must both be considered live.

25 Check Sync Angle – the phase difference between the line and bus voltages has to be less than the phase angle setting value. Whilst within the limits the phase angle can be increasing or decreasing and the element will still issue a valid close signal.

25 Check Sync Slip Freq, [if enabled] – the frequency difference between line and bus has to be less than the slip frequency setting value.

25 Check Sync Timer, [if enabled] – the phase angle and voltage blocking features have to be within their parameters for the length of the slip timer setting. If either the phase angle or the voltage elements fall outside of their limits the slip timer is reset. If they subsequently come back in then the slip timer has to time out before an output is given. (This ensures that a close output will not be given if there is a transient disturbance on the system due to e.g. some remote switching operations).

25 Line Undervolts, [if enabled] – the line voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

25 Bus Undervolts, [if enabled] – the bus voltage has to be above the bus under-voltage setting value and also above 5V for an output to be given.

25 Volt Differential, [if enabled] – the difference between the line and bus voltages has to be less than the differential voltage detector setting value for an output to be given.

The synchronising is always started in the Check Synchronising mode of operation and the Check Synchronising limits are applied. To proceed to System Synchronisation a system split must be detected as described in section 4.3.6

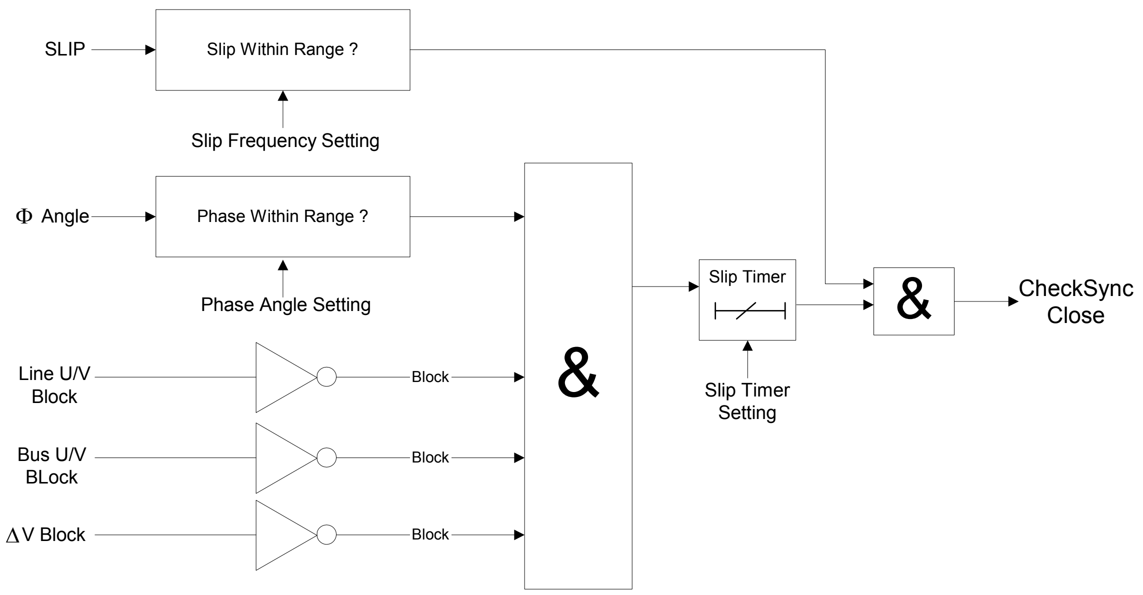


Figure 4.3-2 Check Sync Function

4.3.6 System Split Detector

A system split occurs where part of the system becomes islanded and operates separately. Under these conditions the frequencies of the voltages either side of the breaker are asynchronous and therefore high phase angle differences can occur as the voltage phasors slip past each other.

The decision to change to System Split settings, apply Close on Zero function, Lockout or ignore, during autoreclose and manual closing is set separately by the *25 DAR Split Mode* and *25 MC Split Mode settings*. The

System Split condition is detected when either the measured phase difference angle exceeds the pre-set *25 Slip Angle* value or if the slip frequency exceeds a pre-set *25 Split Slip* rate based on the selection of *25 System Split Mode.*

Note : the system split setting is effectively an absolute value and therefore a split will occur at the value regardless of the direction of the frequency slip e.g. if an angle of 170° is selected, then starting from 0°, a split will occur at +170° or -170° (effectively +190°).

If a system split occurs during an autoreclose Check Sync operation, with *25 System Sync* set to *Enabled*, the following events occur:

A System Split event is recorded.

The split flag can be mapped to an output relay for alarm indication.

The system split LED will stay on for a minimum time, or can be latched using non self reset LEDs.

If the *25 DAR Split Mode is set to CS,* Check Sync will continue

If the *25 DAR Split Mode* setting has been set to *SS*, the System Sync function is started.

If the *25 DAR Split Mode* has been set to LOCKOUT, then, a system split LED indication is given. The relay will stay in this lockout mode until one of the following methods of resetting it is performed

1. The relay is reset from Lockout by binary input or a command.
2. The CB is manually closed

4.3.7 System Sync Reversion

If the close conditions of System Sync are not met and a zero slip condition is subsequently detected, by the slip falling below the *25 Split Slip* setting, the relay will exit from System Sync mode and revert to Check Synchronising mode. The reversion allows the device to use the wider Check Sync parameters, to allow a close following the restoration of normal operation when the islanded network has been reconnected to the main network by successful reclosure of a parallel connection.

4.3.8 System Synchronising Mode

For the relay to issue a System Sync Close the following conditions have to be met :

Both the Bus and Line voltages must be considered Live by the Voltage Monitoring elements.

25 System Sync Angle – the phase difference between the line and bus voltages has to be less than the phase angle setting value **and the phase angle has to be decreasing** before the element will issue a valid close signal.

25 System Sync Slip, [if Enabled] – the frequency difference between line and bus has to be less than the slip frequency setting value. Slip frequency must be above the *25 Split Slip* setting to avoid reversion to Check Synchronising conditions. The settings for *25 System Sync Slip* and *25 Split Slip* must differ by at least 20mHz.

25 System Sync Timer, [if Enabled] – the phase angle and voltage blocking features have to be within their parameters for the length of the slip timer setting. If either the phase angle or the voltage elements fall outside of their limits the slip timer is reset. If they subsequently come back in then the slip timer has to time out before an output is given. (This ensures that a close output will not be given if there is a transient disturbance on the system due to e.g. some remote switching operations).

25 Line Undervolts, [if Enabled] – the line voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

25 Bus Undervolts, [if Enabled] – the bus voltage has to be above the line under-voltage setting value and also above 5V for an output to be given.

25 Volt Differential, [if Enabled] – the difference between the line and bus voltages has to be less than the □V detector setting value for an output to be given.

The System Synchronising operation of the relay will only be started after a System Split is detected as described in section 4.3.6 during an autoreclose or manual close sequence.

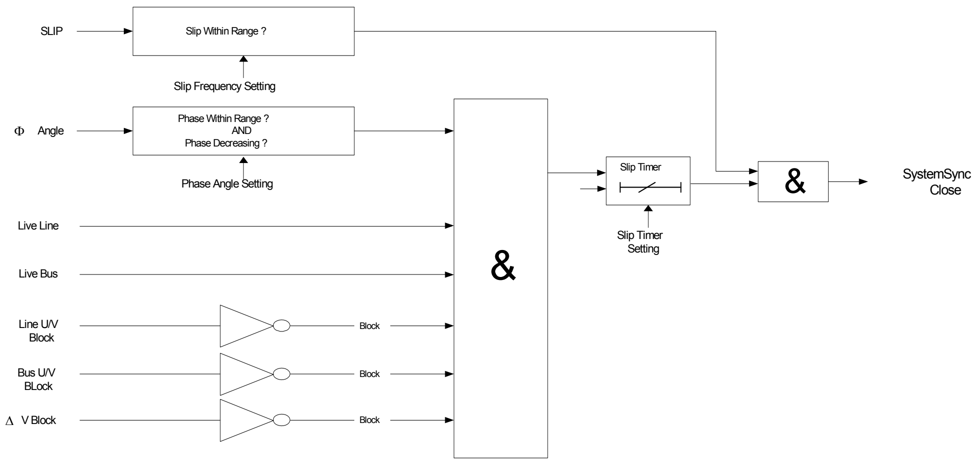


Figure 4.3-3 System Sync Function

4.3.9 Close on Zero Mode

If the *25 DAR Split Mode* or *25 MC Split Mode* is set *to COZ* the relay will apply a Close On Zero to the respective closing operation if the synchronising mode changes to System Split. The measured slip frequency and the measured phase difference are used to provide a Close Pulse which will close the CB when the phase difference is reducing and timed with the setting *25 CB Close Time* such that the instant of closure is when the phase difference is zero. The slip frequency must be less than the *25 COZ Slip Freq* but greater than the *25 Split Slip* setting to avoid reversion to Check Synchronising conditions.

Since this feature is part of the System Synchronising function, *25 System Sync* must also be set to *Enabled*.

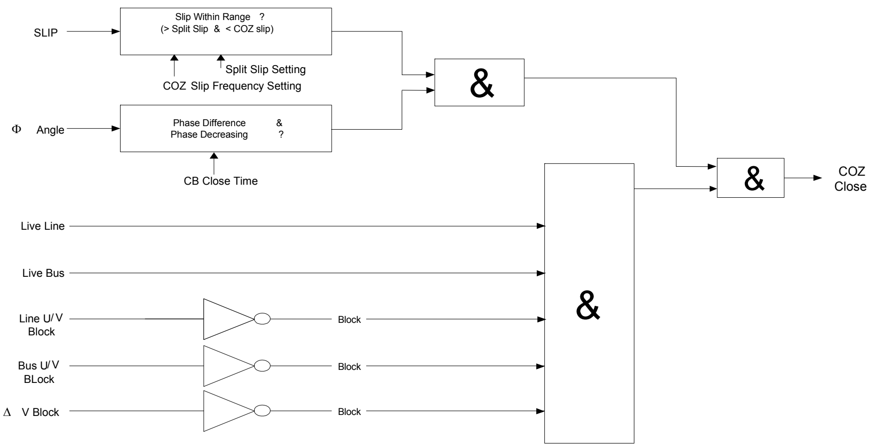
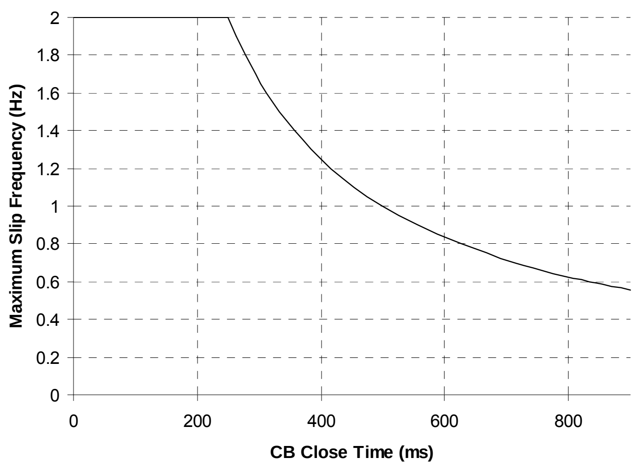


Figure 4.3-4 Cloze On Zero Function

Close on Zero will not be accurate if slow CB times are applied in conjunction with fast slip rates during testing. Practical application limits are shown below



4.4 Circuit Breaker

This menu includes relay settings applicable to both manual close (MC) and autoreclose (AR) functionality.

CB Controls Latched

CB controls for closing and tripping can be latched i.e. until confirmation that the action has been completed i.e. binary input is edge triggered when latched.

Close CB Delay

The Close CB Delay is applicable to manual CB close commands received through a ***Close CB*** binary input or via the Control Menu. Operation of the ***79 MC Close CB*** binary output is delayed by the ***Close CB Delay*** setting.

Close CB Pulse

The duration of the ***CB Close Pulse*** is settable to allow a range of CBs to be used. The Close pulse will be terminated if any protection picks-up operates or a trip occurs. This is to prevent Close and Trip Command pulses existing simultaneously. A ***79 Close On Fault*** Output is given if a pick-up or trip operates during the Close Pulse. This can be independently wired to Lockout.

'CB Failed To Open and CB Failed to Close features are used to confirm that a CB has not responded correctly to each Trip and Close Command. If a CB fails to operate, the AR feature will go to lockout.

'79 CB Close Fail' is issued if the CB is not closed at the end of the close pulse, ***CB Close Pulse***.

Reclaim Timer

The 'Reclaim time' will start each time a Close Pulse has timed out and the CB has closed.

Where a protection pickup is raised during the reclaim time the relay advances to the next part of the reclose sequence.

The relay goes to the Lockout state if the CB is open at the end of the reclaim time or a protection operates during the final reclaim time.

Blocked Close Delay

The close command may be delayed by a ***Block Close CB*** signal applied to a binary input. This causes the feature to pause before it issues the CB close command and can be used, for example, to delay CB closure until the CB energy has reached an acceptable level. If the Block signal has not been removed before the end of the defined time, ***Blocked Close Delay***, the relay will go to the lockout state.

Open CB Delay

The Open CB Delay setting is applicable to CB trip commands received through an ***Open CB*** binary input or via the Control Menu. Operation of the ***Open CB*** binary output is delayed by the ***Open CB Delay*** setting.

Open CB Pulse

The duration of the CB open Command pulse is user settable to allow a range of CBs to be used.

CB Failed To Open is taken from the Circuit Breaker Failure Element.

CB Travel Alarm

The CB Open/CB Closed binary inputs are monitored. The relay goes to Lockout and an output can be given where a 0/0 condition exists for longer than the ***CB Travel Alarm*** setting.

An instantaneous output is given for a 1/1 state.

Hot Line In/Out

When ‘Hot Line’ is enabled all autoreclose sequences are inhibited and any fault causes an instantaneous trip to lockout.

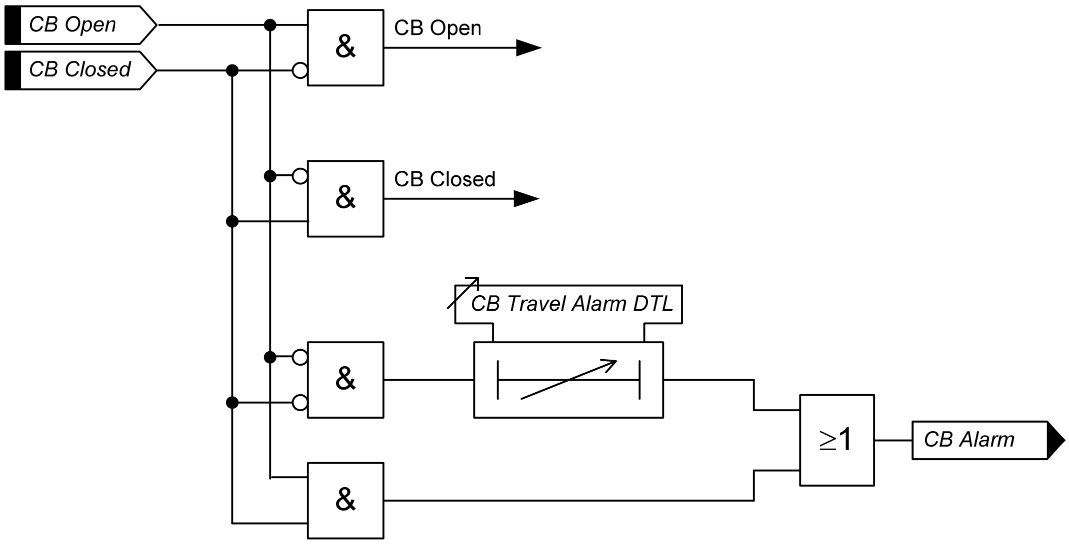


Figure 4.4-1 Logic Diagram: Circuit Breaker Status

4.5 Quick Logic

The 'Quick Logic' feature allows the user to input up to 16 logic equations (E1 to E16) in text format. Equations can be entered using Reydisp or at the relay fascia.

Each logic equation is built up from text representing control characters. Each can be up to 20 characters long. Allowable characters are:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9	Digit
( )	Parenthesis
!	'NOT' Function
.	'AND' Function
^	'EXCLUSIVE OR' Function
+	'OR' Function
E*n*	Equation (number)
F*n*	Function Key (number)
	'1' = Key pressed, '0' = Key not pressed
I*n*	Binary Input (number)
	'1' = Input energised, '0' = Input de-energised
L*n*	LED (number)
	'1' = LED energised, '0' = LED de-energised
O*n*	Binary output (number)
	'1' = Output energised, '0' = Output de-energised
V*n*	Virtual Input/Output (number)
	'1' = Virtual I/O energised, '0' = Virtual I/O de-energised

<u>Example Showing Use of Nomenclature</u>

***E1*= ((I1^F1).!O2)+L1**

Equation 1 = ((Binary Input 1 XOR Function Key 1) AND NOT Binary Output 2)

OR

LED 1

When the equation is satisfied (=1) it is routed through a pick-up timer (***En Pickup Delay***), a drop-off timer (***En Dropoff Delay***), and a counter which instantaneously picks up and increments towards its target (***En Counter Target***).

The counter will either maintain its count value ***En Counter Reset Mode*** = **OFF**, or reset after a time delay:

En Counter Reset Mode = **Single Shot**: The ***En Counter Reset Time*** is started only when the counter is first incremented (i.e. counter value = 1) and not for subsequent counter operations. Where ***En Counter Reset Time*** elapses and the count value has not reached its target the count value is reset to zero.

En Counter Reset Mode = **Multi Shot**: The ***En Counter Reset Time*** is started each time the counter is incremented. Where ***En Counter Reset Time*** elapses without further count increments the count value is reset to zero.

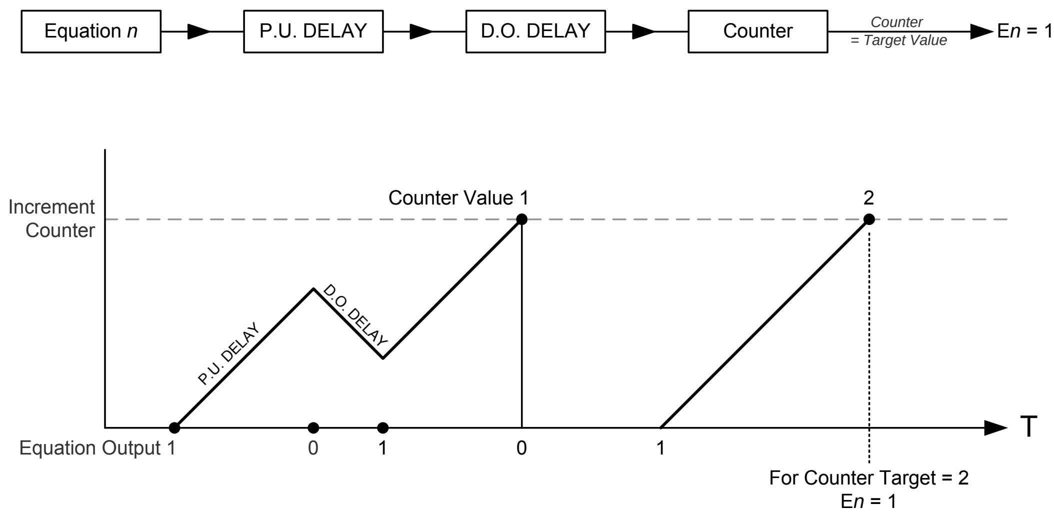


Figure 4.5-1 Sequence Diagram: Quick Logic PU/DO Timers (Counter Reset Mode Off)

When the count value = ***En Counter Target*** the output of the counter (En) = 1 and this value is held until the initiating conditions are removed when En is instantaneously reset.

The output of E*n* is assigned in the OUTPUT CONFIG>OUTPUT MATRIX menu where it can be programmed to any binary output (O), LED (L) or Virtual Input/Output (V) combination.

Protection functions can be used in Quick Logic by mapping them to a Virtual Input / Output.

Refer to Section 7 – Applications Guide for examples of Logic schemes.

Section 5: Supervision Functions

5.1 Circuit Breaker Failure (50BF)

The circuit breaker fail function has two time delayed outputs that can be used for combinations of re-tripping or back-tripping. CB Fail outputs are given after elapse of the ***50BF-1 Delay*** or ***50BF-2 Delay*** settings.

The circuit breaker fail protection time delays are initiated either from:

An output **Trip Contact** of the relay (MENU: OUTPUT CONFIG\BINARY OUTPUT CONFIG\Trip Contacts), or

A binary input configured **50BF Ext Trip** (MENU: INPUT CONFIG\BINARY INPUT MATRIX\50BF Ext Trip).

A binary or virtual input assigned to **50BF Mech Trip** (MENU: INPUT CONFIG\INPUT MATRIX\ 50BF Mech Trip).

CB Fail outputs will be issued providing any of the 3 phase currents are above the ***50BF Setting*** or the current in the fourth CT is above ***50BF-I4*** for longer than the ***50BF-n Delay*** setting, or for a mechanical protection trip the circuit breaker is still closed when the ***50BF-n Delay*** setting has expired – indicating that the fault has not been cleared.

Both ***50BF-1*** and ***50BF-2*** can be mapped to any output contact or LED.

If the ***50BF CB Faulty*** input (MENU: INPUT CONFIG\INPUT MATRIX\50BF CB Faulty) is energised when a CB trip is given the time delays ***50BF-n Delay*** will be by-passed and the output given immediately.

Operation of the CB Fail elements can be inhibited from:

Inhibit 50BF A binary or virtual input.

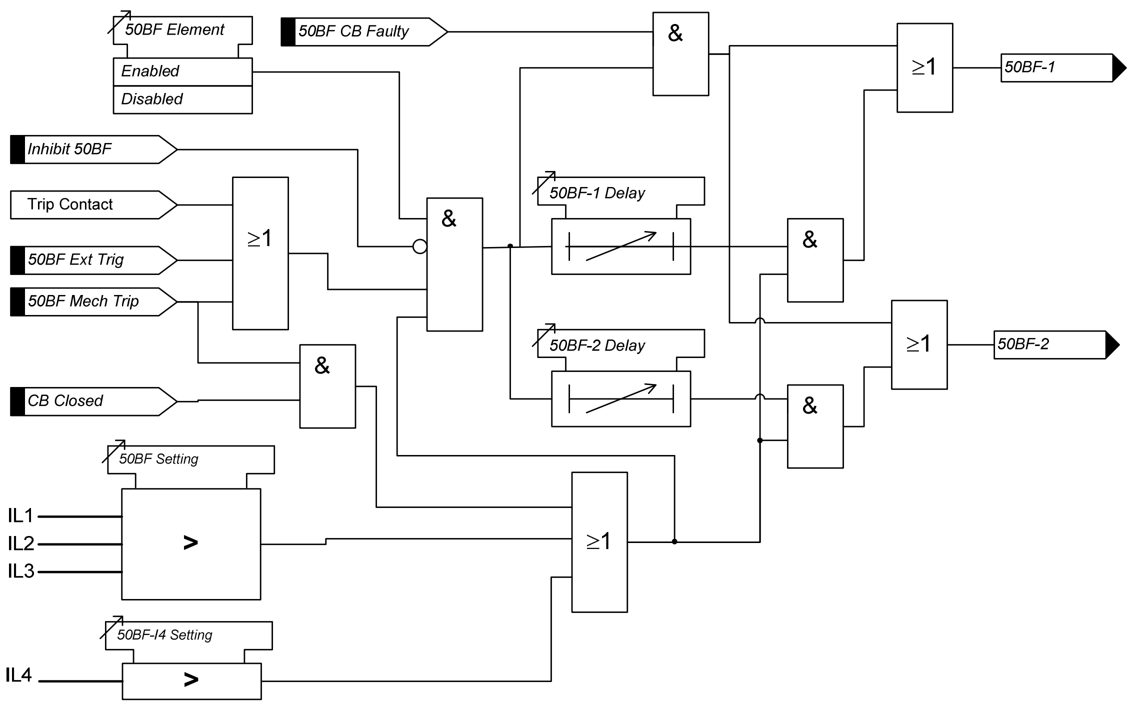


Figure 5.1-1 Logic Diagram: Circuit Breaker Fail Protection (50BF)

5.2 VT Supervision (60VTS)

1 or 2 Phase Failure Detection

Normally the presence of negative phase sequence (NPS) or zero phase sequence (ZPS) voltage in a power system is accompanied by NPS or ZPS current. The presence of either of these sequence voltages without the equivalent level of the appropriate sequence current is used to indicate a failure of one or two VT phases.

The ***60VTS Component*** setting selects the method used for the detection of loss of 1 or 2 VT phases i.e. **ZPS** or **NPS** components. The sequence component voltage is derived from the line voltages; suitable VT connections must be available. The relay utilises fundamental voltage measurement values for this function.

The element has user settings ***60VTS V*** and ***60VTS I.*** A VT is considered to have failed where the voltage exceeds ***60VTS V*** while the current is below ***60VTS I*** for a time greater than ***60VTS Delay***.

3 Phase Failure Detection

Under normal load conditions rated PPS voltage would be expected along with a PPS load current within the circuit rating. Where PPS load current is detected without corresponding PPS voltage this could indicate a three phase VT failure. To ensure these conditions are not caused by a 3 phase fault the PPS current must also be below the fault level.

The element has a ***60VTS*** V_{PPS} setting, an ***60VTS*** I_{PPS} ***Load*** setting and a setting for ***60VTS*** I_{PPS} ***Fault***. A VT is considered to have failed where positive sequence voltage is below ***60VTS*** V_{PPS} while positive sequence current is above I_{PPS} ***Load*** and below I_{PPS} ***Fault*** level for more than ***60VTS Delay*** then a VT failure will be detected.

External MCB

A binary input can be set as ***Ext_Trig 60VTS*** to allow the ***60VTS Delay*** element to be started from an external MCB operating.

Once a VT failure condition has occurred the output is latched on and is reset by any of the following:-

Voltage is restored to a healthy state i.e. above V_{PPS} setting while NPS voltage is below V_{NPS} setting.

Ext Reset 60VTS — A binary or virtual input, or function key and a VT failure condition no longer exists.

Inhibit 60VTS — A binary or virtual input.

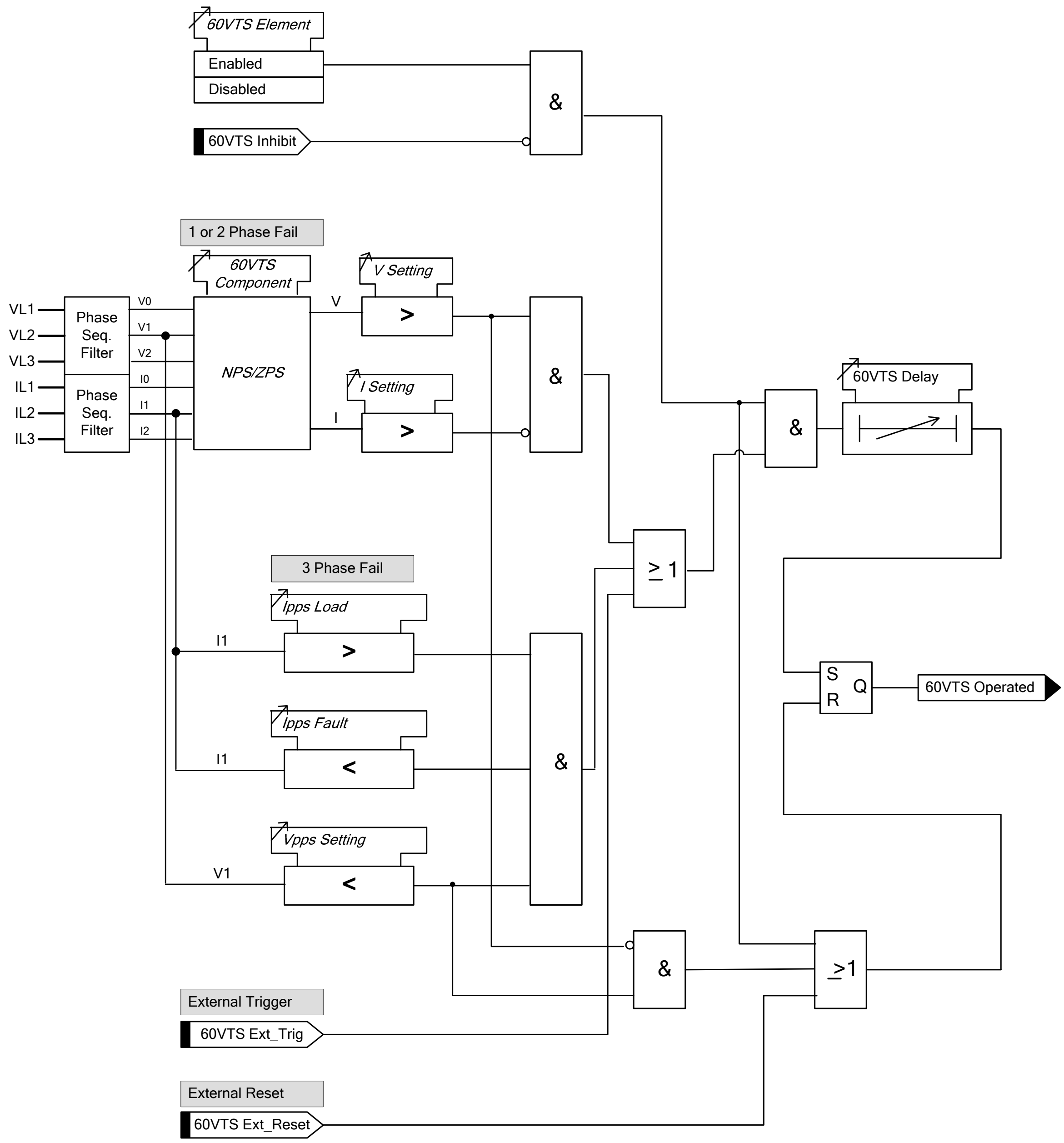


Figure 5.2-1 Logic Diagram: VT Supervision Function (60VTS)

5.3 Busbar VT Fail (60VTF-Bus)

When the optional synchronising function is fitted, the synchronising voltage transformer is utilised to provide an additional monitoring function to check the validity of the measured line and busbar voltages. When the circuit breaker is closed, both voltages should be either Live or Dead. If the Bus voltage indicates that the VT is Dead but the corresponding Line voltage is Live, this raises the Bus VT Fail output. A time delay setting is provided to avoid spurious operations during transient switching conditions. Additionally, this output can be enabled by a setting, *79 LO Bus VT Fail*, to apply a Lockout signal to the autoreclose function so that a sequence will not be attempted after a trip occurs if it is known that the voltage measurement is not reliable. A similar setting is available, *79 LO Line VT Fail,* which when Enabled will provide a Lockout for a Line VT failure detected by the *60VTS* function.

5.4 CT Supervision (60CTS)

Normally the presence of negative phase sequence (NPS) current in a power system is accompanied by NPS voltage. The presence of NPS current without NPS voltage is used to indicate a current transformer failure.

The element has a setting for NPS current level ***60CTS Inps*** and a setting for NPS voltage level ***60CTS Vnps*** If the negative sequence current exceeds its setting while the negative sequence voltage is below its setting for more than ***60CTS Delay*** then a CT failure output (***60CTS Operated***) is given.

Operation of the under/over voltage elements can be inhibited from:

Inhibit 60CTS A binary or virtual input.

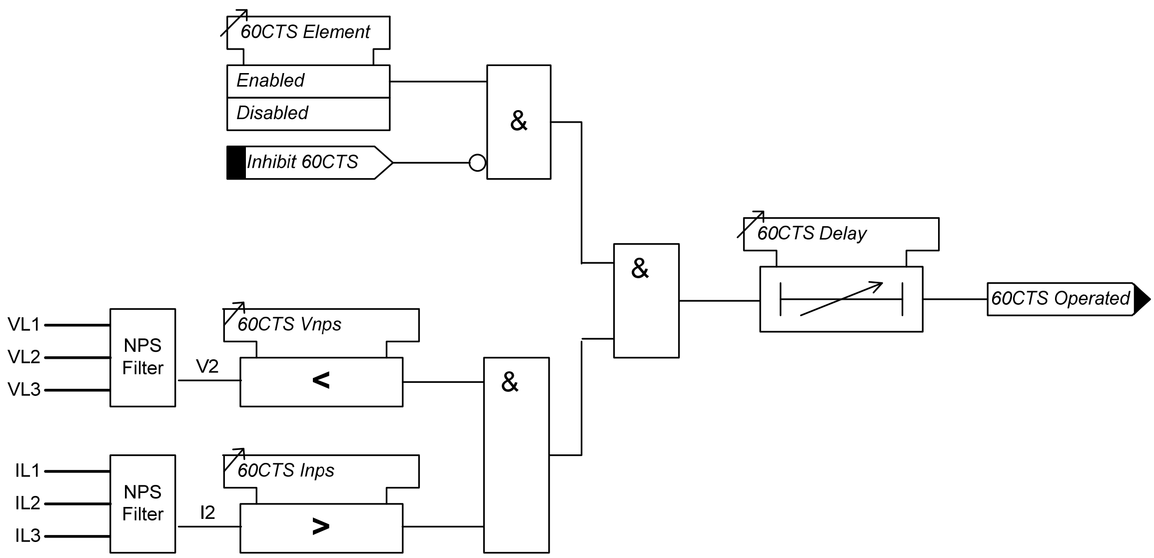


Figure 5.4-1 Logic Diagram: CT Supervision Function (60CTS)

5.5 Broken Conductor (46BC)

The element calculates the ratio of NPS to PPS currents. Where the NPS:PPS current ratio is above ***46BC Setting*** an output is given after the ***46BC Delay***.

The Broken Conductor function can be inhibited from

Inhibit 46BC	A binary or virtual input.

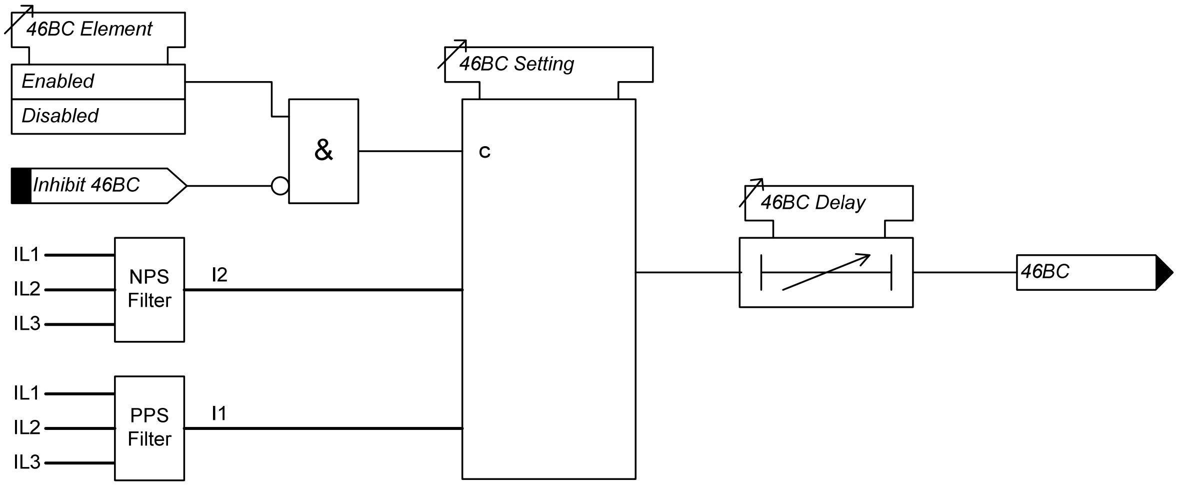


Figure 5.5-1 Logic Diagram: Broken Conductor Function (46BC)

5.6 Trip Circuit Supervision (74TCS)

The relay provides three trip circuit supervision elements.

One or more binary inputs can be mapped to ***74TCS-n.*** The inputs are connected into the trip circuit such that at least one input is energised when the trip circuit wiring is intact. If all mapped inputs become de-energised, due to a break in the trip circuit wiring or loss of supply an output is given.

The ***74TCS-n Delay*** setting prevents failure being incorrectly indicated during circuit breaker operation. This delay should be greater than the operating time of the circuit breaker.

The use of one or two binary inputs mapped to the same Trip Circuit Supervision element (e.g. 74TCS-n) allows the user to realise several alternative monitoring schemes – see 'Applications Guide'.

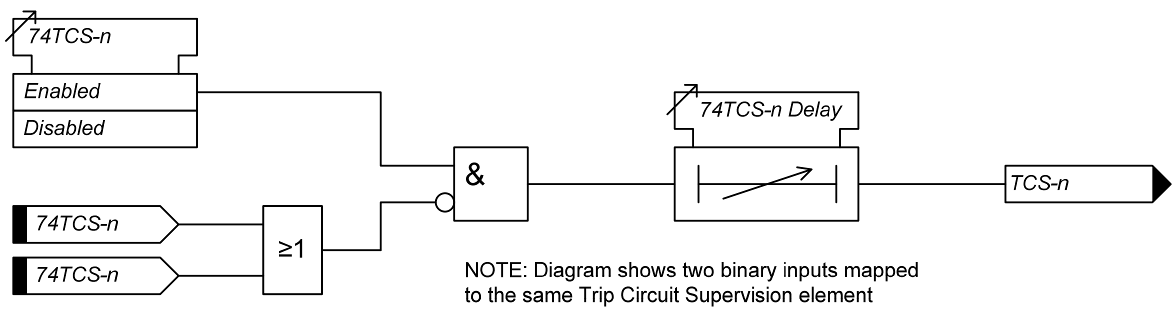


Figure 5.6-1 Logic Diagram: Trip Circuit Supervision Feature (74TCS)

5.7 Inrush Detector (81HBL2)

Inrush restraint detector elements are provided, these monitor the line currents.

The inrush restraint detector can be used to block the operation of selected elements during transformer magnetising inrush conditions.

The ***81HBL2 Bias*** setting allows the user to select between **Phase**, **Sum** and **Cross** methods of measurement:

Phase Each phase is inhibited separately.

Sum With this method the square root of the sum of the squares of the second harmonic in each phase is compared to each operate current individually.

Cross All phases are inhibited when any phase detects an inrush condition.

An output is given where the measured value of the second harmonic component is above the **81HBL2** setting.

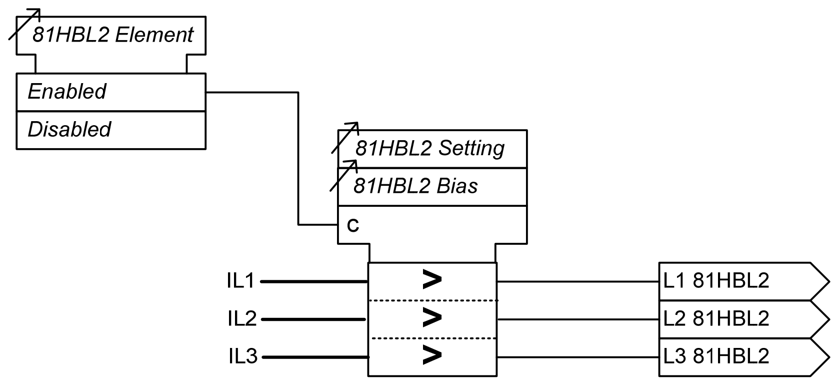


Figure 5.7-1 Logic Diagram: Harmonic Block Feature (81HBL2)

5.8 Battery Test

The DC battery voltage is constantly monitored by the relay. The output function ***Battery Healthy*** is provided to indicate that the battery charging system is connected and functioning correctly by measurement of the 'Float Charge' voltage level and comparison with the minimum float voltage based on the ***Battery Nominal Voltage*** setting.

In addition to this, the relay can be used to apply a loading test to the battery system at a settable periodic interval. The test sequence is shown below.

If a protection Pickup occurs at any time during the test, the test will be abandoned and the charging system re-connected. The battery voltage level will be maintained such that the Recloser will be capable of normal operation throughout the duration of the test. Battery tests can be executed at manual request from a binary input or from the Control Menu of the relay. If the time elapsed since the previous battery test is less than 12 hours, the test will not execute and Test Aborted will be displayed on the Battery Condition meter.

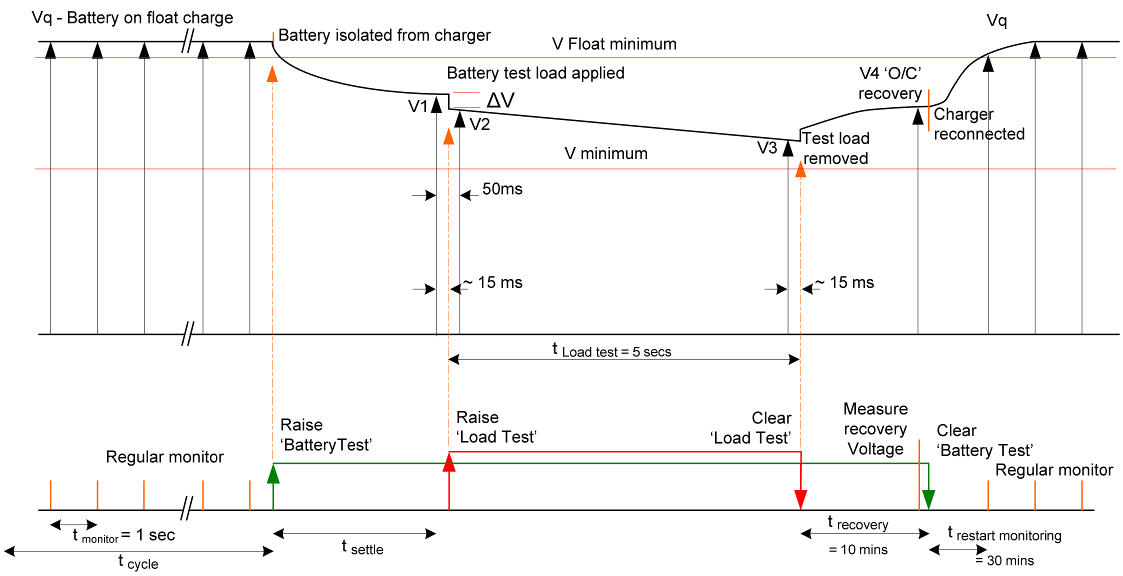


Figure 5.8-1 Battery Test timing diagram

When the test is required, the output ***Battery Test*** is raised to interface with external equipment. This signal is used to disconnect the charging system and the battery is allowed to settle for a fixed period of 30 minutes. The battery voltage with no load is then measured (V1) and the output ***Battery Load Test*** is then raised. This is used to connect the resistive load to the battery and the voltage is measured again after 500ms (V2). This voltage is used to asses the battery internal resistance and the resistance of connections. If V1-V2 (ΔV) is greater than the ***Battery Volts Drop*** setting the test will be considered as a failure and the test stopped, otherwise voltage is measured again after a further 5 seconds with the load resistance connected. This voltage, (V3), is compared to V2 and must not differ by more than 2 volts or the test will be stopped and recorded as a fail. The load is then disconnected, by the drop-off of the ***Battery Load Test*** output and a 10 minute recovery time applied before the voltage is measured again (V4). This voltage must not differ from the pre-test voltage by more than 0.5 volts or ***Recovery Fail*** output will be raised. The ***Battery Test*** output is now cleared which will reconnect the charging system to allow the system to return to normal. The quiescent voltage monitoring will resume after 30 minutes.

5.9 Capacitor Test

The actuator mechanism of the recloser can be driven from a charged capacitor network. The condition of the capacitors is monitored externally to the relay and the interface to the relay is in the form of two binary signals which are driven by undervoltage detectors as shown below. These inputs are ***CapMon Input 1*** and ***CapMon Input 2***.

In the quiescent state, both logical inputs should be in the '1' state and the detection of '0' on both inputs will trigger the ***CapacitorSupplyFail*** output.

In addition to the monitoring during quiescent conditions, the state of the inputs can be monitored to assess capacitor condition during an externally applied discharge test. When the ***Cap Element*** setting is Enabled, the sequence is executed automatically, 30 minutes after completion of a successful battery test. The sequence can be started manually on demand by energising the ***Capacitor Test*** binary input. If any protection element pickup occurs at any time during the capacitor test sequence, the sequence will be terminated.

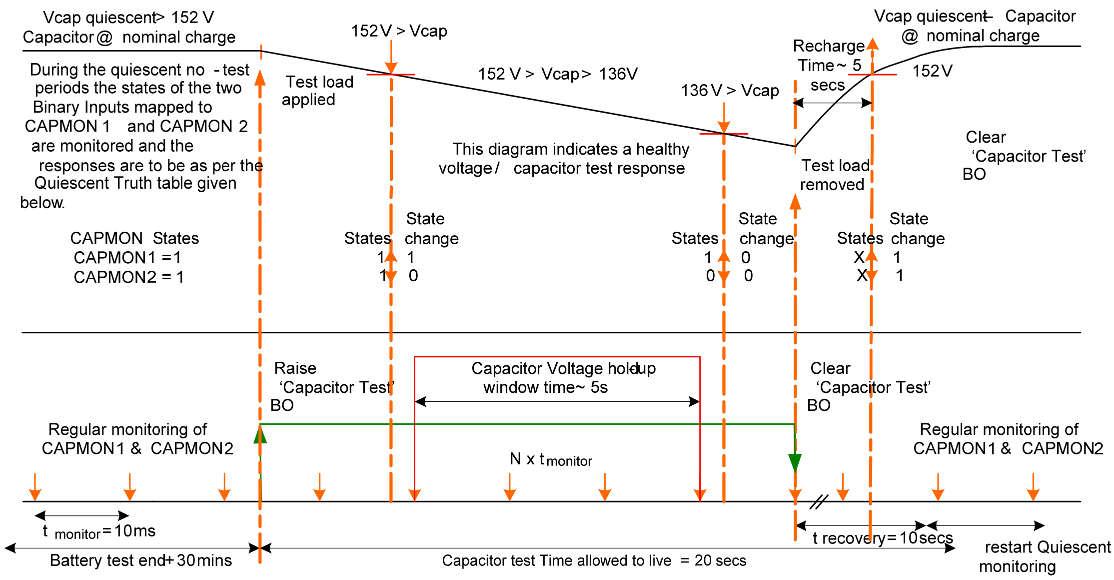


Figure 5.9-1 Capacitor Test timing diagram

When the test is required, the output ***Cap Test Active*** is raised. This is used externally to start the discharge test. When the voltage reduces to the higher voltage detector, the relay binary inputs ***CapMon Input 2*** will change to state '0' from the quiescent '1'. ***CapMon Input 1*** will remain at the '1' state. The relay recognises this 1-0 condition and starts a timer which runs for the ***Cap Holdup Time***. If the ***CapMon Input 1*** changes state to '0' during this time, the test is recorded as a fail and the relay goes to the recovery state as described below. If the timer expires with the 1-0 condition still maintained, the test is considered as a pass. The sequence now enters the recovery state and the ***Cap Test Active*** output is cleared causing the external discharge test to end The Capacitor voltage will now recover and the quiescent 1-1 state for ***CapMon Input 1*** and ***CapMon Input 2*** will be re-established. If the 1-1 state is not achieved at the end of the 10 second recovery time, the ***Cap Recovery Fail*** output and the ***Capacitor Only Trip*** output are raised and the reclose function of the relay are internally blocked. Normal continuous monitoring of the quiescent state will be resumed 10 seconds after the reset of the ***Cap Test Active*** output.

5.10 Power Quality (27S/59S)

Voltage sag (27S) and voltage swell (59S) elements monitor the power supply quality.

The elements monitor the deviation of the voltage from the nominal value and the duration of this under or over voltage in accordance with IEEE 1159.

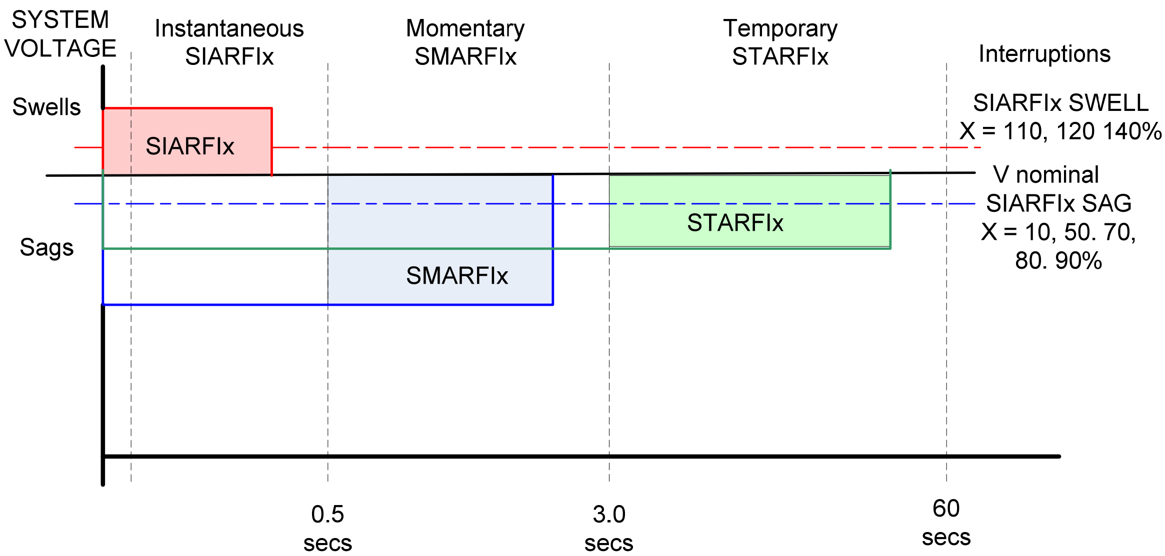


Figure 5.10-1 Sag and Swell Indices - IEEE 1159

5.11 Demand

Maximum, minimum and mean values of line currents and voltage (where applicable) are available as instruments which can be read in the relay INSTRUMENTS MENU or via Reydisp.

The ***Gn Demand Log Time Sync*** when set as **ENABLED** configures the Demand Log Update Period (see below) equal to the **DATA STORAGE >** ***Data Log Period*** setting.

The ***Gn Demand Log Update Period*** setting is used to define the time/duration after which the instrument is updated. The updated value indicates the maximum, minimum and mean values for the defined period. Note that this setting can be over-ridden by the ***Gn Demand Log Time Sync*** setting.

The ***Gn Demand Window*** setting defines the maximum period of time over which the demand values are valid. A new set of demand values is established after expiry of the set time.

The ***Gn Demand Window Type*** can be set to **FIXED** or **PEAK**.

> When set to **FIXED** the maximum, minimum and mean values demand statistics are calculated over fixed Window duration. At the end of each window the internal statistics are reset and a new window is started.
>
> When set to **PEAK** the maximum and minimum values within the ***Demand Window*** time setting is recorded.

Section 6: Other Features

6.1 Data Communications

Two communication ports, COM1 and COM2 are provided. RS485 connections are available on the terminal blocks at the rear of the relay (COM1). A USB port, (COM 2), is provided at the front of the relay for local access using a PC.

Other rear mounted communication ports are available as an optional extra - two fibre optic communication ports with ST connectors plus IRIG B (COM 3 and COM 4), a RS232 port plus IRIG B (COM 3) or a RS485 port plus IRIG B (COM 3).

Communication is compatible with Modbus-RTU, IEC60870-5-103 FT 1.2 and DNP 3.0 transmission and application standards.

For communication with the relay via a PC (personal computer) a user-friendly software package, Reydisp Evolution, is available to allow transfer of relay settings, waveform records, event records, fault data records, Instruments/meters and control functions. REYDISP EVOLUTION is compatible with IEC60870-5-103.

Data communications operation is described in detail in Section 4 of this manual.

6.2 CB Maintenance

Several CB trip operations counters are provided:

CB Total Trip Count:	Increments on each trip command issued. During an autoreclose sequence, when the target count is reached the relay will perform one Delayed Trip and lockout*.
CB Delta Trip Count:	Additional counter which can be reset independently of the Total Trip Counter. This can be used, for example, for recording trip operations between visits to a substation.
CB Count to AR Block:	Displays the number of CB trips experienced by the CB. When the target is reached the relay will only do 1 Delayed Trip to Lockout.
CB Frequent Ops Count	Logs the number of trip operations in a rolling window period of one hour. During an autoreclose sequence, when the target count is reached the relay will perform one Delayed Trip and lockout*.
CB LO Handle Ops	Displays the number of CB (lock out) LO Handle Ops experienced by the CB. When the target is reached the relay will only do 1 Delayed Trip to Lockout.

*NB: If Delayed Trips are not assigned in the AUTORECLOSE PROT'N menu the relay will not trip.

An I^2t counter is also included; this can provide an estimation of contact wear and maintenance requirements. The I^2t value at the time of trip is added to the previously stored value.

Binary outputs can be mapped to each of the above counters, these outputs are energised when the user defined ***Count Target*** or ***Alarm Limit*** is reached.

The counters do not increment for manual operations.

6.3 Output Matrix Test

The feature is only visible from the Relay fascia and allows the user to operate the relays functions. The test of the function will automatically operate any Binary Inputs or LED's already assigned to that function.

Any protection function which is enabled in the setting menu will appear in the Output Matrix Test.

6.4 Data Storage

6.4.1 General

The relay stores three types of data: relay event records, analogue/digital waveform records and fault records. Data records are backed up in non-volatile memory and are permanently stored even in the event of loss of auxiliary d.c. supply voltage.

6.4.2 Event Records

The event recorder feature allows the time tagging of any change of state (Event) in the relay. As an event occurs, the actual event condition is logged as a record along with a time and date stamp to a resolution of 1 millisecond. There is capacity for a maximum of 5000 event records that can be stored in the relay and when the event buffer is full any new record will over-write the oldest. Stored events can be erased from the front fascia via DATA STORAGE>***Clear Events*** setting or using Reydisp Evolution via Relay > Events > Reset Events.

The following events are logged:

Change of state of Binary outputs.

Change of state of Binary inputs.

Change of Settings and Settings Group

Change of state of any of the control functions of the relay.

All events can be retrieved over the data communications channel(s) and can be displayed in the 'Reydisp Evolution' package in chronological order, allowing the sequence of events to be viewed. Events are also made available spontaneously to an IEC 60870-5-103, Modbus RTU or DPN 3.0 compliant control system.

For a complete listing of events available in each model, refer to Technical Manual section 4 'Data Comms'.

6.4.3 Waveform Records.

Relay waveform storage can be triggered either after user selected relay operations, from the relay fascia, from a suitably programmed binary input or via the data comms channel(s). The stored analogue and digital waveforms illustrate the system and relay conditions at the time of trigger.

In total the relay provides 10 seconds of waveform storage, this is user selectable to 1 record of 10 seconds duration, 2 records of 5 seconds duration, 5 records of 2 seconds duration or 10 records of 1 second duration. When the waveform recorder buffer is full any new waveform records will over-write the oldest. The most recent record is Waveform 1.

As well as defining the stored waveform record duration the user can select the percentage of the waveform storage prior to triggering.

The waveform recorder samples at a rate of 32 samples per cycle (1600Hz).

Stored waveforms can be erased using the DATA STORAGE>***Clear Waveforms*** setting or using Reydisp Evolution via Relay > Waveform > Reset Waveform Records.

6.4.4 Fault Records

Up to ten fault records can be stored and displayed on the Fascia LCD.

Fault records provide a summary of the relay status at the time of trip, i.e. the element that issued the trip, any elements that were picked up, the fault type, LED indications, date and time. The ***Max Fault Rec. Time*** setting sets the time period from fault trigger during which the operation of any LEDs is recorded.

When examined together the event records and the fault records will detail the full sequence of events leading to a trip.

Fault records are stored in a rolling buffer, with the oldest faults overwritten. The fault storage can be cleared with the DATA STORAGE>***Clear Faults*** setting or using Reydisp Evolution via Relay > Data Records > Reset Data Log Record.

6.4.5 Data Log

The Data log feature can be used to build trend and maximum/minimum demand records. Up to 10,080 individual time stamped records of each phase current and voltage (where fitted) analogue signal are recorded and stored at a user defined rate e.g. 7 days @ 1 minute intervals and > 1 year @ 1 hour intervals.

6.5 Metering

The metering feature provides real-time data available from the relay fascia in the ‘Instruments Mode’ or via the data communications interface.

For a detailed description refer to Technical Manual Section 2 – Settings and Instruments.

6.6 Operating Mode

The relay has three operating modes, Local, Remote and Out of Service. The following table identifies the functions operation in each mode.

The modes can be selected by the following methods:

SYSTEM CONFIG>***RELAY MODE*** setting, a Binary Input or Command

OPERATION	REMOTE MODE	LOCAL MODE	SERVICE MODE
Control			
Rear Ports	Enabled	Disabled	Disabled
Fascia (Control Mode)	Disabled	Enabled	Disabled
USB	Disabled	Enabled	Disabled
Binary Inputs	Setting Option	Setting Option	Enabled
Binary Outputs	Enabled	Enabled	Disabled
Reporting			
Spontaneous			
IEC	Enabled	Enabled	Disabled
DNP	Enabled	Enabled	Disabled
General Interogation			
IEC	Enabled	Enabled	Disabled
DNP	Enabled	Enabled	Disabled
MODBUS	Enabled	Enabled	Enabled
Changing of Settings			
Rear Ports	Enabled	Disabled	Enabled
Fascia	Enabled	Enabled	Enabled
USB	Disabled	Enabled	Enabled
Historical Information			
Waveform Records	Enabled	Enabled	Enabled
Event Records	Enabled	Enabled	Enabled
Fault Information	Enabled	Enabled	Enabled
Setting Information	Enabled	Enabled	Enabled

Table 6-1 Operation Mode

6.7 Control Mode

This mode provides convenient access to commonly used relay control and test functions. When any of the items listed below are selected control is initiated by pressing the ENTER key. The user is prompted to confirm the action, again by pressing the ENTER key, before the command is executed.

Control Mode commands could be password protected using the Control Password function – see section 6.8.

Commands available in the Control Mode are:

Open CB

Close CB

79 In/Out

79 Trip and Reclose

79 Trip & Lockout

Hotline Work In/Out

E/F In/Out

SEF In/Out

Instantaneous Protection In/Out

Battery Test Required

Set Local Mode

Set Local or Remote Mode

Set Remote Mode

Set Service Mode

6.8 Real Time Clock

Time and date can be set either via the relay fascia using appropriate commands in the System Config menu, via the data comms channel(s) or via the optional IRIG-B input. Time and date are maintained while the relay is de-energised by a back up storage capacitor.

The default date is set at 01/01/2000 deliberately to indicate the date has not yet been set. When editing the **Time**, only the hours and minutes can be edited. When the user presses **ENTER** after editing the seconds are zeroed and the clock begins running.

6.8.1 Time Synchronisation - IEC 60870-5-103 & DNP3.0

Where the data comms channel(s) is connected the relay can be directly time synchronised to the nearest second or minute using the IEC 60870-5-103 & DNP3.0 global time synchronisation. This can be from a dedicated substation automation system or from 'Reydisp Evolution' communications support software.

6.8.2 Time Synchronisation – Binary Input

A binary input can be mapped ***Clock Sync from BI***. The seconds or minutes will be rounded up or down to the nearest value when the BI is energised. This input is leading edge triggered.

6.8.3 Time Synchronisation – IRIG-B (Optional)

A BNC connector on the relay rear provides an isolated IRIG-B time synchronisation port. The IRIG-B input expects a modulated 3-6 Volt signal and provides time synchronisation to the nearest millisecond.

6.9 Settings Groups

The relay provides eight groups of settings – Group number (Gn) 1 to 8. At any one time only one group of settings can be 'active' – SYSTEM CONFIG>***Active Group*** setting.

It is possible to edit one group while the relay operates in accordance with settings from another 'active' group using the ***View/Edit Group*** setting.

Some settings are independent of the active group setting i.e. they apply to all settings groups. This is indicated on the top line of the relay LCD – where only the **Active Group No**. is identified. Where settings are group dependent this is indicated on the top line of the LCD by both the **Active Group No**. and the **View Group No**. being displayed.

A change of settings group can be achieved either locally at the relay fascia, remotely over the data comms channel(s) or via a binary input. When using a binary input an alternative settings group is selected only whilst the input is energised (***Select Grp Mode*****: Level triggered**) or latches into the selected group after energisation of the input (***Select Grp Mode*****: Edge triggered**).

6.10 Password Feature

The relay incorporates two levels of password protection – one for settings, the other for control functions.

The programmable password feature enables the user to enter a 4 character alpha numeric code to secure access to the relay functions. The relay is supplied with the passwords set to **NONE**, i.e. the password feature is disabled. The password must be entered twice as a security measure against accidental changes. Once a password has been entered then it will be required thereafter to change settings or initiate control commands. Passwords can be de-activated by using the password to gain access and by entering the password **NONE**. Again this must be entered twice to de-activate the security system.

As soon as the user attempts to change a setting or initiate control the password is requested before any changes are allowed. Once the password has been validated, the user is 'logged on' and any further changes can be made without re-entering the password. If no more changes are made within 1 hour then the user will automatically be 'logged off', re-enabling the password feature.

The Settings Password prevents unauthorised changes to settings from the front fascia or over the data comms channel(s). The Control Password prevents unauthorised operation of controls in the relay Control Menu from the front fascia.

The password validation screen also displays a numerical code. If the password is lost or forgotten, this code should be communicated to Siemens Protection Devices Ltd. and the password can be retrieved.