

# 7SR21 Non-Directional

# 7SR22 Directional

Overcurrent Relay

## Document Release History

This document is issue 2010/05. The list of revisions up to and including this issue is:

2010/05	Additional Comms modules option of (RS485 + IRIG-B) and (RS232 + IRIG-B) and typographical revisions
2010/02	Document reformat due to rebrand
2009/09	Third Issue. Software revision 2435H80004/5 R4b-4
2008/07	Second issue. Software revision 2435H80004/5 R3d-3.
2008/03	First issue

## Software Revision History

2009/09	2435H80004/5 R4b-4	CTS-I Supervision. Undercurrent 37G & 37SEF. Vx U/O Voltage. 46BC U/C. Comms Settings. Waveform Storage Settings. Fault Storage Settings. Energy Storage. Trip test function. Local/Remote modes. Settings ranges extended. Protocol changes.
2008/07	2435H80004/5R3d-3	Demand records. Optional DNP3.0 data comms.
2008/03	2435H80004/5R2c-2b	First Release

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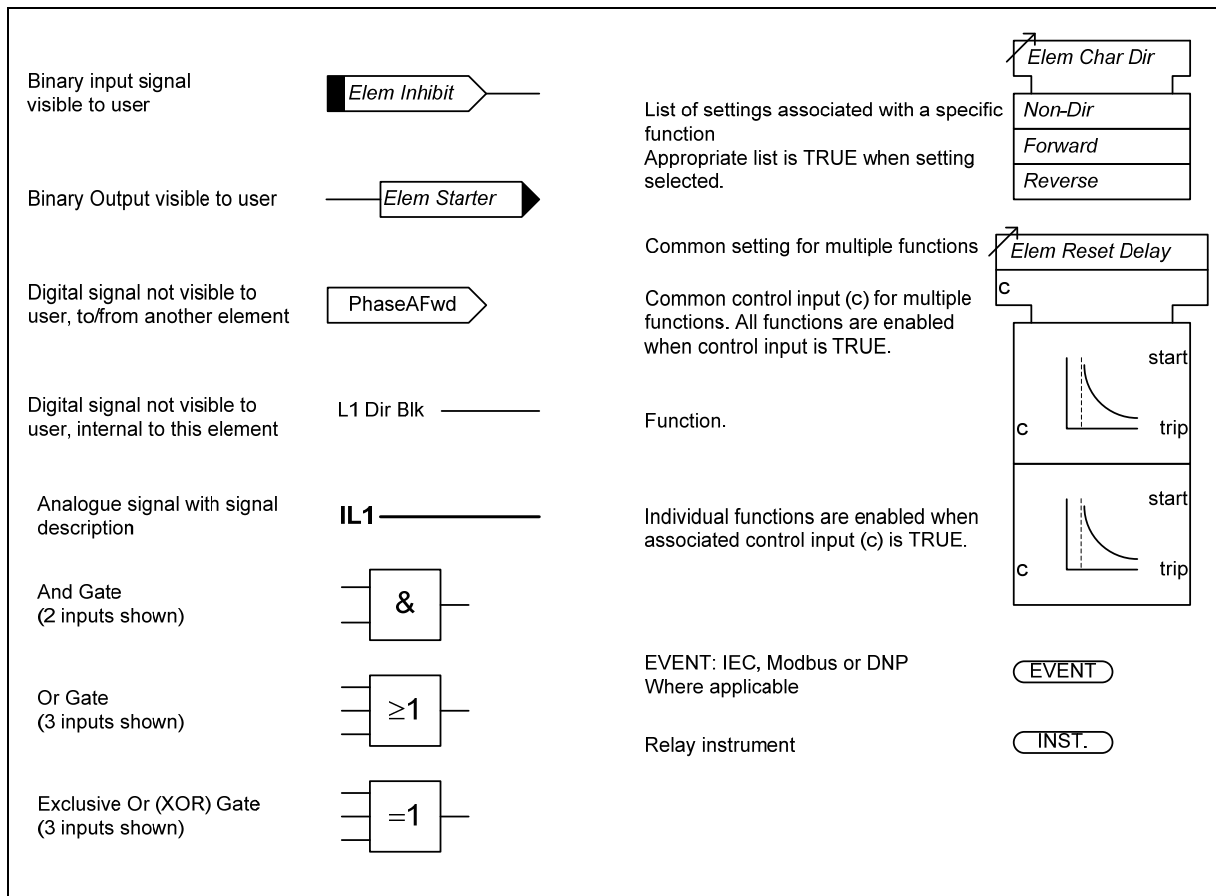
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### Symbols and Nomenclature

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

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



## Section 1: Introduction

This manual is applicable to the following relays:

- **7SR21 Multi-Function Non-directional Overcurrent and Earth Fault Relay**
- **7SR22 Multi-Function Directional Overcurrent and Directional Earth Fault Relay**

The 7SR21 and 7SR22 relays integrate the protection and control elements required to provide a complete overcurrent based protection.

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

## General Safety Precautions



### 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.



### 2 External Resistors

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



### 3 Fibre Optic Communication

Where fibre optic communication ports are fitted, the lasers are Class 1 devices but recommend they should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.



### 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.

Table 1-1 Ordering Information – 7SR21 Non-Directional Overcurrent

Product description	Variants	Order No.
<b>Nondirectional O/C Relay</b>		<b>7 S R 2 1 0 □ - 1 □ A □ □ - 0 □ A 0</b>
Multi function overcurrent and earth fault protection relay	<u>Protection Product</u> Overcurrent – Non Directional	↑ 1
	<u>Case I/O and Fascia</u> <sup>1)</sup> E6 case, 4 CT, 9 Binary Inputs / 8 Binary Outputs, 8 LEDs	↑ 2
	E8 case, 4 CT, 19 Binary Inputs / 16 Binary Outputs, 16LEDs	↑ 3
	E8 case, 4 CT, 19 Binary Inputs / 16 Binary Outputs, 8 LEDs + 6 Keys	↑ 4
	<u>Measuring Input</u> 1/5 A, 50/60Hz	↑ 1
	<u>Auxiliary voltage</u> 30 to 220V DC, binary input threshold 19V DC	↑ A
	30 to 220V DC, binary input threshold 88V DC	↑ B
	<u>Communication Interface</u> Standard version – included in all models, USB front port, RS485 rear port	↑ 1
	Standard version – plus additional rear F/O ST connectors (x2) and IRIG-B	↑ 2
	Standard version – plus additional rear 1x RS485 and IRIG-B	↑ 3
	Standard version – plus additional rear 1x RS232 and IRIG-B	↑ 4
	<u>Protocol</u> IEC 60870-5-103 and Modbus RTU (user selectable setting)	↑ 1
	IEC 60870-5-103, Modbus RTU and DNP3.0 (user selectable setting)	↑ 2
	<u>Protection Function Packages</u> Standard version – Included in all models	
	37 Undercurrent	
	46BC Broken conductor/load unbalance	
	46NPS Negative phase sequence overcurrent	
	49 Thermal overload	
	50 Instantaneous phase fault overcurrent	
	50BF Circuit breaker fail	
	50G/50N Instantaneous earth fault	
	51 Time delayed phase fault overcurrent	
	51G/51N Time delayed earth fault/SEF	
	60CTS-I CT Supervision	
	64H High Impedance REF	
	74TC Trip circuit supervision	
	81HBL2 2 <sup>nd</sup> harmonic block/inrush restraint	
	Cold load pickup	
	Programmable logic	
	Standard version – plus	
	79 Autoreclose	↑ D
	<u>Additional Functionality</u> No Additional Functionality	↑ A

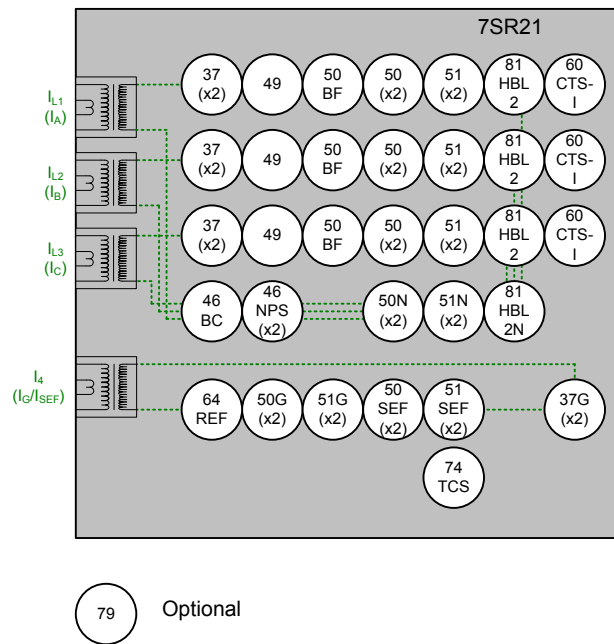


Figure 1-1 Functional Diagram of 7SR21 Relay



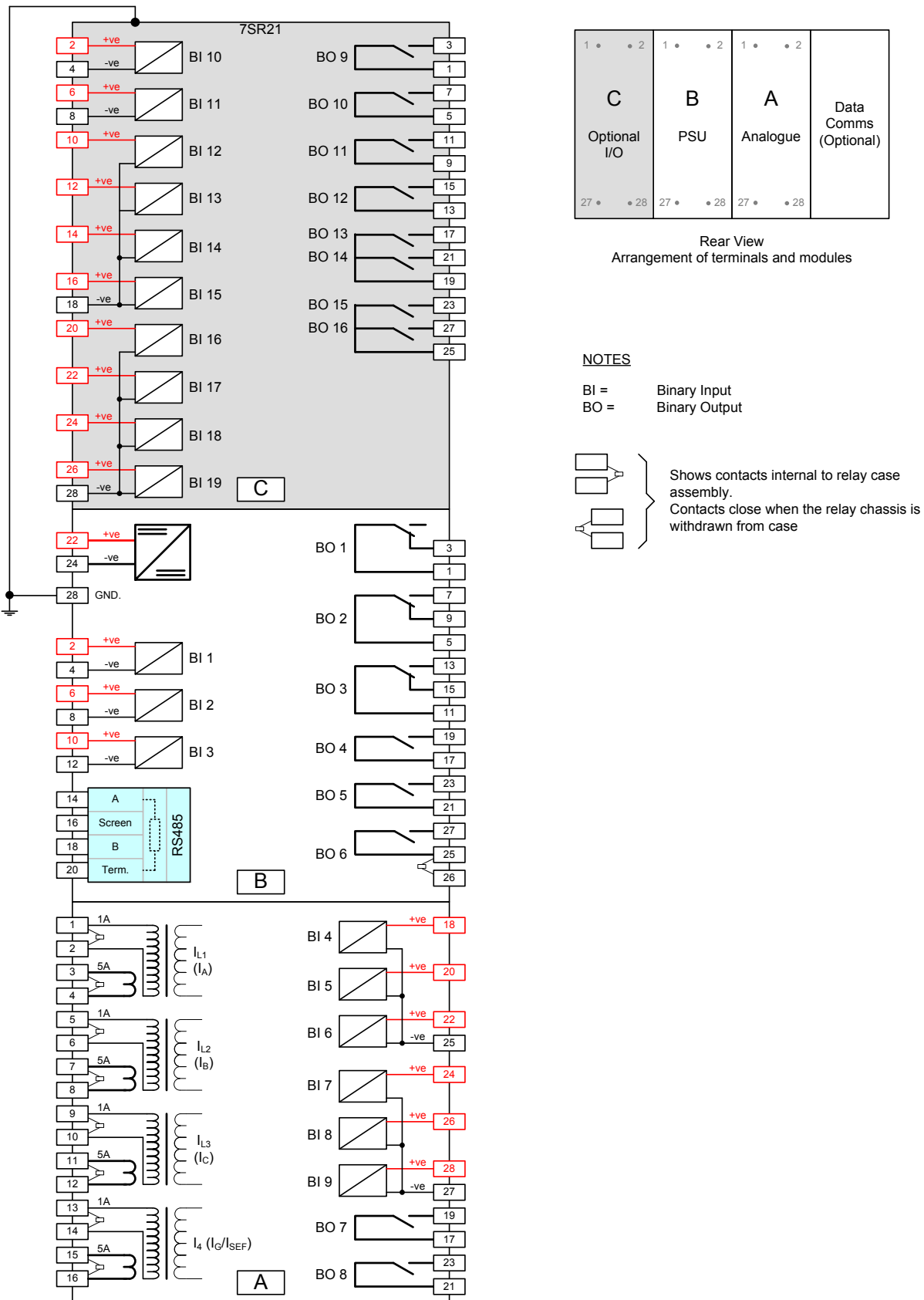


Figure 1-2 Connections Diagram for 7SR21 Relay

Table 1-2 Ordering Information – 7SR22 Directional Overcurrent

Product description	Variants	Order No.
<b>Directional O/C Relay</b>		<b>7 S R 2 2 0 □ - 2 □ A □ □ - 0 □ A 0</b>
Multi function overcurrent and earth fault protection relay		↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑
<u>Protection Product</u> Overcurrent – Directional		2
<u>Case I/O and Fascia</u> <sup>1)</sup>		
E6 case, 5 CT, 4 VT, 3 Binary Inputs / 6 Binary Outputs, 8 LEDs		2
E8 case, 5 CT, 4 VT, 13 Binary Inputs / 14 Binary Outputs, 16 LEDs		3
E8 case, 5 CT, 4 VT, 13 Binary Inputs / 14 Binary Outputs, 8 LEDs + 6 Keys		4
<u>Measuring Input</u> 1/5 A, 63.5/110V, 50/60Hz		2
<u>Auxiliary voltage</u> 30 to 220V DC, binary input threshold 19V DC 30 to 220V DC, binary input threshold 88V DC		A B
<u>Communication Interface</u> Standard version – included in all models, USB front port, RS485 rear port Standard version – plus additional rear F/O ST connectors (x2) and IRIG-B Standard version – plus additional rear 1x RS485 and IRIG-B Standard version – plus additional rear 1x RS232 and IRIG-B		1 2 3 4
<u>Protocol</u> IEC 60870-5-103 and Modbus RTU (user selectable setting) IEC 60870-5-103, Modbus RTU and DNP3.0 (user selectable setting)		1 2
		C

Continued on next page

Product description      Variants      Order No.

**Directional O/C Relay**

**7 S R 2 2 0 □ - 2 □ A □ □ - 0 □ A 0**

Protection Function Packages

Standard version – Included in all models

- 27/59      Under/overvoltage
- 37      Undercurrent
- 37G      Ground Undercurrent
- 37SEF      SEF Undercurrent
- 46BC      Broken conductor/load unbalance
- 46NPS      Negative phase sequence overcurrent
- 47      Negative phase sequence voltage
- 49      Thermal overload
- 50BF      Circuit breaker fail
- 51V      Voltage controlled overcurrent
- 59N      Neutral voltage displacement
- 60CTS      CT supervision
- 60CTS-I      CT Supervision
- 60VTS      VT supervision
- 64H      High Impedance REF
- 67/50      Directional instantaneous phase fault overcurrent
- 67/50G 67/50N      Directional instantaneous earth fault
- 67/51      Directional time delayed phase fault overcurrent
- 67/51G 67/51N      Directional time delayed earth fault/SEF
- 74TC      Trip circuit supervision
- 81      Under/overfrequency
- 81HBL2      2<sup>nd</sup> harmonic block/inrush restraint
- Cold load pickup
- Programmable logic

Standard version – plus  
79      Autoreclose

Additional Functionality

No Additional Functionality



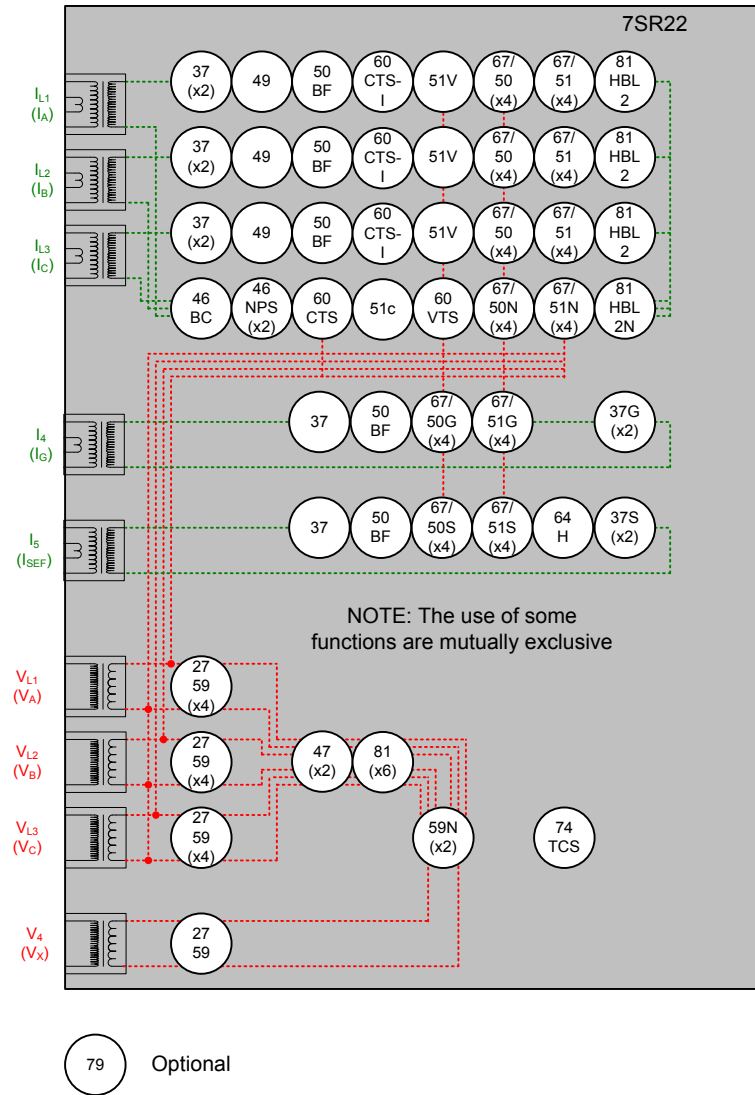


Figure 1-3 Functional Diagram of 7SR22 Relay

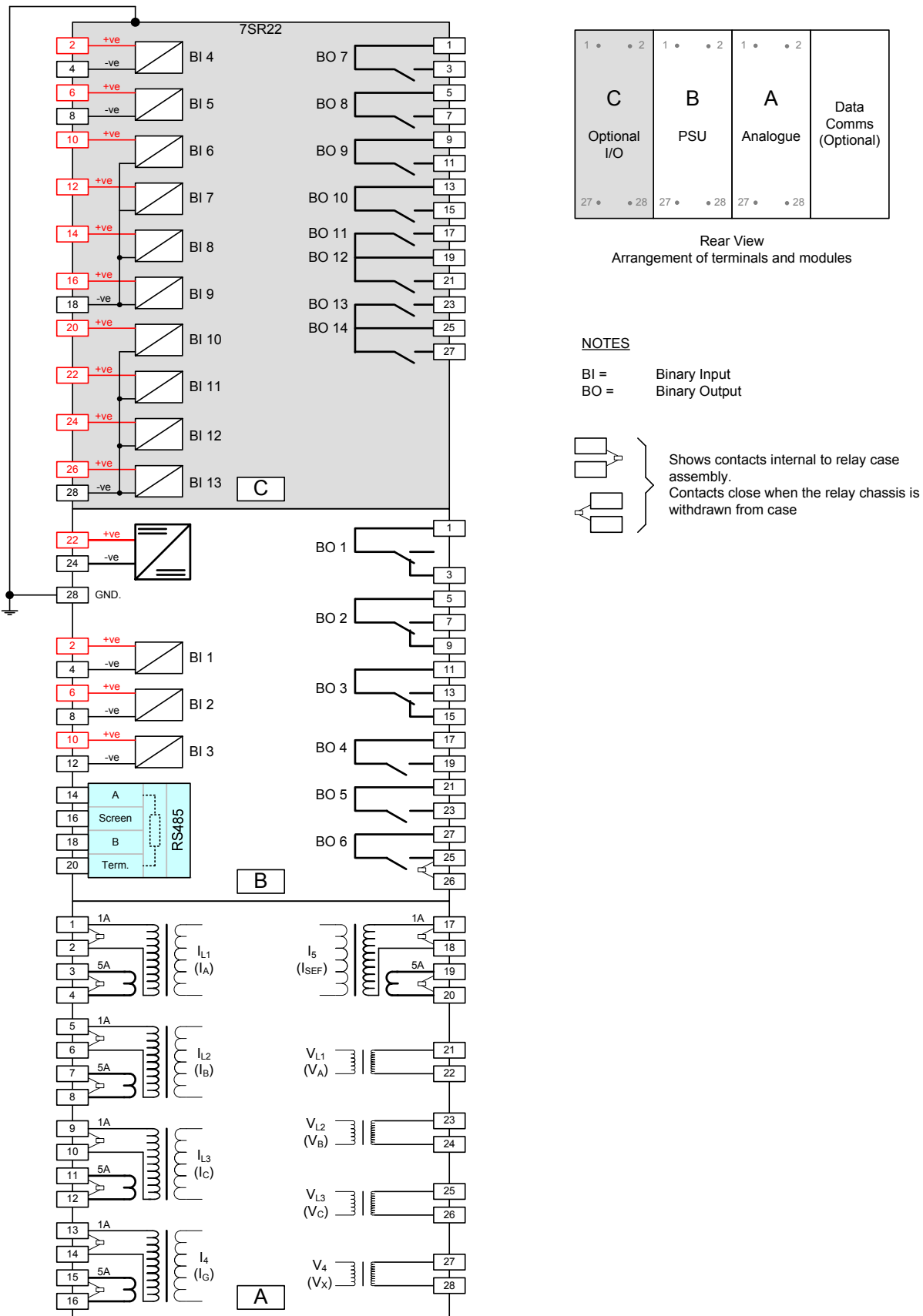


Figure 1-4 Connection Diagram for 7SR22 Relay

## 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 either size E6 or size E8 cases (where 1 x E = width of 26mm). The hardware design provides commonality between products and components across the Multi-function range of relays.

**Table 2-1 Summary of Overcurrent Relay Configurations**

Relay	Current Inputs	Voltage Inputs	Binary Inputs	Output Relays	LEDs	Function Keys	Case
7SR2102	4		9	8	8		E6
7SR2103	4		19	16	16		E8
7SR2104	4		19	16	8	6	E8
7SR2202	5	4	3	6	8		E6
7SR2203	5	4	13	14	16		E8
7SR2204	5	4	13	14	8	6	E8

Relays are assembled from the following modules:

1. Front Fascia with three fixed function LEDs and ordering options of configurable LEDs/Function Keys.
2. Processor module
3. Analogue Input module, either
  - 4 x Current + 6 x Binary Inputs + 2 x Binary Outputs (7SR21), or
  - 5 x Current + 4 x Voltage (7SR22).
4. Power Supply and Basic Binary Input (BI) and Binary Output (BO).
5. Optional Binary Input/Output Module
  - 10 x Binary Inputs + 8 x Binary Outputs
6. Optional Communications Module (2x rear fibre optic + 1x IRIG-B ports), (1x rear RS485 + 1x IRIG-B port), (1x rear RS232 + 1x IRIG-B port)

### 2.2 Case

The relays are housed in cases designed to fit directly into standard panel racks. The two case options have widths of 156mm (E6) and 208 mm (E8), both have a height of 177 mm (4U). The required panel depth (with wiring clearance) is 242 mm. An additional 75 mm depth clearance should be allowed 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. Contacts in the case ensure that the CT circuits remain short-circuited when the relay is removed.

The rear terminal blocks comprise M4 female terminals for wire connections. 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 ▼ 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 substation dc system rated from 30V dc to 220V dc.

In the event of the station battery voltage level falling below the relay minimum operating 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.

The warning and information labels on the relay fascia provide the following information:





	Dielectric Test Voltage 2kV
	Impulse Test Above 5kV
	Caution: Refer to Equipment Documentation
	Caution: Risk of Electric Shock



Figure 2.5 7SR21 with 3 + 8 LEDs in E6 Case



Figure 2.5-1 7SR22 with 3 + 16 LEDs in E8 Case



Figure 2.5-2 7SR22 with Function Keys and 3 + 8 LEDs in E8 Case

NOTE: Pushbuttons on cover not shown

The fascia is an integral part of the relay. Handles are located at each side of the element to 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.

User defined identifying text can be programmed into the relay using the **System config/Relay Identifier** setting. The 'Relay Identifier' text is displayed on the LCD display at the top level of the menu structure and is used in communication with Reydisp to identify the relay. Pressing the Cancel button several times will always return the user to this screen.

### '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. The same LED can be assigned two different colours dependent upon whether a Pickup or Operate condition exists.

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 Pushbuttons

The relay is supplied as standard with five pushbuttons. The 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.
<b>TEST/RESET▶</b>	Moves right, can be used to reset selected functionality and for LED test (at relay identifier screen).
<b>ENTER</b>	Used to initiate and accept settings changes.
<b>CANCEL.</b>	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 Evolution'.

### Function Keys/ LEDs (Optional)

Six additional programmable pushbuttons can be specified. These can be configured by the user to initiate selected functions from the Control menu (INPUT CONFIG > FUNCTION KEY MATRIX).

Each pushbutton has an associated LED. LEDs 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 in the 7SR21 relay and five inputs are provided in the 7SR22 relay

Current inputs are located 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 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 (16th harmonic) + 1600 Hz (32nd harmonic) + 2400 Hz (48th harmonic).

## 2.7 Voltage Inputs

Four voltage inputs are provided in the 7SR22 relay.

Voltage inputs are located on the Analogue Input module.

Voltage is sampled at 1600Hz for 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 1600Hz.

## 2.8 Binary Inputs

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

Relays are fitted with 3, 9, 13 or 19 binary inputs (BI). 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. The module includes 3 x BI and 6 x BO.

Non-directional (7SR21) relays have an additional 6 x BI on the analogue module.

Additional I/O modules may be fitted, these provide 10 x BI.

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.

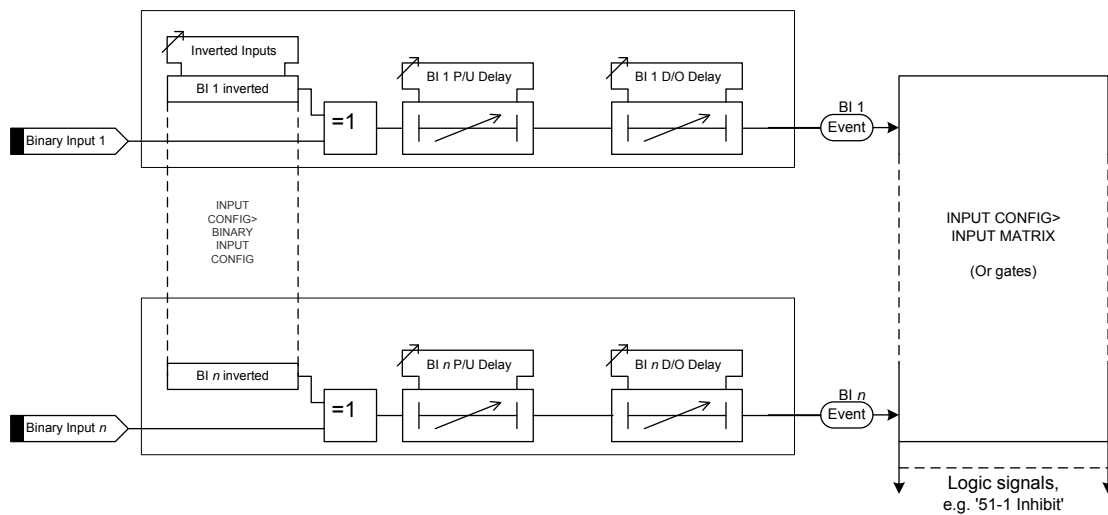


Figure 2.8-1 Binary Input Logic

## 2.9 Binary Outputs (Output Relays)

Relays are fitted with 6, 8, 14 or 16 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.

Non-directional (7SR21) relays have two additional binary outputs providing 2 x NO contacts on the analogue module. Additional I/O modules may be fitted; these provide 8 x 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' relays.

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 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.

### 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 in the primary system 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.

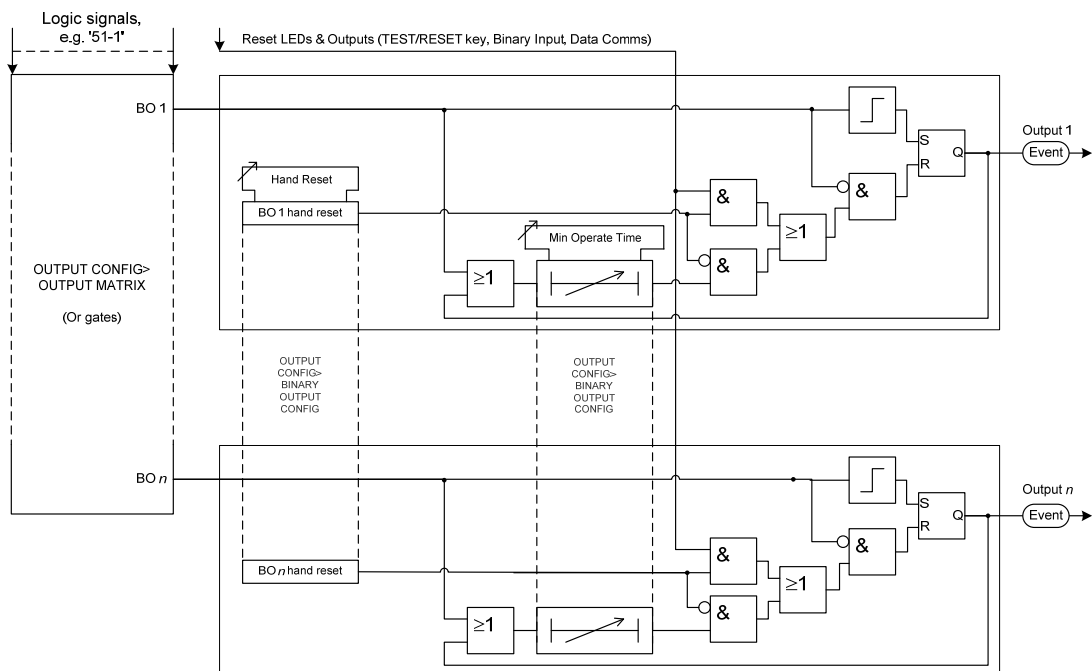


Figure 2.9-1 Binary Output Logic

## 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

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 used to signal protection healthy. When the relay has DC supply and it has successfully passed its self-checking procedure then the Protection Healthy contacts are made.

A normally closed contact is used to signal protection defective. When the DC supply is not applied to the relay or a problem is detected within the relay then this output is de-energised and the normally closed contacts make to provide an external alarm.

An alarm can be provided if the relay is withdrawn from the case. A contact is provided in the case at positions 25-26 of the PSU module, this contact closes when the relay is withdrawn.

## 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) – 7SR22

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  $90^\circ$ . Each phase current is compared to the voltage between the other two phases:

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

The characteristic angle can be user programmed to any angle between  $-95^\circ$  and  $+95^\circ$  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  $-60^\circ$  ( $I$  lagging  $V$  by  $60^\circ$ ) a **67 Char Angle** of  $+30^\circ$  is required for maximum sensitivity (i.e. due to quadrature connection  $90^\circ - 60^\circ = 30^\circ$ ).

OR

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

#### 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.

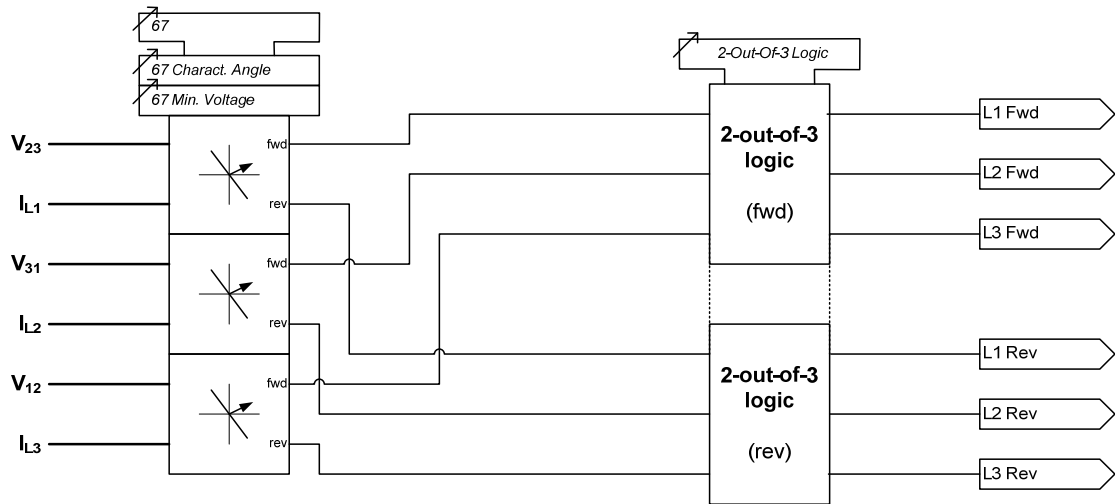


Figure 3.1-1 Logic Diagram: Directional Overcurrent Element (67)

### 3.1.2 Instantaneous Overcurrent Protection (50)

Two instantaneous overcurrent elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 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.

Where directional elements are present 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 auto-reclose 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 (7SR22).

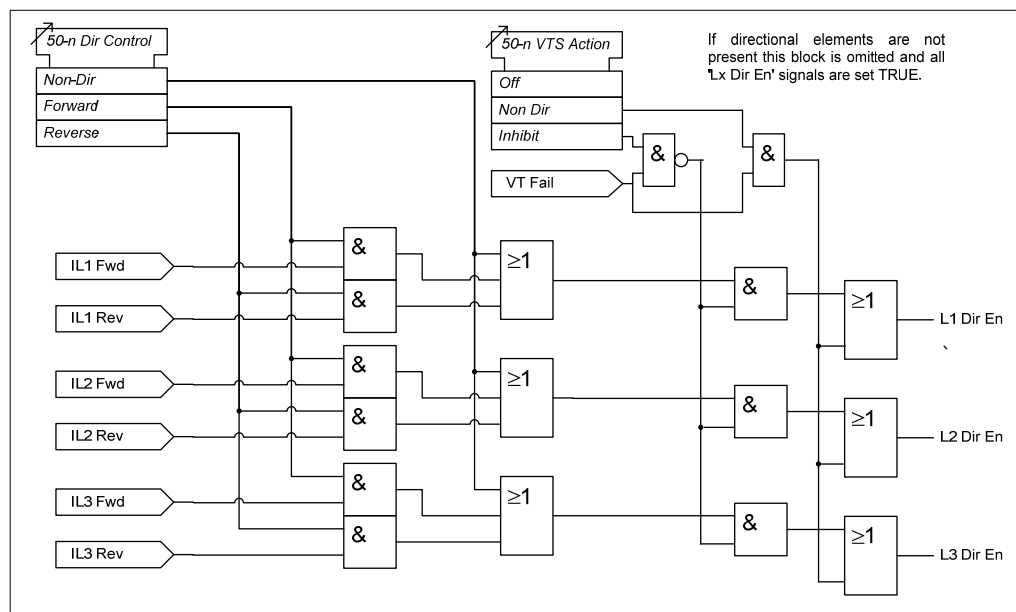
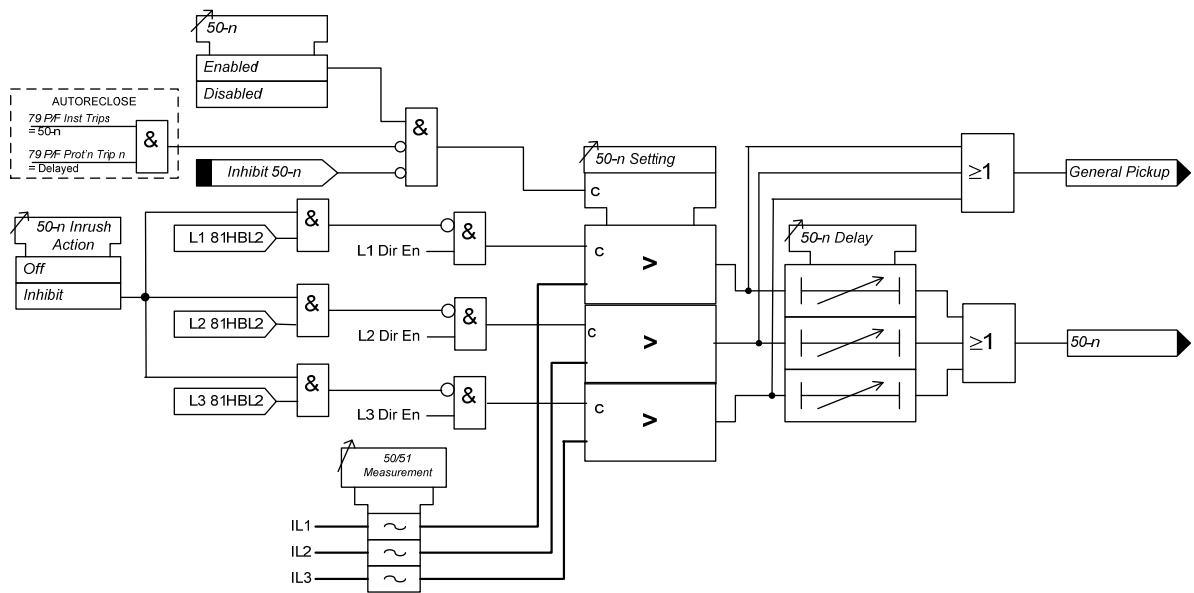


Figure 3.1-2 Logic Diagram: Instantaneous Over-current Element



### 3.1.3 Time Delayed Overcurrent Protection (51)

Two time delayed overcurrent elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay 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 (7SR22 relays only) 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 and ANSI 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 **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.

Where directional elements are present 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:

<b>Inhibit 51-n</b>	A binary or virtual input, or function key
<b>79 P/F Inst Trips: 51-n</b>	When 'delayed' trips only are allowed in the auto-reclose sequence ( <b>79 P/F Prot'n Trip n = Delayed</b> ).
<b>51c</b>	Activation of the cold load settings (see section 3.7).
<b>51-n Inrush Action: Inhibit</b>	Operation of the inrush current detector function.
<b>51-n VTSAction: Inhibit</b>	Operation of the VT Supervision function (7SR22).

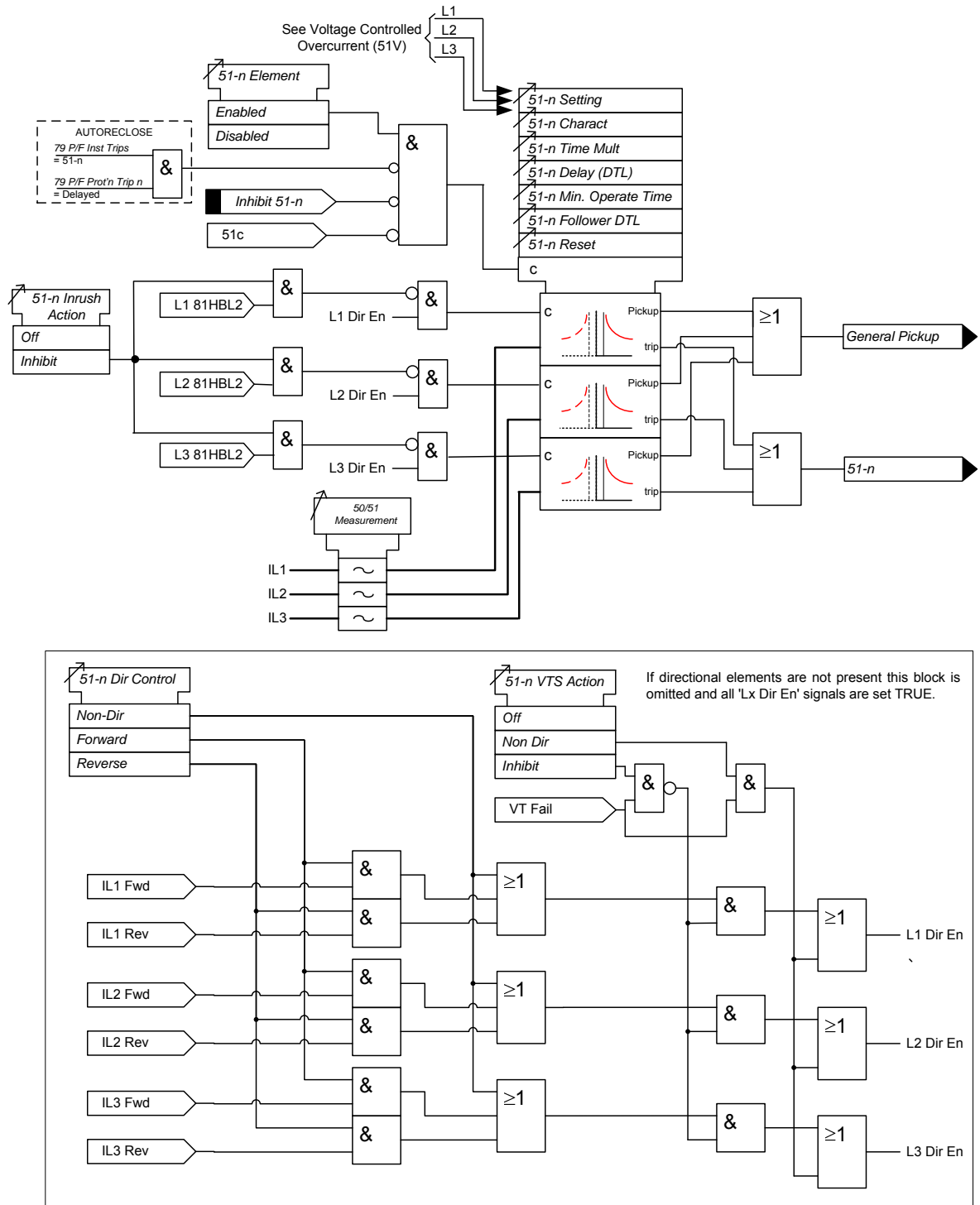


Figure 3.1-3 Logic Diagram: Time Delayed Overcurrent Element

## 3.2 Current Protection: Voltage Controlled Overcurrent (51V) – 7SR22

Voltage controlled overcurrent is available in the 7SR22 relay.

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.

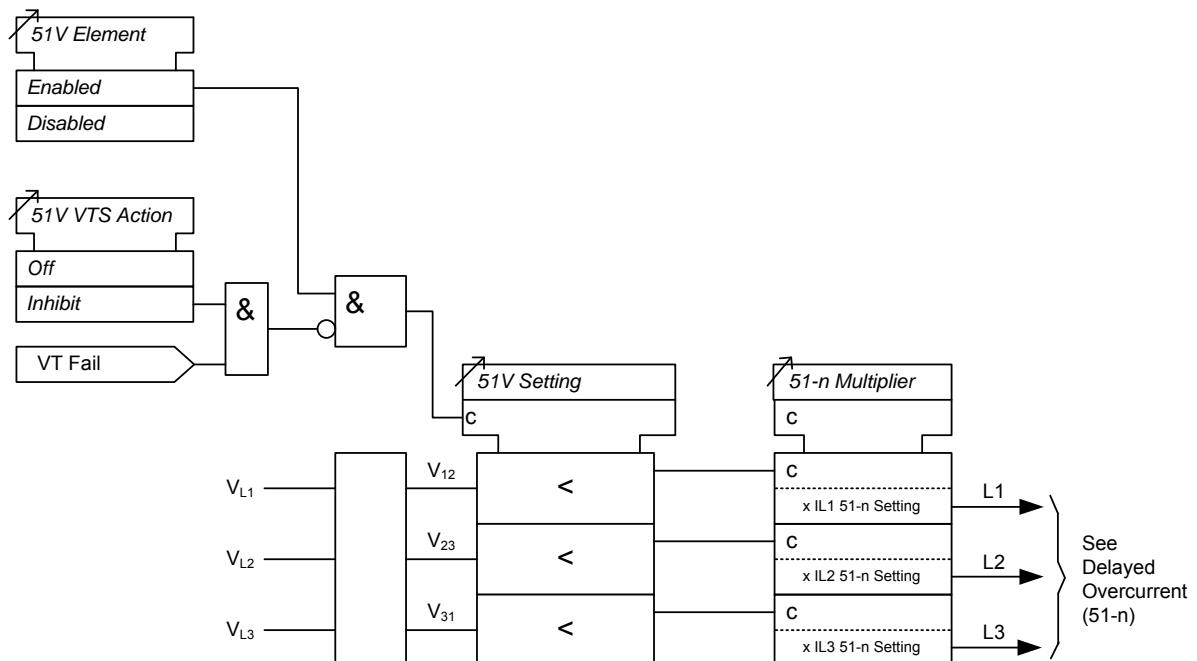


Figure 3.2-1 Logic Diagram: Voltage Controlled Overcurrent Protection

### 3.3 Current Protection: Derived Earth Fault (67N, 51N, 50N)

The earth current is derived by calculating the sum of the measured line currents. The elements measure the fundamental frequency RMS current.

#### 3.3.1 Directional Control of Derived Earth Fault Protection (67N) – 7SR22

The directional element produces forward and reverse outputs for use with derived 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 derived directional earth fault elements can use either zero phase sequence (ZPS) or negative phase sequence (NPS) polarising. This is selected using the **67N Polarising Quantity** setting. Whenever a zero-sequence voltage is available (a five-limb VT that can provide a zero sequence path or an open-delta VT connection) the earth-fault element can use zero-sequence voltage and current for polarisation. If zero-sequence polarising voltage is not available e.g. when a two phase (phase to phase) connected VT is installed, then negative-sequence voltage and negative-sequence currents must be used. The type of VT connection is specified by **Voltage Config** (CT/VT CONFIG menu). Settings advice is given in the Applications Guide.

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

**67N Polarising Quantity: ZPS**      $I_0 \sim V_0$

**67N Polarising Quantity: NPS**      $I_2 \sim V_2$

The characteristic angle can be user programmed to any angle between  $-95^\circ$  and  $+95^\circ$  using the **67N Char Angle** setting. The voltage is the reference phasor ( $V_{ref}$ ) and the **67N 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 + **67N Char Angle**) and should be set to correspond with  $I_{fault}$  Angle for maximum sensitivity e.g.

For fault current of  $-15^\circ$  (I lagging V by  $15^\circ$ ) a **67N Char Angle** of  $-15^\circ$  is required for maximum sensitivity.

OR

For fault current of  $-45^\circ$  (I lagging V by  $45^\circ$ ) a **67 Char Angle** of  $-45^\circ$  is required for maximum sensitivity.

### Minimum Polarising Voltage

The **67N 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.

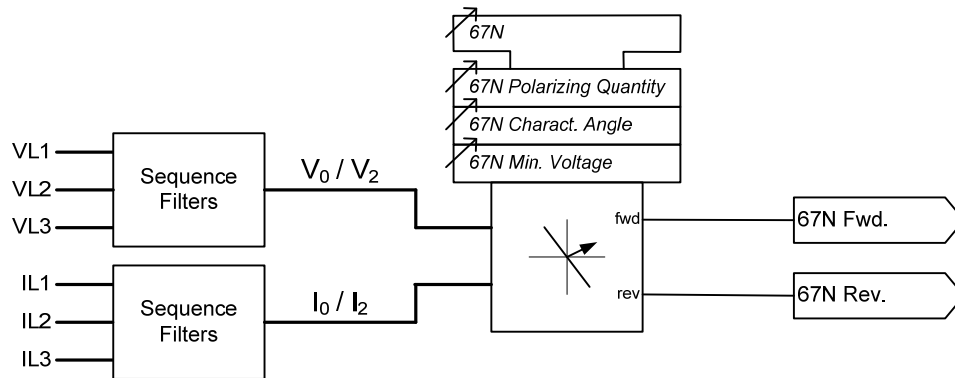


Figure 3.3-1 Logic Diagram: Derived Directional Earth Fault Element

### 3.3.2 Instantaneous Derived Earth Fault Protection (50N)

Two instantaneous derived earth fault elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay 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 **50N-n Setting** and a follower time delay **50N-n Delay**. The instantaneous elements have transient free operation.

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

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

<b>Inhibit 50N-n</b>	A binary or virtual input, or function key
<b>79 E/F Inst Trips: 50N-n</b>	When 'delayed' trips only are allowed in the auto-reclose sequence ( <b>79 E/F Prot'n Trip n = Delayed</b> ).
<b>50N-n VTSAction: Inhibit</b>	Operation of the VT Supervision function (7SR22).
<b>50N-n Inrush Action: Inhibit</b>	Operation of the current inrush detector function.

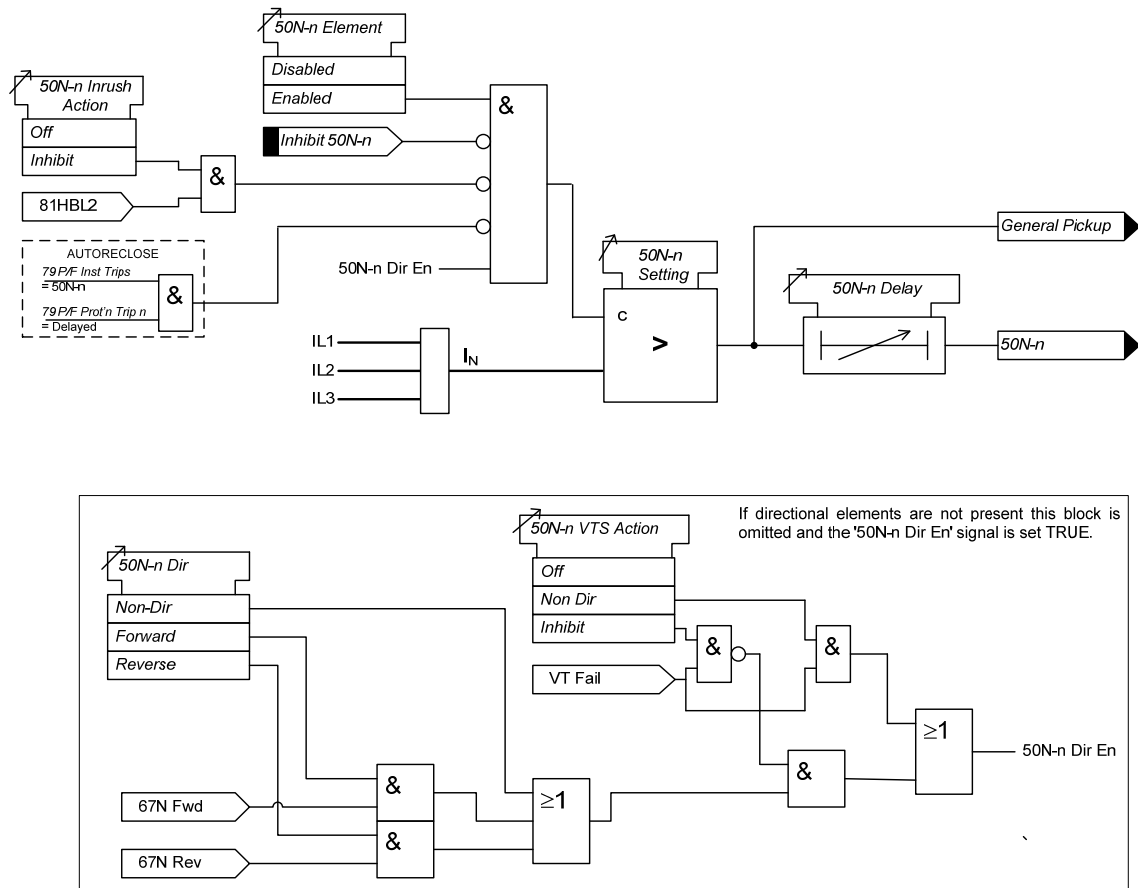


Figure 3.3-2 Logic Diagram: Derived Instantaneous Earth Fault Element

### 3.3.3 Time Delayed Derived Earth Fault Protection (51N)

Two time delayed derived earth fault elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay e.g. giving the option of using two elements set to forward and two to reverse.

**51N-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 **51N-n Char**. A time multiplier is applied to the characteristic curves using the **51N-n Time Mult** setting. Alternatively, a definite time lag delay (DTL) can be chosen using **51N-n Char**. When Delay (DTL) is selected the time multiplier is not applied and the **51N-n Delay (DTL)** setting is used instead.

The **51N-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 the **51N-n Min. Operate Time** setting.

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

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

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

<b>Inhibit 51N-n</b>	A binary or virtual input, or function key
<b>79 E/F Inst Trips: 51N-n</b>	When 'delayed' trips only are allowed in the auto-reclose sequence ( <b>79 E/F Prot'n Trip n = Delayed</b> ).
<b>51N-n Inrush Action: Inhibit</b>	Operation of the current inrush detector function.
<b>51N-n VTSAction: Inhibit</b>	Operation of the VT Supervision function (7SR22).

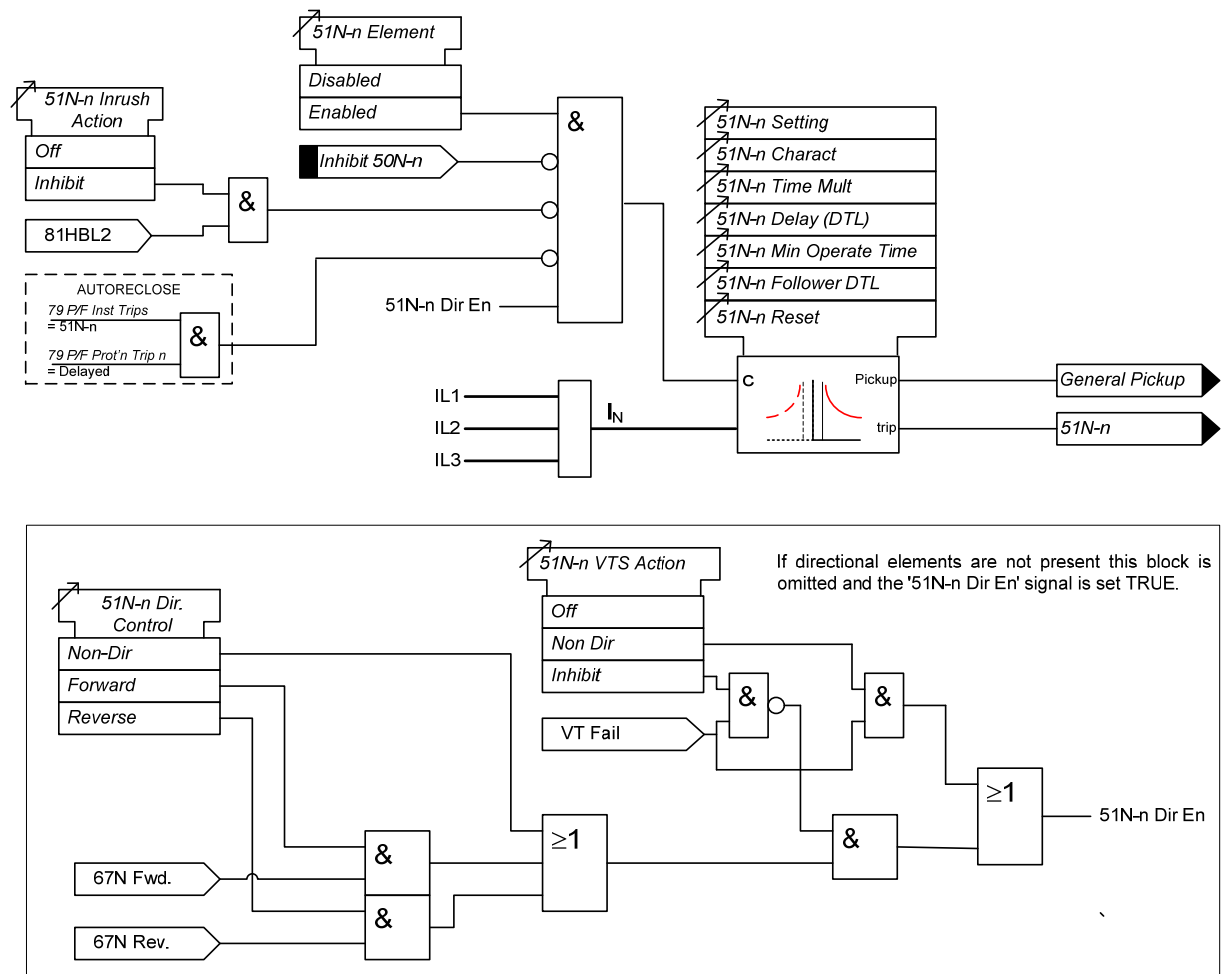


Figure 3.3-3 Logic Diagram: Derived Time Delayed Earth Fault Protection

### 3.4 Current Protection: Measured Earth Fault (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 or True RMS current:

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

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

#### 3.4.1 Directional Control of Measured Earth Fault Protection (67G) – 7SR22

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  $-95^\circ$  and  $+95^\circ$  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  $-15^\circ$  (I lagging V by  $15^\circ$ ) a **67G Char Angle** of  $-15^\circ$  is required for maximum sensitivity, OR

For fault current of  $-45^\circ$  (I lagging V by  $45^\circ$ ) a **67G Char Angle** of  $-45^\circ$  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.

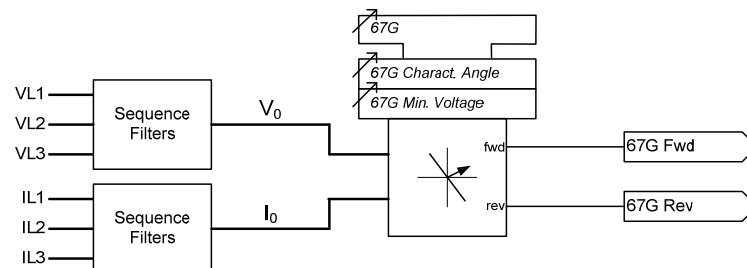


Figure 3.4-1 Logic Diagram: Measured Directional Earth Fault Protection



### 3.4.2 Instantaneous Measured Earth Fault Protection (50G)

Two instantaneous measured earth fault elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay 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.

Where directional elements are present 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 auto-reclose 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 (7SR22).

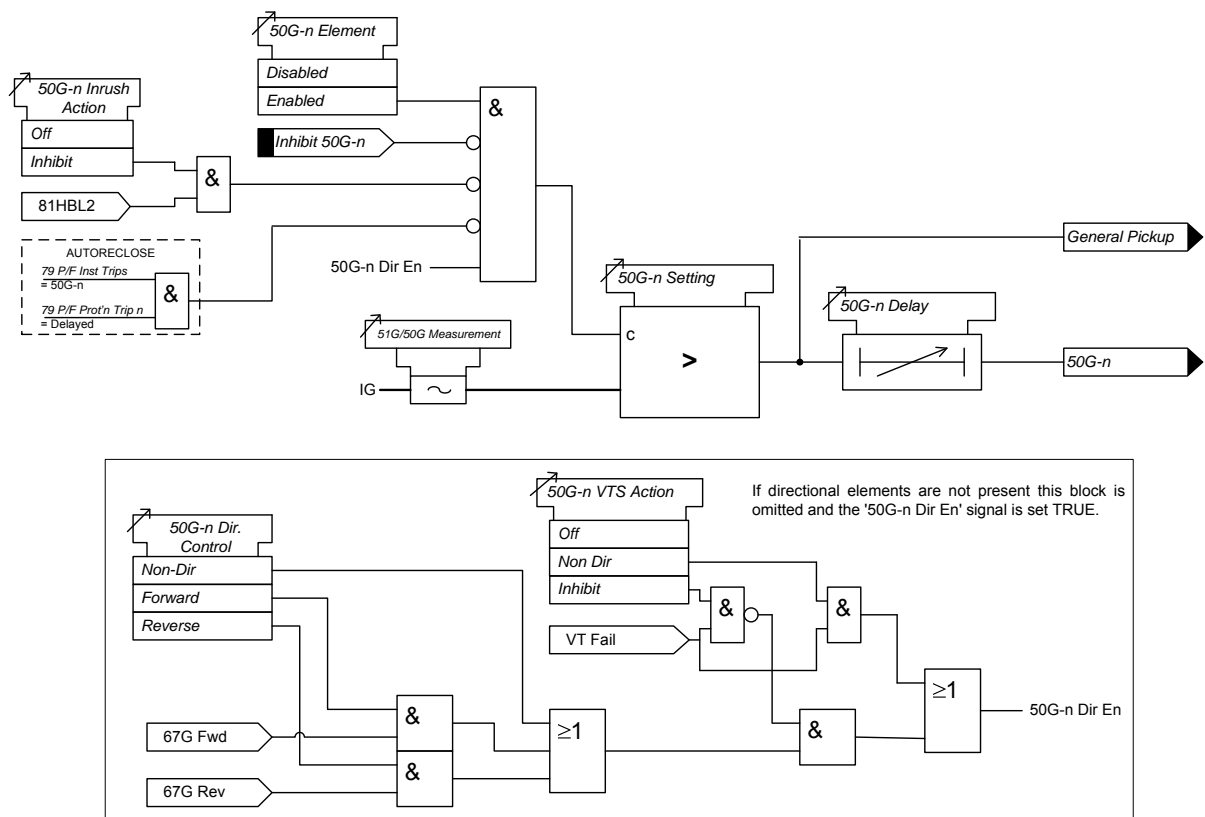


Figure 3.4-2 Logic Diagram: Measured Instantaneous Earth-fault Element

### 3.4.3 Time Delayed Measured Earth Fault Protection (51G)

Two time delayed measured earth fault elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay 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 **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) 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 **51G-n Min. Operate Time** setting.

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

Where directional elements are present 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:

<b>Inhibit 51G-n</b>	A binary or virtual input, or function key
<b>79 E/F Inst Trips: 51G-n</b>	When 'delayed' trips only are allowed in the auto-reclose sequence ( <b>79 E/F Prot'n Trip n = Delayed</b> ).
<b>51G-n Inrush Action: Inhibit</b>	Operation of the inrush current detector function.
<b>51G-n VTSAction: Inhibit</b>	Operation of the VT Supervision function (7SR22).

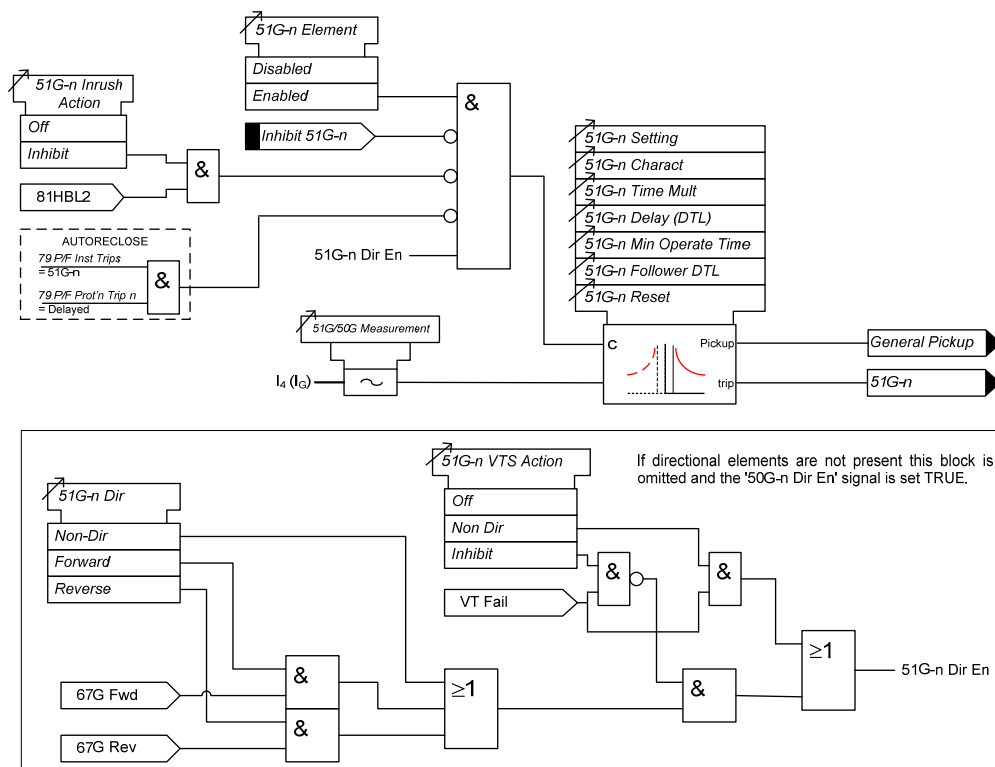


Figure 3.4-3 Logic Diagram: Measured Time Delayed Earth Fault Element (51G)

### 3.5 Current Protection: Sensitive Earth Fault (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.

#### 3.5.1 Directional Control of Sensitive Earth Fault Protection (67SEF) – 7SR22

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  $-95^\circ$  and  $+95^\circ$  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  $-15^\circ$  (I lagging V by  $15^\circ$ ) a **67SEF Char Angle** of  $-15^\circ$  is required for maximum sensitivity.

OR

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

#### 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.

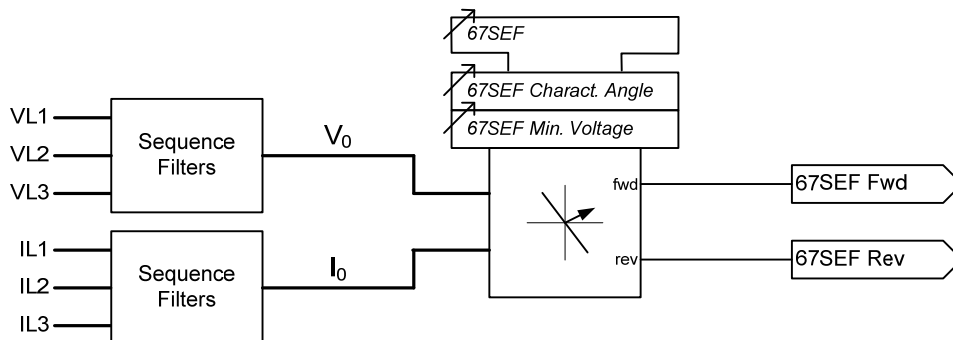


Figure 3.5-1 Logic Diagram: SEF Directional Element (67SEF)

### 3.5.2 Instantaneous Sensitive Earth Fault Protection (50SEF)

Two instantaneous SEF elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay 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.

Where directional elements are present 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 auto-reclose sequence (**79 SEF Prot'n Trip n = Delayed**).
- 50SEF-n VTSAction: Inhibit**        Operation of the VT Supervision function (7SR22).

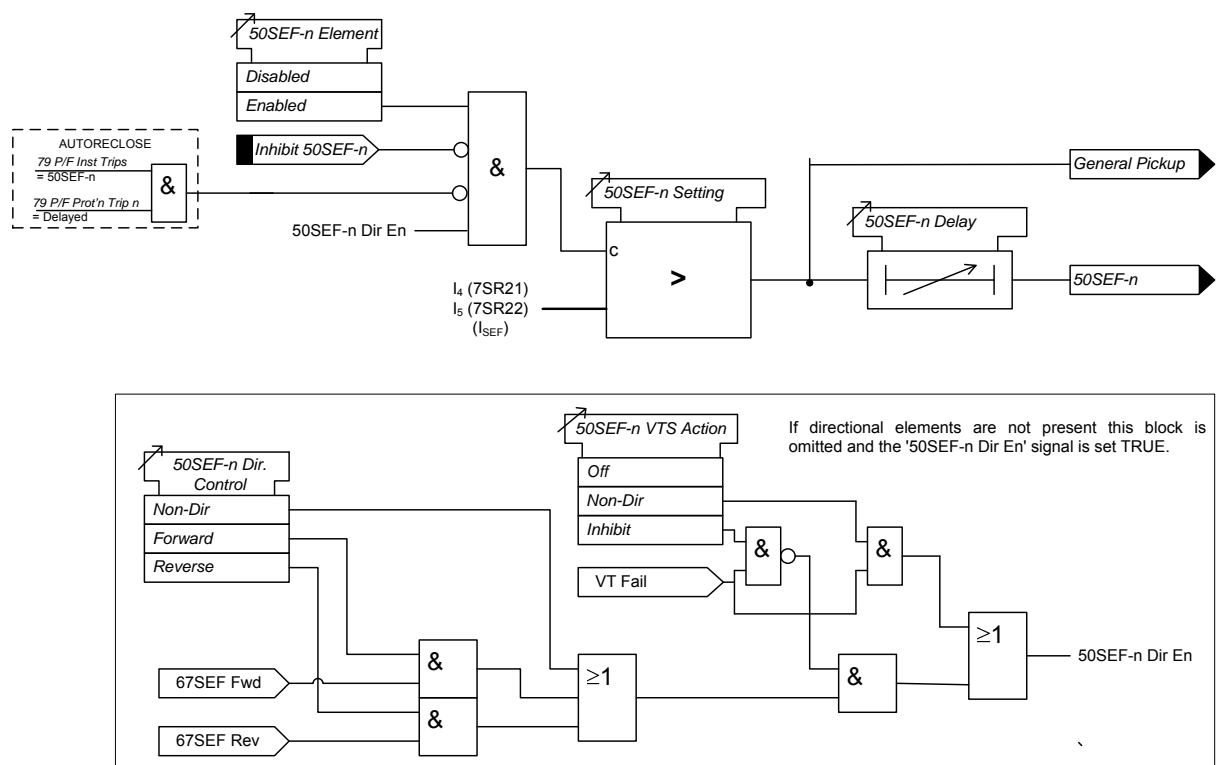


Figure 3.5-2 Logic Diagram: SEF Instantaneous Element

### 3.5.3 Time Delayed Sensitive Earth Fault Protection (51SEF)

Two time delayed sensitive earth fault elements are provided in the 7SR21 relay. Four elements are provided in the 7SR22 relay. 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.

Where directional elements are present 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 auto-reclose sequence (**79 SEF Prot'n Trip n = Delayed**).
- 51SEF-n VTSAction: Inhibit** Operation of the VT Supervision function (7SR22).

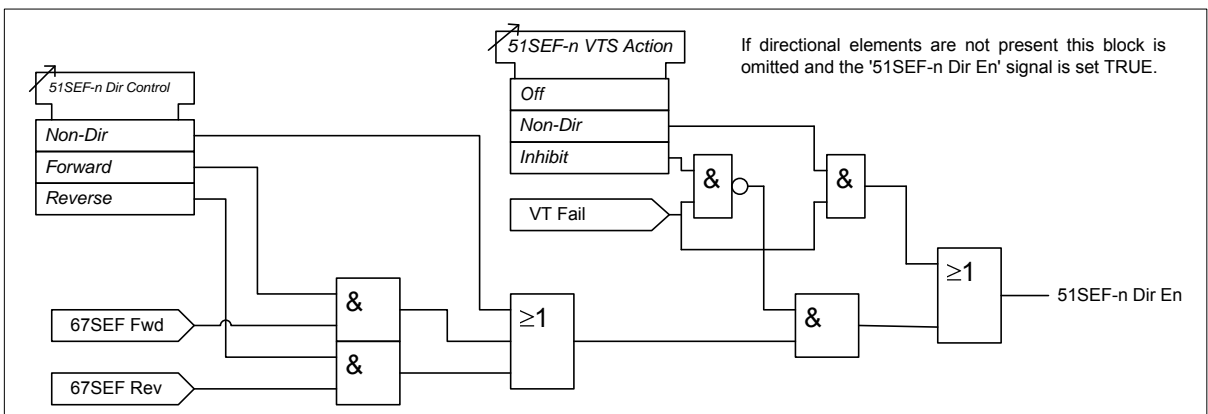
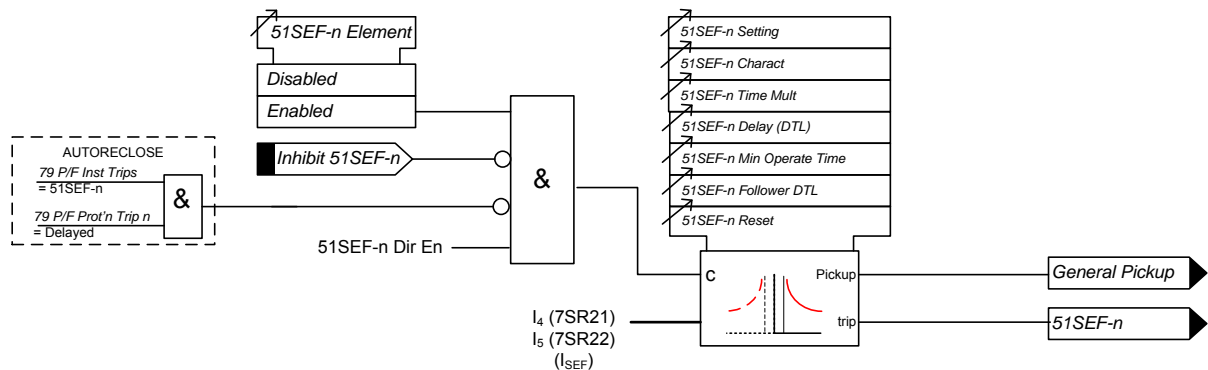


Figure 3.5-3 Logic Diagram: SEF Time Delayed Element (51SEF)

### 3.6 Current Protection: High Impedance Restricted Earth Fault (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.

**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, or function key

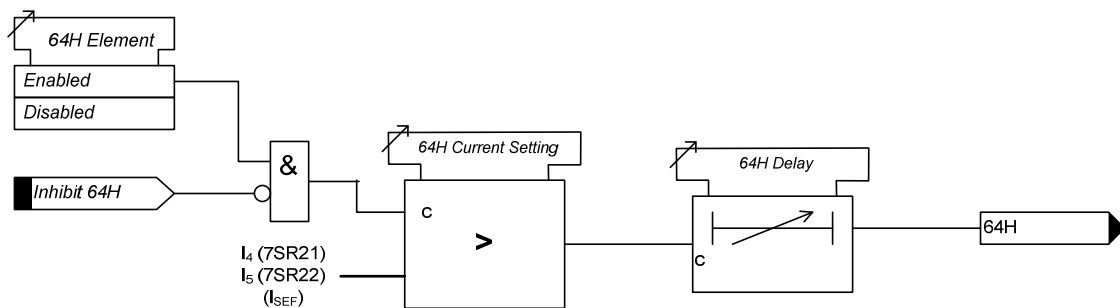


Figure 3.6-1 Logic Diagram: High Impedance REF (64H)

### 3.7 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 a recloser is present).

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.

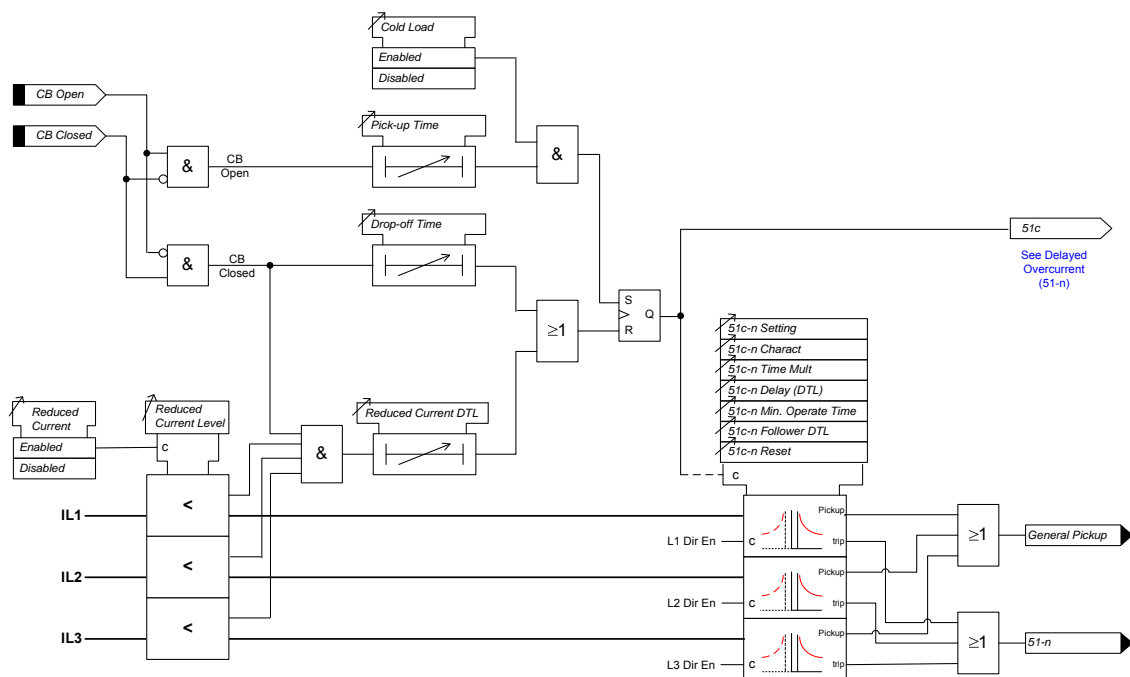


Figure 3.7-1 Logic Diagram: Cold Load Settings (51c)

### 3.8 Current Protection: Negative Phase Sequence Overcurrent (46NPS)

The negative sequence phase (NPS) component of current ( $I_2$ ) is derived from the three phase currents. It is a measure of the quantity of unbalanced current in the system.

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:

<b>Inhibit 46IT</b>	A binary or virtual input, or function key
<b>Inhibit 46DT</b>	A binary or virtual input, or function key

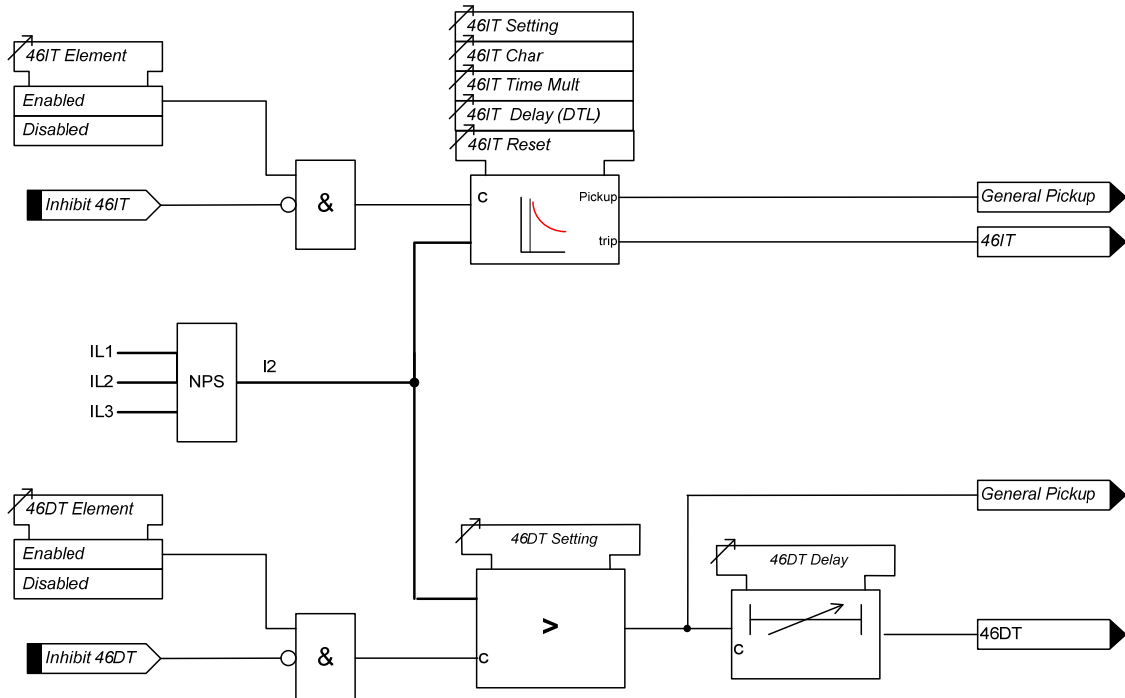


Figure 3.8-1 Logic Diagram: Negative Phase Sequence Overcurrent (46NPS)



### 3.9 Current Protection: Under-Current (37, 37G & 37SEF)

Two under-current elements are provided for each 37, 37G & 37SEF protection function.

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, or function key

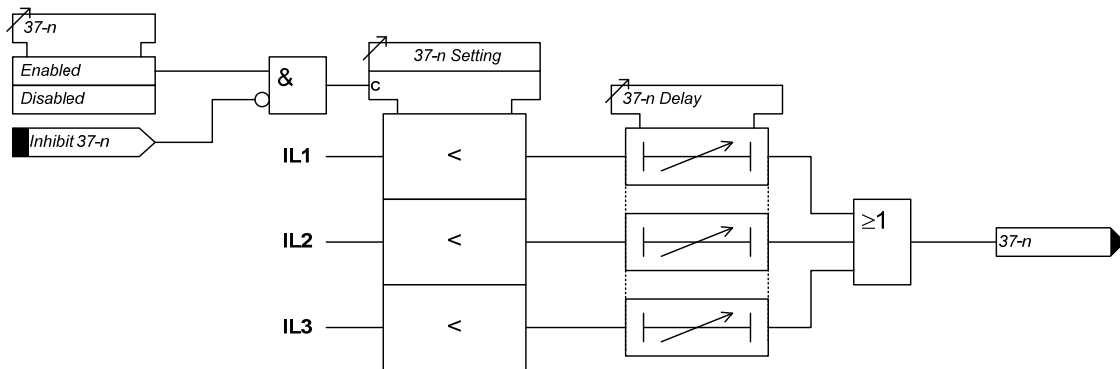


Figure 3.9-1 Logic Diagram: Undercurrent Detector (37, 37G & 37SEF)

### 3.10 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

$\tau$  = **49 Time Constant** setting (minutes)

ln = Log Natural

I = measured current

$I_p$  = Previous steady state current level

k = Constant

$I_B$  = Basic current, typically the same as  $I_n$

$k \cdot I_B$  = **49 Overload** Setting ( $I_\theta$ )

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:  $\theta$  = thermal state at time t

I = measured thermal current

$I_\theta$  = **49 Overload** setting (or  $k \cdot I_B$ )

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

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

Where:  $\theta_F$  = final thermal state before disconnection of device

**49 Overload Setting**  $I_\theta$  is expressed as a multiple of the relay nominal current and is equivalent to the factor  $k \cdot I_B$  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, or function key

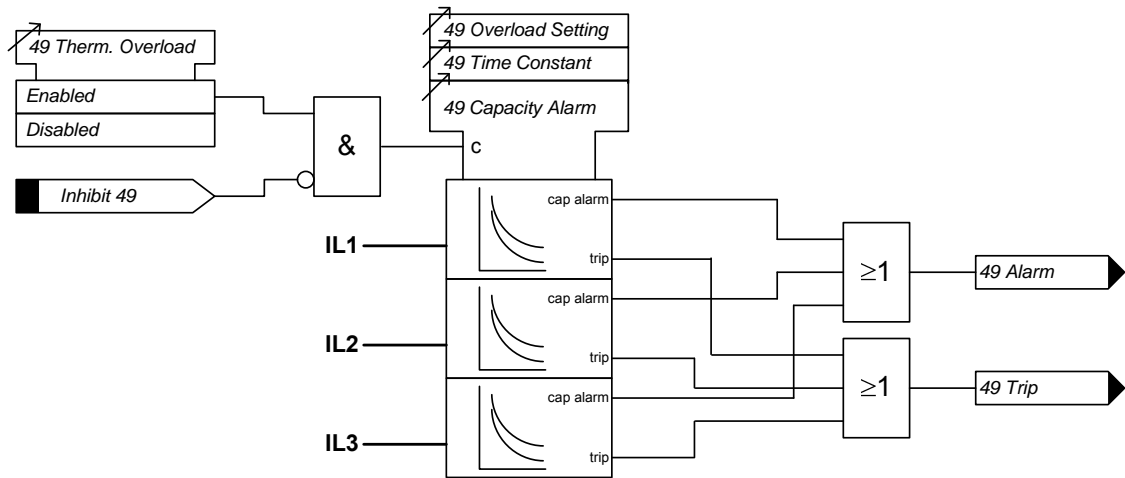


Figure 3.10-1 Logic Diagram: Thermal Overload Protection (49S)

### 3.11 Voltage Protection: Phase Under/Over Voltage (27/59) - 7SR22

In total five under/over voltage elements are provided in the 7SR22 relay. 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:

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

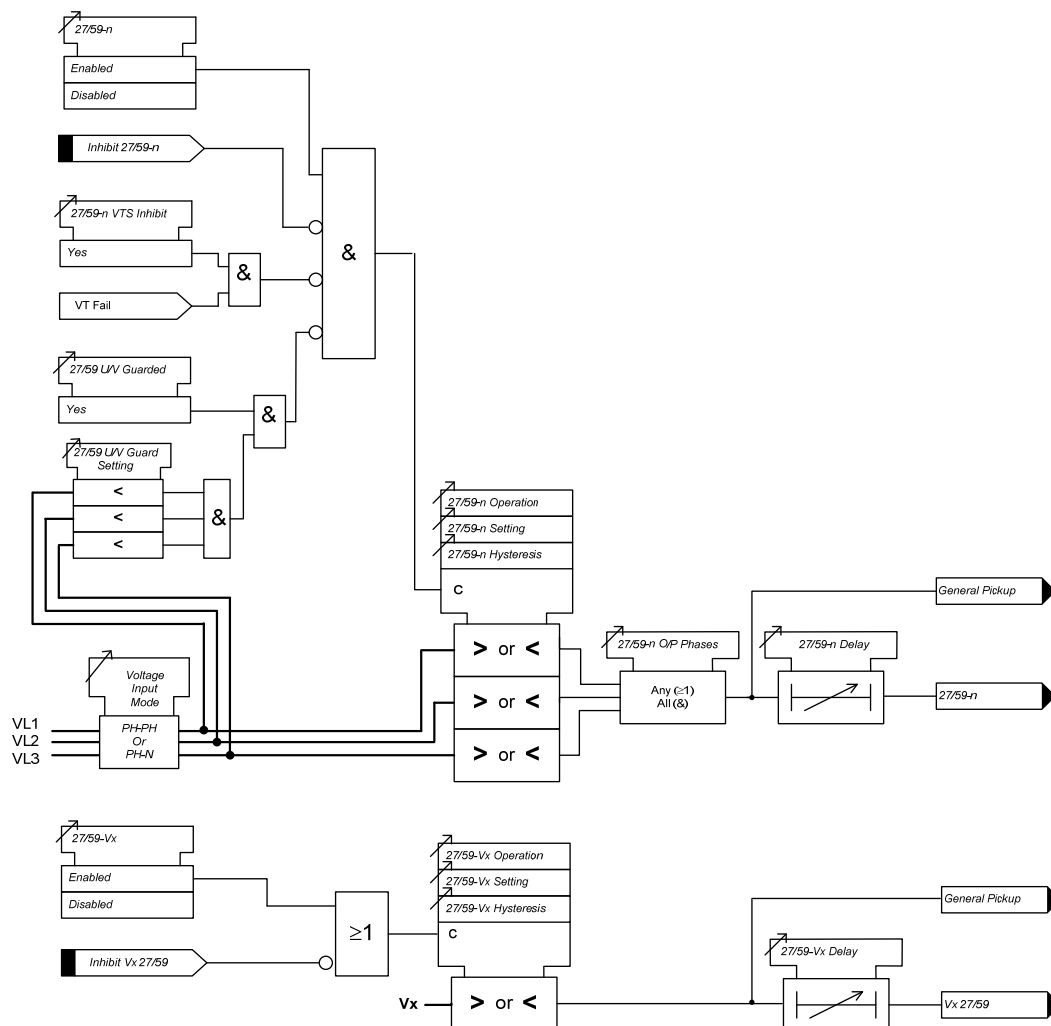


Figure 3.11-1 Logic Diagram: Under/Over Voltage Elements (27/59)

### 3.12 Voltage Protection: Negative Phase Sequence Overvoltage (47) – 7SR22

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 in the 7SR22 relay.

**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, or function key.

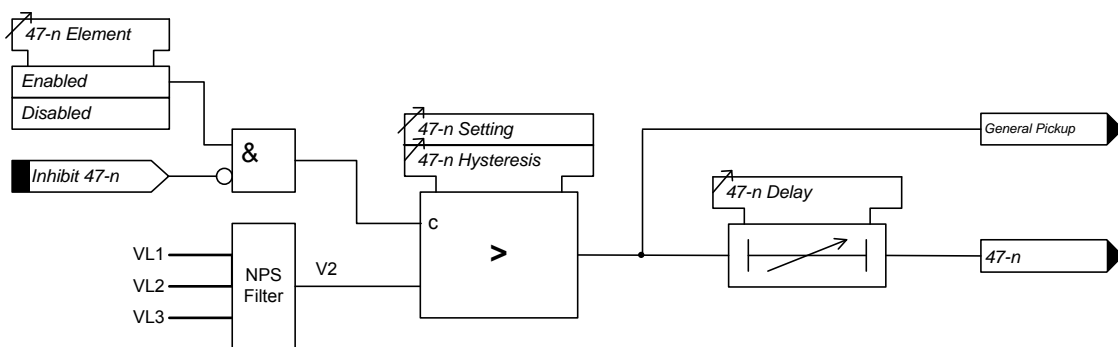


Figure 3.12-1 Logic Diagram: NPS Overvoltage Protection (47)

### 3.13 Voltage Protection: Neutral Overvoltage (59N) – 7SR22

Two Neutral Overvoltage (or Neutral Voltage Displacement) elements are provided in the 7SR22 relay.

**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),

The Neutral Inverse Time Lag **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):

$$t_{op} = \left[ \frac{M}{\left[ \frac{3V_0}{V_s} \right] - 1} \right] s$$

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. The Neutral Definite Time Lag **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:

<b>Inhibit 59NIT</b>	A binary or virtual input, or function key
<b>Inhibit 59NDT</b>	A binary or virtual input, or function key

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.

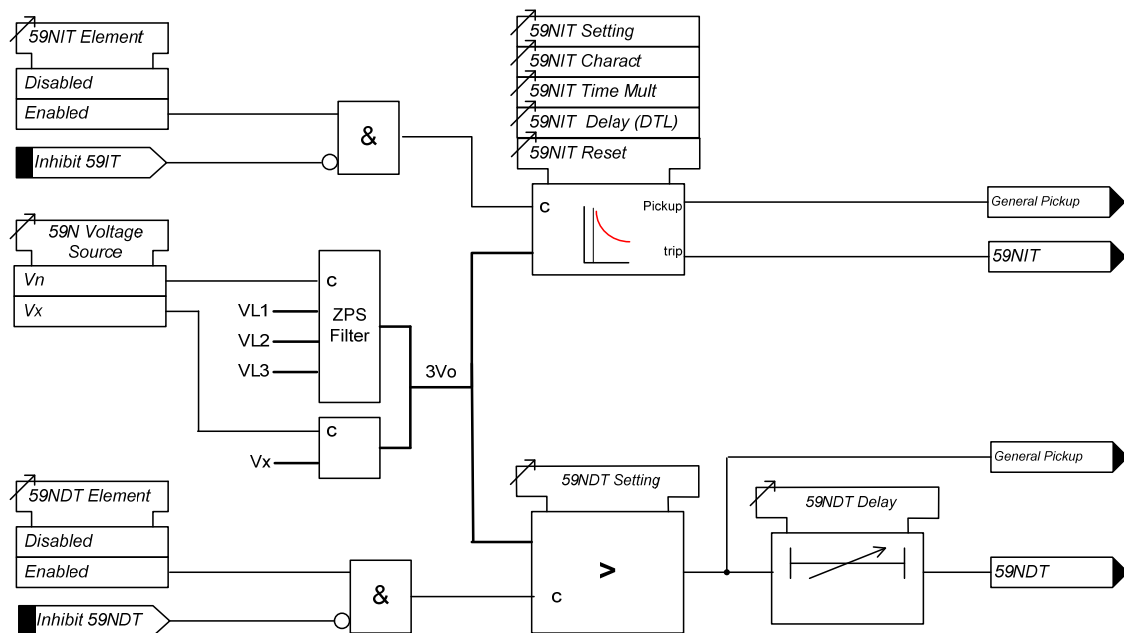


Figure 3.13-1 Logic Diagram: Neutral Overvoltage Element

### 3.14 Voltage Protection: Under/Over Frequency (81) – 7SR22

Six under/over frequency elements are provided in the 7SR22 relay.

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 frequency elements can be inhibited from:

<b>Inhibit 81-n</b>	A binary or virtual input, or function key.
<b>81-n U/V Guarded</b>	Under voltage guard element.

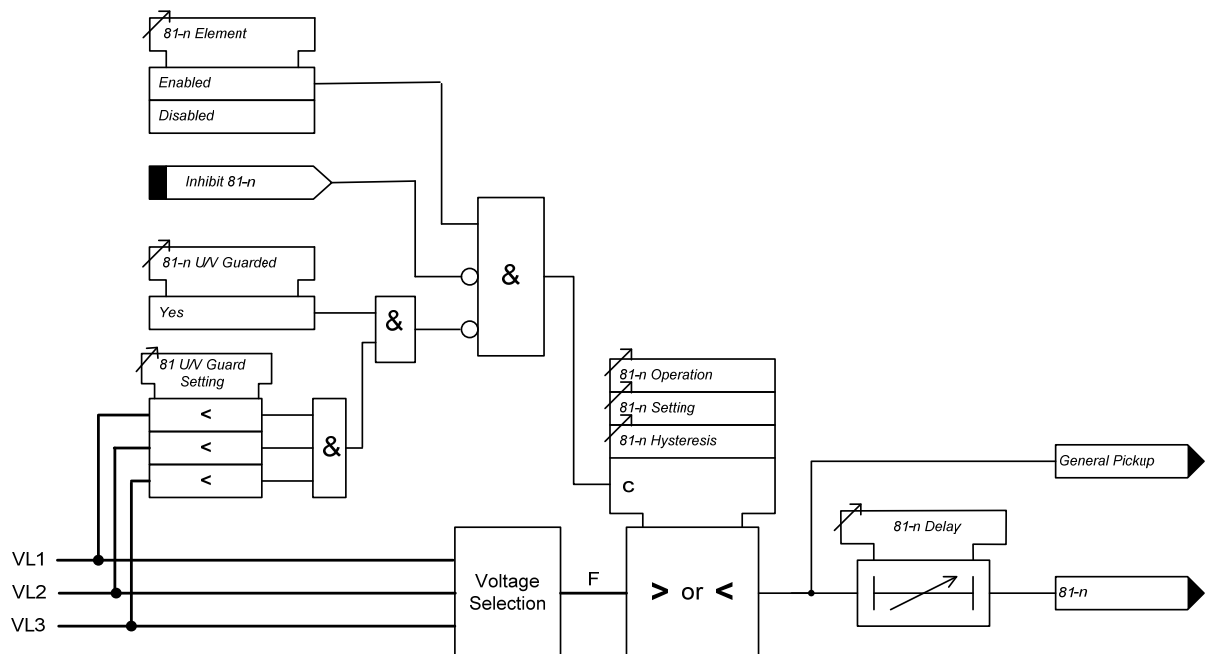


Figure 3.14-1 Logic Diagram: Under/Over Frequency Detector (81)

## Section 4: Control & Logic Functions

### 4.1 Auto-Reclose (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 Circuit Breaker (CB) reclosures after the line has been dead for a short time, this 'deadtime' allows the fault current arc to fully extinguish.

Typically this auto reclose (AR) sequence of Instantaneous Trip(s) and Reclose Delays (Dead times) followed by Delayed Trip(s) provide 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 Auto Reclose of the Circuit Breaker to provide the necessary network Dead times, to allow time for Arc extinction

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

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

The Auto Reclose feature may be switched in and out of service by a number of methods, these are:

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

- A keypad change from the CONTROL MODE

- 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 auto-reclose will be Out of Service.

Knowledge of the CB position status is integral to the auto-reclose 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 circuit memory functionality prevents autoreclosing when the line is de-energised, or normally open.

AR is started by a valid protection operation that is internally mapped to trip in the 79 Autoreclose protection menu or an external trip received via a binary input **79 Ext Trip**, 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 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 is locked-out. The relay is programmed to initiate a number of AR attempts, the number 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 auto-reclose 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 Auto-Reclose and Manual Closing of the circuit breaker: -

- Autoreclose Status
- Out of Service
- Close Shot.
- 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
- Block Close CB
- Close CB
- 79 Trip & Reclose
- 79 Trip & Lockout
- 79 Line Check
- Hot Line In
- Hot Line 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
- 79 AR Close CB
- 79 Successful AR
- 79 Lockout
- 79 Close Onto Fault
- 79 CB Fail to Close
- 79 Trip \_Reclose
- 79 Trip \_Lockout
- 79 Block Extern

### 4.1.2 Auto Reclose sequences

The CONTROL & LOGIC>AUTO RECLOSE PROT'N and CONTROL & LOGIC>AUTORECLOSE CONFIG' menus, allow the user to set independent Protection and Auto Reclose sequences for each type of fault i.e. Phase Fault (P/F), Derived/Measured Earth Fault (E/F), Sensitive Earth Fault (SEF) or External Protections (EXTERN). Each Auto Reclose sequence can be user set to up to four-shots i.e. five trips + four reclose sequence, with independently configurable type of Protection Trip. Overcurrent and earth fault elements can be assigned to any combination of Fast (**Inst**), **Delayed** or highset (**HS**) trips. **Deadtime** Delay time settings are independent for each AR shot. The user has programming options for Auto Reclose Sequences time 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 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 **Delayed** 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, ie. 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.

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

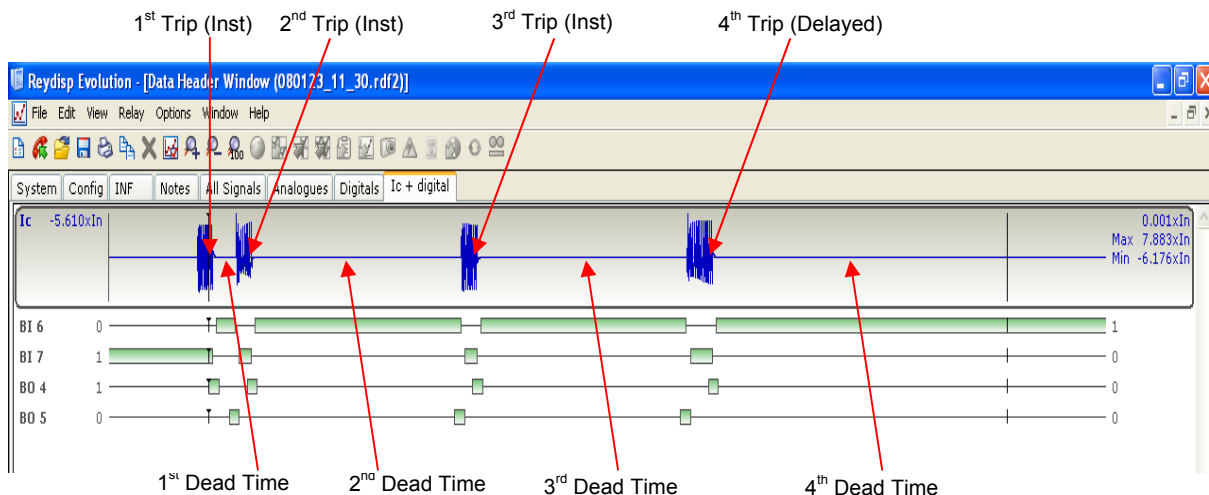


Figure 4.1-1 Typical Auto Reclose Sequence with 3 Instantaneous and 1 Delayed trip

## 4.2 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 Auto Reclose Relay. The resultant configuration enables the Auto Reclose function to correctly apply the required Protection for each shot in a sequence.

## 4.3 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 AutoReclose start can be primed. Where this time expires before all the DAR 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 LO 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 auto-reclose 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.

### Notes on the 'Lockout' State

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

- At the end of the **79 Sequence Fail Timer**.
- At the end of the **Reclaim timer** if the CB is in the open position.
- A protection operates during the final Reclaim time.
- If a Close Pulse is given and the CB fails to close.
- The **79 Lockout** binary input is active.

- At the end of the **79 Reclose Blocked Delay** due to presence of a persistent Block signal.
- When the **79 Elem HS Trips to Lockout** count is reached.
- 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:

- By a Manual Close command, from fascia, comms or **Close CB** binary input.
- By a **79 Reset Lockout** binary input, provided there is no signal present that will cause Lockout.
- 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.
- 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.
- By the **CB Closed** binary input, provided there is no signal present which will cause Lockout.

The Lockout condition has a delayed drop-off time of 2s. The Lockout condition can not be reset if there is an active lockout input.

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.

## 4.4 P/F Shots Sub-Menu

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

- |  |   |
|--|---|
| <b>79 P/F Prot'n Trip1</b>             | The first protection Trip in the P/F sequence can be set to either <b>Inst</b> or <b>Delayed</b> .  |
| <b>79 P/F Deadtime 1</b>               | Sets the first Reclose Delay (Dead time) in the P/F sequence.   |
| <b>79 P/F Prot'n Trip2</b>             | The second protection Trip in the P/F sequence can be set to either <b>Inst</b> or <b>Delayed</b> .   |
| <b>79 P/F Deadtime 2</b>               | Sets the second Reclose Delay (Dead time) in the P/F sequence.  |
| <b>79 P/F Prot'n Trip3</b>             | The third protection Trip in the P/F sequence can be set to either <b>Inst</b> or <b>Delayed</b> .  |
| <b>79 P/F Deadtime 3</b>               | Sets the third Reclose Delay (Dead time) in the P/F sequence.   |
| <b>79 P/F Prot'n Trip 4</b>            | The fourth protection Trip in the P/F sequence can be set to either <b>Inst</b> or <b>Delayed</b> .   |
| <b>79 P/F Deadtime 4</b>               | Sets the fourth Reclose Delay (Dead time) in the P/F sequence.  |
| <b>79 P/F Prot'n Trip5</b>             | The fifth and last protection Trip in the P/F sequence can be set to either <b>Inst</b> or <b>Delayed</b> .   |
| <b>79 P/F HighSet Trips to Lockout</b> | 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. |
| <b>79 P/F Delayed Trips to Lockout</b> | 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.  |

## 4.5 E/F Shots Sub-Menu

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

As above but E/F settings.

## 4.6 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

## 4.7 Extern Shots Sub-Menu

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

<b>79 P/F Prot'n Trip1</b>	<b>Not Blocked/Blocked</b> - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's Trip Output.
<b>79 P/F Deadtime 1</b>	Sets the first Reclose Delay (Deadtime) for the External sequence.
<b>79 P/F Prot'n Trip2</b>	<b>Not Blocked/Blocked</b> - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's second Trip output.
<b>79 P/F Deadtime 2</b>	Sets the second Reclose Delay (Deadtime) in the External sequence.
<b>79 P/F Prot'n Trip3</b>	<b>Not Blocked/Blocked</b> - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's third Trip Output.
<b>79 P/F Deadtime 3</b>	Sets the third Reclose Delay (Deadtime) in the External sequence.
<b>79 P/F Prot'n Trip4</b>	<b>Not Blocked/Blocked</b> - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's fourth Trip Output.
<b>79 P/F Deadtime 4</b>	Sets the fourth Reclose Delay (Deadtime) in the External sequence.
<b>79 P/F Prot'n Trip5</b>	<b>Not Blocked/Blocked</b> - Blocked raises an output which can be mapped to a Binary output to Block an External Protection's fifth Trip Output.
<b>79 P/F Extern Trips to Lockout</b>	- 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.

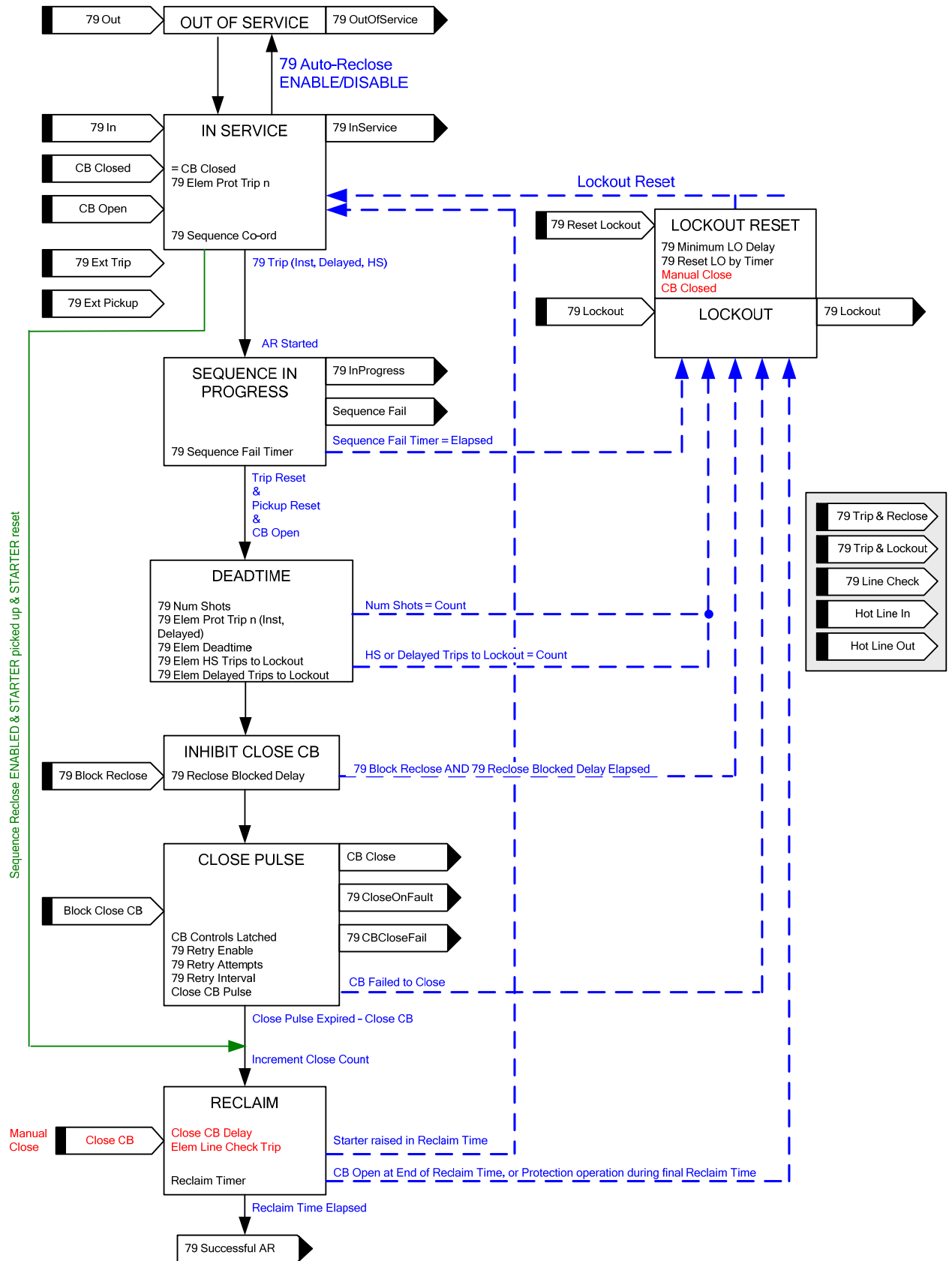


Figure 4.7-1 Basic Auto-Reclose Sequence Diagram

## 4.8 Manual Control

A Manual Close Command can be initiated in one of three ways: via a **Close CB** binary input, via the data communication Channel(s) or from the relay CONTROL MODE menu. It causes an instantaneous operation via **79MC Close CB** binary output, over-riding any AR sequence in progress.

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.

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.

## 4.9 Circuit Breaker

This menu includes relay settings applicable to both manual close (MC) and auto-reclose (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 pick-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 DAR 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 (DBI)

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 auto reclose sequences are inhibited and any fault causes an instantaneous trip to lockout.

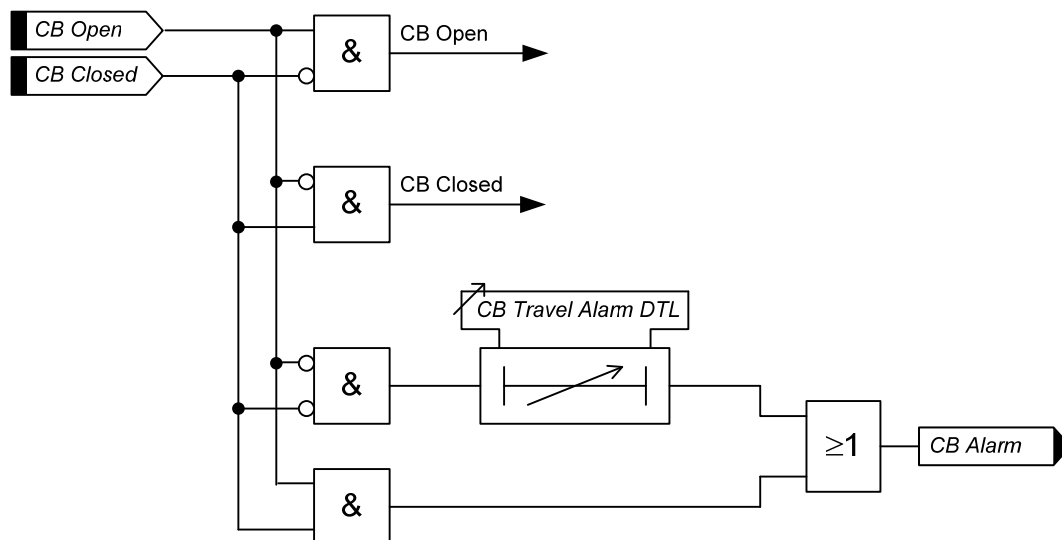


Figure 4.9-1 Logic Diagram: Circuit Breaker Status

## 4.10 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: -

<b>0, 1, 2, 3, 4, 5, 6, 7, 8, 9</b>	Digit
<b>( )</b>	Parenthesis
<b>!</b>	'NOT' Function
<b>.</b>	'AND' Function
<b>^</b>	'EXCLUSIVE OR' Function
<b>+</b>	'OR' Function
<b>En</b>	Equation (number)
<b>Fn</b>	Function Key (number)
	'1' = Key pressed, '0' = Key not pressed
<b>In</b>	Binary Input (number)
	'1' = Input energised, '0' = Input de-energised
<b>Ln</b>	LED (number)
	'1' = LED energised, '0' = LED de-energised
<b>On</b>	Binary output (number)
	'1' = Output energised, '0' = Output de-energised
<b>Vn</b>	Virtual Input/Output (number)
	'1' = Virtual I/O energised, '0' = Virtual I/O de-energised

### Example Showing Use of Nomenclature

**$E1 = ((I1 \wedge F1) \cdot !O2) + L1$**

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

OR

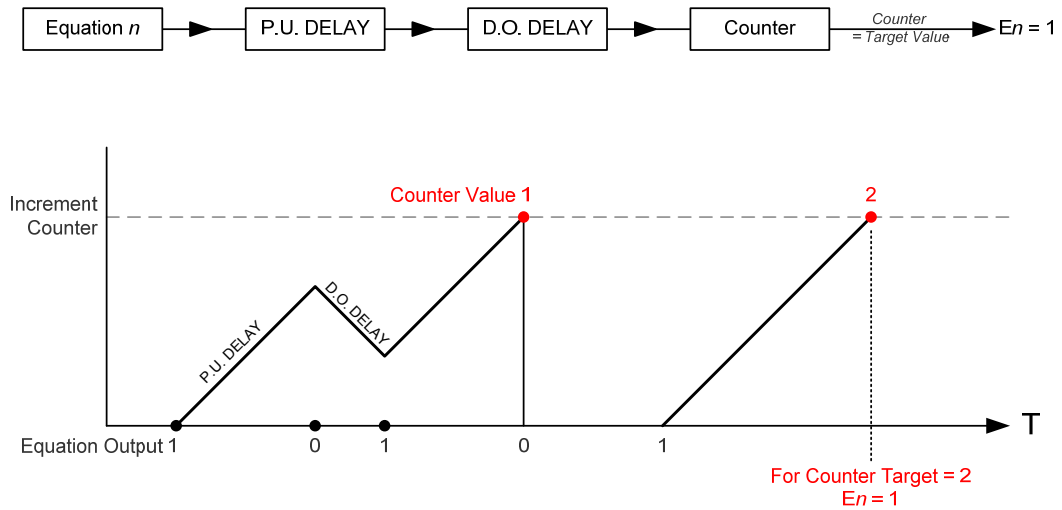
LED 1

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 4.10-1 Sequence Diagram: Quick Logic PU/DO Timers (Counter Reset Mode Off)**

When the count value = **En Counter Target** the output of the counter ( $E_n$ ) = 1 and this value is held until the initiating conditions are removed when  $E_n$  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 two timers run concurrently.

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 or virtual input assigned to **50BF Ext Trig** (MENU: INPUT CONFIG\INPUT MATRIX\50BF Ext Trig).

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 **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.

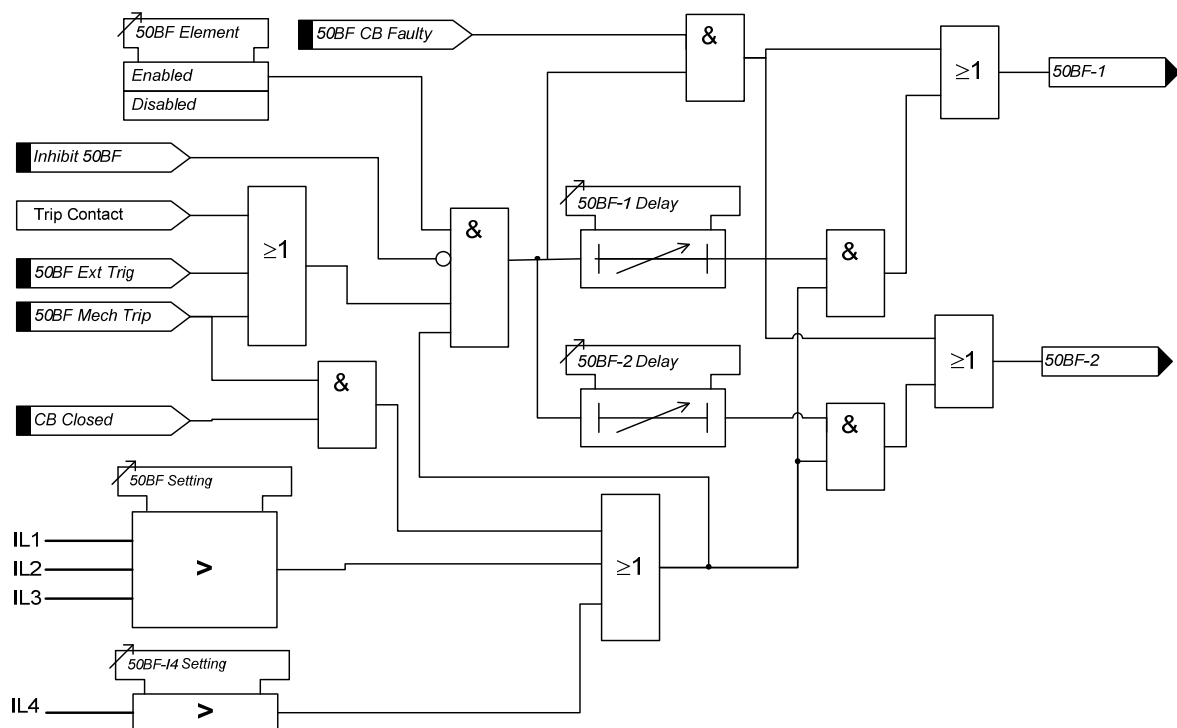


Figure 5.1-1 Logic Diagram: Circuit Breaker Fail Protection (50BF)

## 5.2 VT Supervision (60VTS) – 7SR22

### 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<sub>PPS</sub>** setting, an **60VTS I<sub>PPS</sub> Load** setting and a setting for **60VTS I<sub>PPS</sub> Fault**. A VT is considered to have failed where positive sequence voltage is below **60VTS V<sub>PPS</sub>** while positive sequence current is above **I<sub>PPS</sub> Load** and below **I<sub>PPS</sub> 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<sub>PPS</sub>** setting while NPS voltage is below **V<sub>NPS</sub>** 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 or function key.

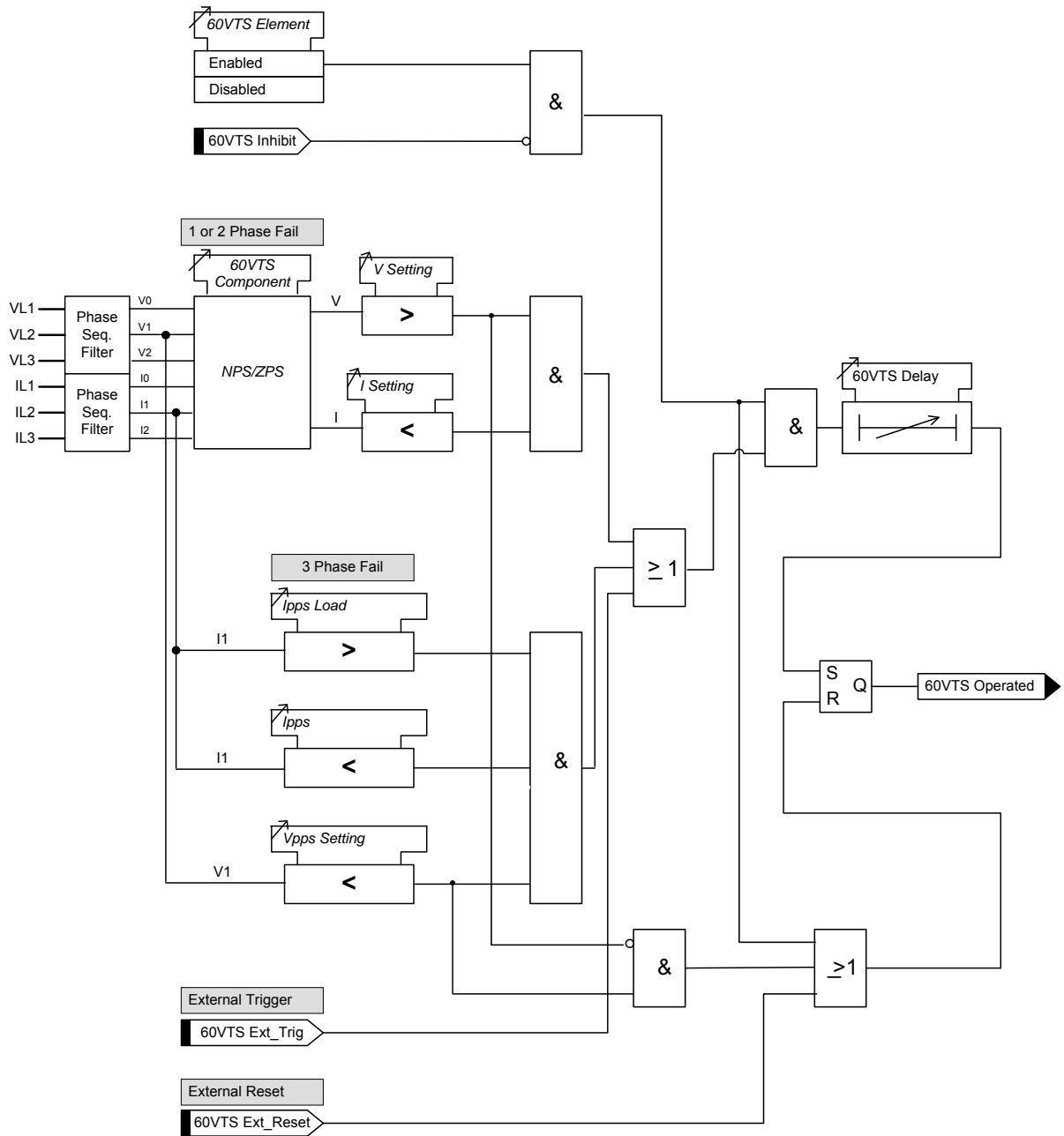


Figure 5.2-1 Logic Diagram: VT Supervision Function (60VTS)

### 5.3 CT Supervision (60CTS & 60CTS-I)

The relay has two methods of detecting a CT failure, depending on the relay variant.

### 5.4 (60CTS-I) – 7SR21 & 7SR22

The current from each of the Phase Current Transformers is monitored. If one or two of the three input currents falls below the CT supervision current setting **CTS-I** for more than **60CTS-I Delay** then a CT failure output (**60CTS-I Operated**) is given. If all three input currents fall below the setting, CT failure is not raised.

Operation of the CT supervision elements can be inhibited from:

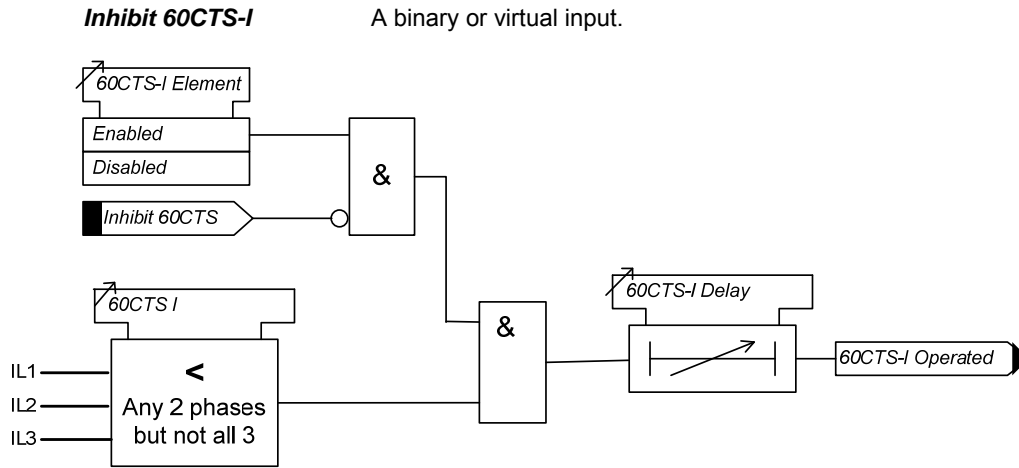


Figure 5.4-1 Logic Diagram: CT Supervision Function (60CTS-I) – 7SR21 & 7SR22

### 5.5 (60CTS) – 7SR22

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 CT supervision elements can be inhibited from:

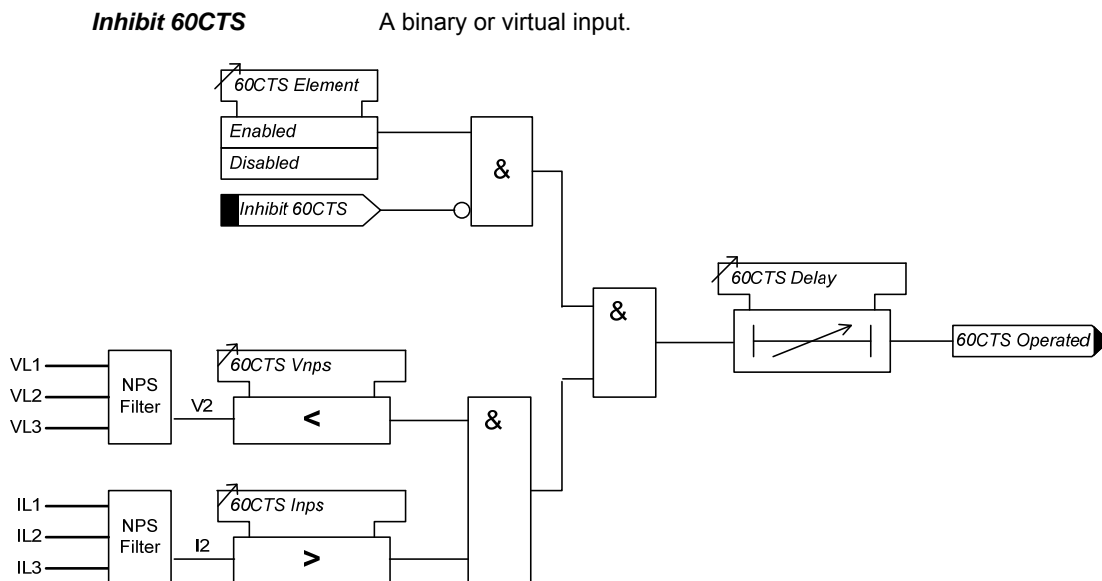


Figure 5.5-1 Logic Diagram: CT Supervision Function (60CTS) – 7SR22

## 5.6 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 or function key.

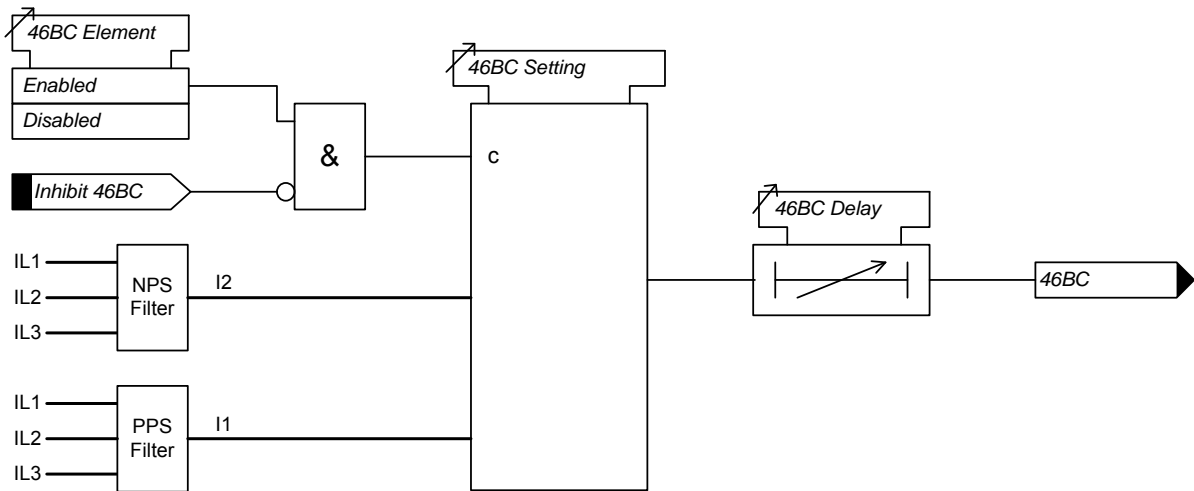


Figure 5.6-1 Logic Diagram: Broken Conductor Function (46BC)

## 5.7 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'.

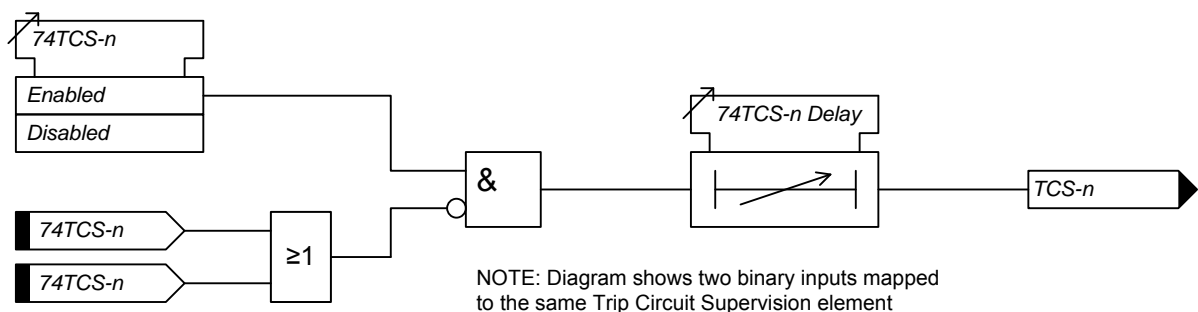


Figure 5.7-1 Logic Diagram: Trip Circuit Supervision Feature (74TCS)



## 5.8 Inrush Restraint (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.

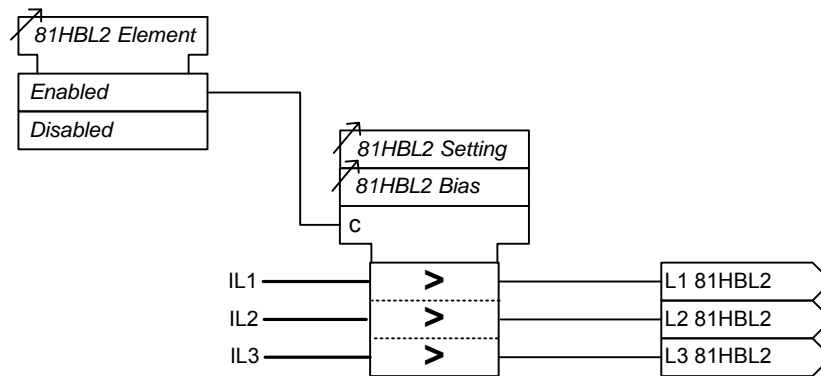


Figure 5.8-1 Logic Diagram: Harmonic Block Feature (81HBL2)

## 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.

Optionally, additional communication ports are available: -

2x fibre optic with ST connectors and 1x IRIG-B – (COM3 and COM4),

1x RS485 and 1x IRIG-B – (COM3),

1x RS232 and IRIG-B – (COM3)

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 Chapter 4 of this manual.

### 6.2 CB Maintenance

Several CB operations counters are provided:

CB Total Trip Count:	Increments on each trip command issued. During an auto-reclose sequence, if 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 auto-reclose sequence, if the target count is reached the relay will perform one Delayed Trip and lockout.

An  $I^2t$  counter is also included, this can provide an estimation of contact wear and maintenance requirements. The algorithm works on a per phase basis, measuring the arcing current during faults. The  $I^2t$  value at the time of trip is added to the previously stored value and an alarm is given when any one of the three phase running counts exceeds the set **Alarm limit**. The  $t$  value is the time between CB contacts separation when an arc is formed, **Separation Time**, and the CB **Clearance time**.

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.

#### 6.2.1 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.

## 6.3 Data Storage

### 6.3.1 General

The relay stores three types of data records: 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.

### 6.3.2 Demand / Data Log

The Demand / Data log feature can be used to build trend and maximum/minimum demand records. Up to 10,080 individual time stamped records can be stored at a user defined rate e.g. 7 days @ 1 minute intervals and > 1 year @ 1 hour intervals.

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

In the menu **DATA STORAGE > DEMAND / DATA LOG: -**

The **Data Log Period** setting is used to define the period between stored samples.

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

The **Gn Demand Window Type** is the mode used to calculate demand values and can be set to **FIXED** or **PEAK** or **ROLLING**: -

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 since the feature was reset are recorded.

When set to **ROLLING** the maximum, minimum and mean values demand statistics are calculated over a moving Window duration. The internal statistics are updated when the window advances.

The statistics can be reset from a binary input or communication command, after a reset the update period and window are immediately restarted.

### 6.3.3 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 using the DATA STORAGE>**Clear Events** setting.

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.
- Protection element operation.

All events can be blocked or made available and uploaded 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 DNP3.0 compliant control system. The function number and event number can also be changed. The events are selected and edited using the Reydisp software tool.

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

### 6.3.4 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 either 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 record 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.

Waveforms are sampled at a rate of 1600Hz.

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

### 6.3.5 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.

The relay can be set to automatically display the fault record on the LCD when a fault occurs by enabling the SYSTEM CONFIG> **Trip Alert** setting. When the trip alert is enabled the fault record will be displayed until the fault is removed.

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 Metering

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

The Primary values are calculated using the CT and VT ratios set in the **CT/VT Config** menu.

The text displayed in the relays 'Instruments Mode' associated with each value can be changed from the default text using the Reydisp software tool.

The user can add the meters that are most commonly viewed to a 'Favourites' window by pressing 'ENTER' key when viewing a meter. The relay will scroll through these meters at an interval set in the **System Config/Favourite Meters Timer** menu.

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

## 6.5 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

Table 6-1 Operation Mode

OPERATION	REMOTE MODE	LOCAL MODE	SERVICE MODE
<b>Control</b>			
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
<b>Reporting</b>			
Spontaneous			
IEC	Enabled	Enabled	Disabled
DNP	Enabled	Enabled	Disabled
General Interrogation			
IEC	Enabled	Enabled	Disabled
DNP	Enabled	Enabled	Disabled
MODBUS	Enabled	Enabled	Disabled
<b>Changing of Settings</b>			
Rear Ports	Enabled	Disabled	Enabled
Fascia	Enabled	Enabled	Enabled
USB	Disabled	Enabled	Enabled
<b>Historical Information</b>			
Waveform Records	Enabled	Enabled	Enabled
Event Records	Enabled	Enabled	Enabled
Fault Information	Enabled	Enabled	Enabled
Setting Information	Enabled	Enabled	Enabled

## 6.6 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 are password protected using the Control Password function – see section 6.9.

## 6.7 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.

In order to maintain synchronism within a substation, the relay can be synchronised to the nearest second or minute using the IEC 60870-5-103 protocol, optional IRIG-B input or binary input.

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.

### 6.7.1 Time Synchronisation - Data Communication Interface

Where the data comms channel(s) is connected the relay can be directly time synchronised using the global time synchronisation. This can be from a dedicated substation automation system or from 'Reydisp Evolution' communications support software.

### 6.7.2 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.

### 6.7.3 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.

## 6.8 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**).

## 6.9 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.