7PG2113/4/5/6

Feeder Protection

Document Release History

This document is issue 2010/08. The list of revisions up to and including this issue is:

2010/08	First Issue

Software Revision History

2009/04	2436H80003R1g-1c 7PG2113/5 2436H80004R1g-1c 7PG2114/6	First Release

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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:

- 7PG2113/5 Pilot Wire Differential Relay with Overcurrent and Earth Fault Relay
- 7PG2114/6 Pilot Wire Differential Relay with Directional Overcurrent and Directional Earth Fault Relay

The ‘Ordering Option’ Tables summarise the features available in each model

1.1 General Safety Precautions

1.1.1 Current Transformer Circuits

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

1.1.2 External Resistors

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

1.1.3 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 7PG2113/5 Ordering Options

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

Protection Product Family	5
Solkor R/Rf Scheme	1

Relay Type	6
Solkor R/Rf	1

Case, I/O and Fascia	7	14
Non Directional OC, E10 case, 4 CT, 3 Binary Inputs / 5 Binary Outputs, 10 LEDs	3	C
Non Directional OC, E10 case, 4 CT, 6 Binary Inputs / 8 Binary Outputs, 10 LEDs	5	

Measuring input	8
1A, 50/60Hz	1
5A, 50/60Hz	2

Auxiliary voltage	9
80-250V DC, binary input threshold 19V DC	G
80-250V DC, binary input threshold 88V DC	H
24-60V DC, binary input threshold 19V DC	J

Spare	10
	A

Communication Interface	11
Standard version - included in all models, USB front port, RS485 rear port	1

Protocol	12
IEC 60870-5-103, Modbus RTU and DNP3(user selectable setting)	2

Spare	13
	1

Protection Function Packages		14
For future development		A
For future development		B
Standard version - included in all models		C
37	Undercurrent	
46BC	Broken conductor/load unbalance	
46NPS	Negative phase sequence overcurrent	
49	Thermal overload	
50BF	Circuit breaker fail	
50G/50N	Instantaneous earth fault	
50	Instantaneous phase fault overcurrent	
51	Time delayed phase fault overcurrent	
51G/51N	Time delayed earth fault	
60CTS	CT Supervision	
64H	High impedance REF	
74TCS	Trip circuit supervision	
51c	Cold load pickup	
81HBL2	Inrush Restraint	
	Programmable logic	
Standard version - plus		D
79	Autoreclose	

Solkor Mode [1)]	15
Solkor Rf	A
Solkor R	B

Spare	16
	0

[1)] Default mode when supplied, relay mode is easily changed later my internal links

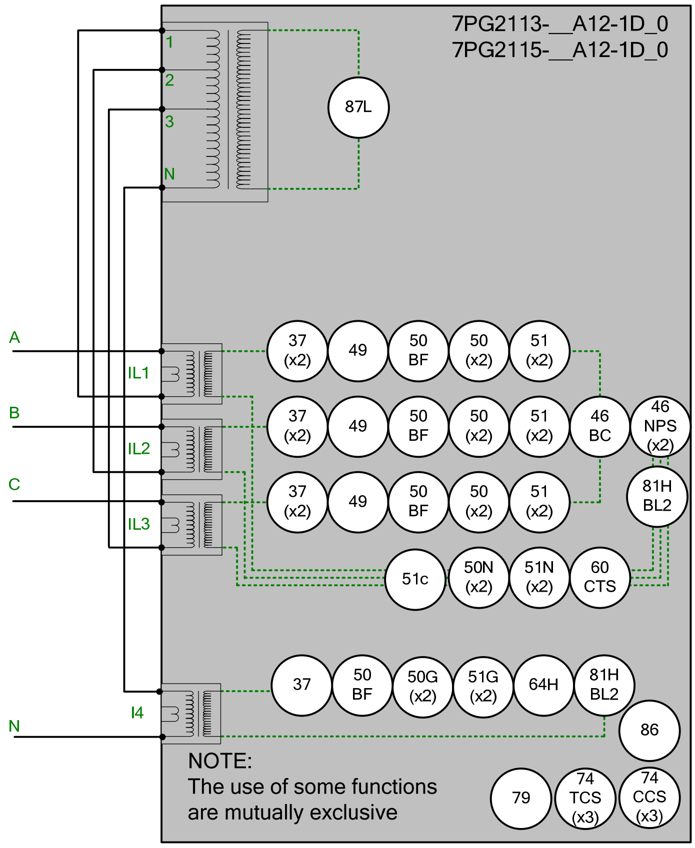


Figure 1.1-1 Functional Diagram of 7PG2113/5 Relay with Autoreclose

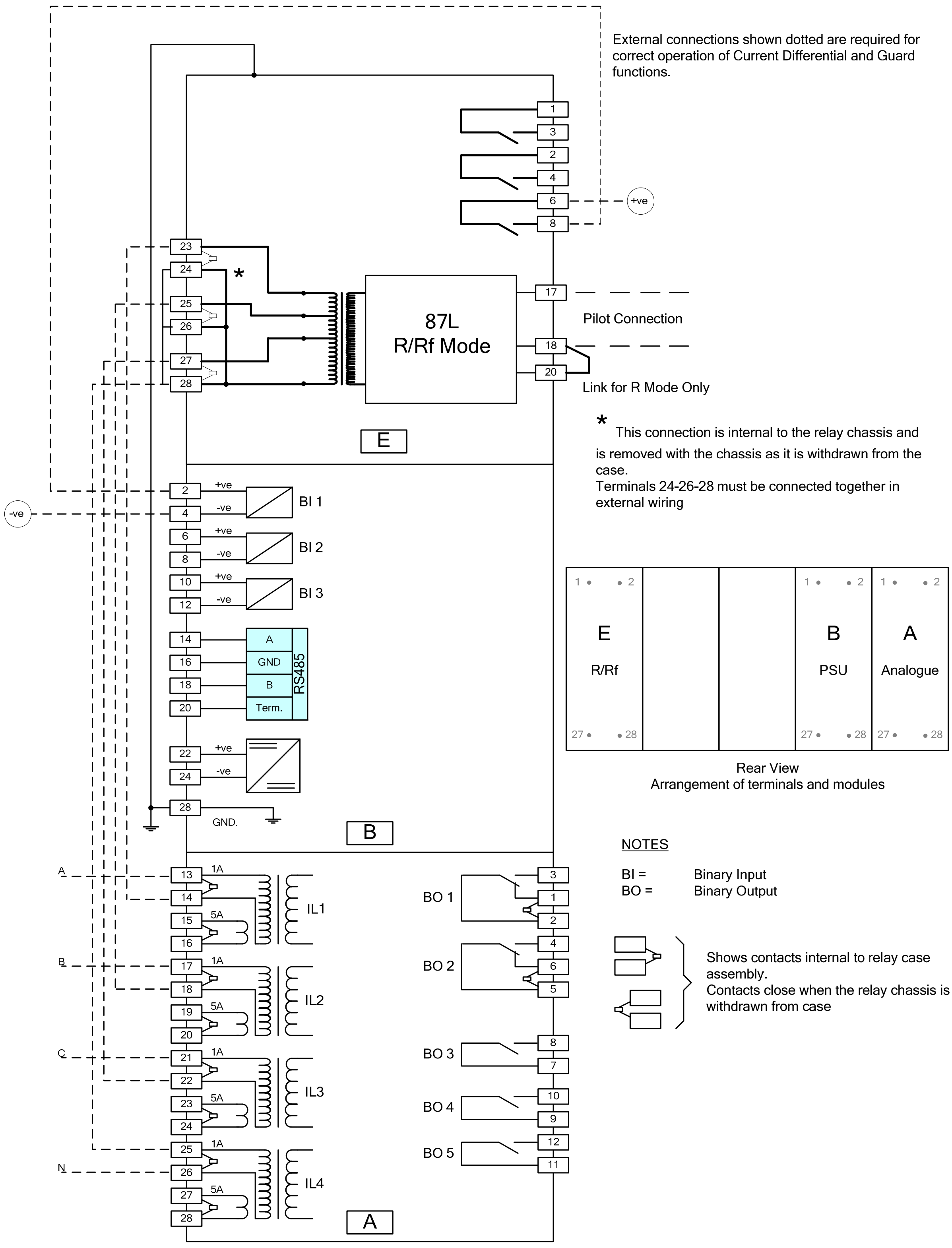


Figure 1.1-2 Connections Diagram for 7PG2113 Relay

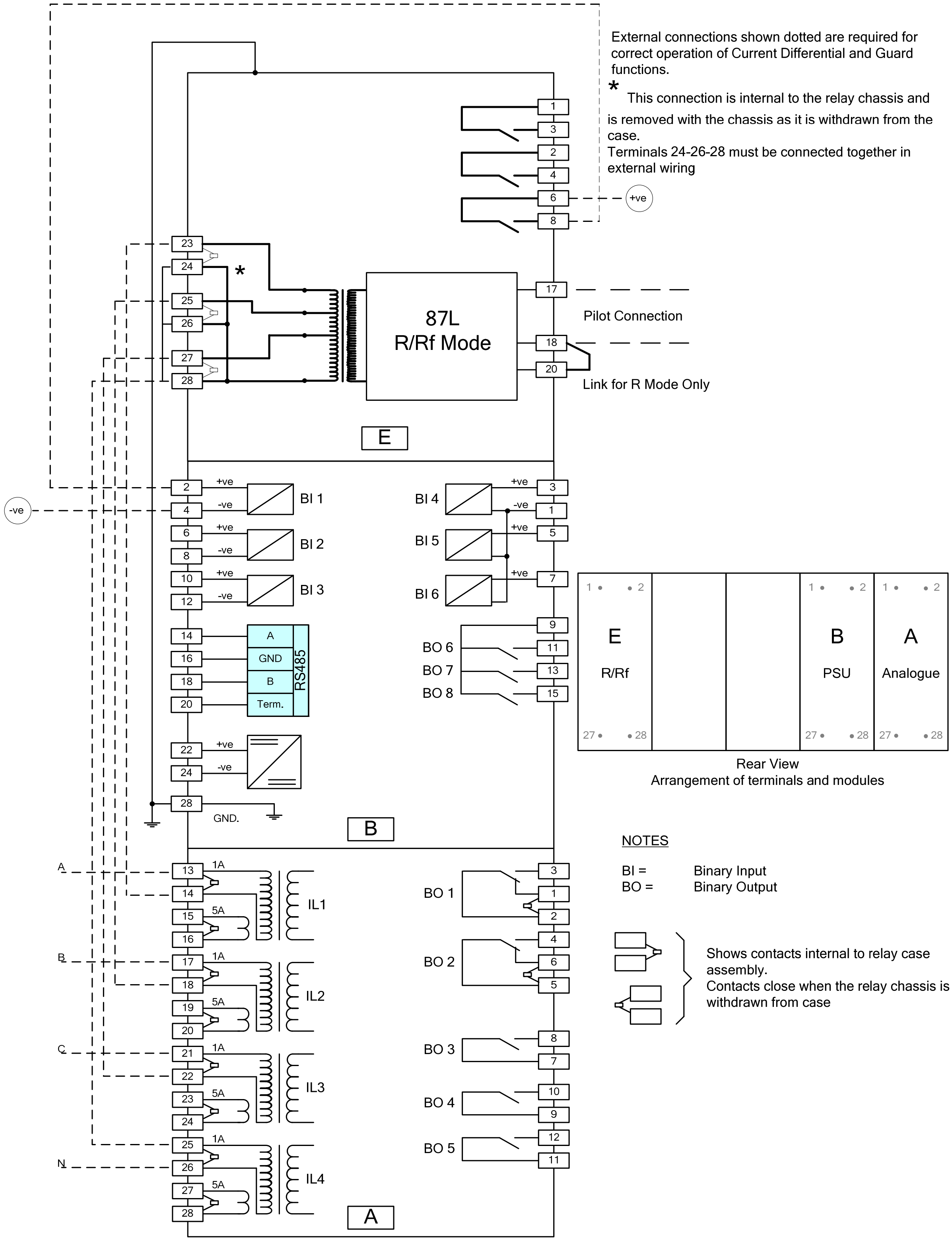


Figure 1.1-3 Connections Diagram for 7PG2115 Relay

Table 1-2 7PG2114/6 Ordering Options

Position	1	2	3	4	5	6	7	-	8	9	10	11	12	-	13	14	15	16
ORDER-No.:	7	P	G	2	1	1		-			A	1	2	-	1			0

C

Protection Product Family	5
Solkor R/Rf Scheme	1

Relay Type	6
Solkor R/Rf	1

Case, I/O and Fascia	7
Directional OC, E10 case, 4 CT, 3 VT, 3 Binary Inputs / 5 Binary Outputs, 10 LEDs	4
Directional OC, E10 case, 4 CT, 3VT, 6 Binary Inputs / 8 Binary Outputs, 10 LEDs	6

Measuring input	8
1A, 50/60Hz	1
5A, 50/60Hz	2

Auxiliary voltage	9
80-250V DC, binary input threshold 19V DC	G
80-250V DC, binary input threshold 88V DC	H
24-60V DC, binary input threshold 19V DC	J

Spare	10
	A

Communication Interface	11
Standard version - included in all models, USB front port, RS485 rear port	1

Protocol	12
IEC 60870-5-103, Modbus RTU and DNP3(user selectable setting)	2

Spare	13
	1

Protection Function Packages		14
For future development		A
For future development		B
Standard version - included in all models		C
27/59	Under/Over Voltage	
37	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	
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	
74TCS	Trip circuit supervision	
51c	Cold load pickup	
81HBL2	Inrush Restraint	
	Programmable logic	
Standard version - plus		D
79	Autoreclose	

Solkor Mode [1]	15
Solkor Rf	A
Solkor R	B

Spare	16
	0

[1] Default mode when supplied, relay mode is easily changed later by internal links

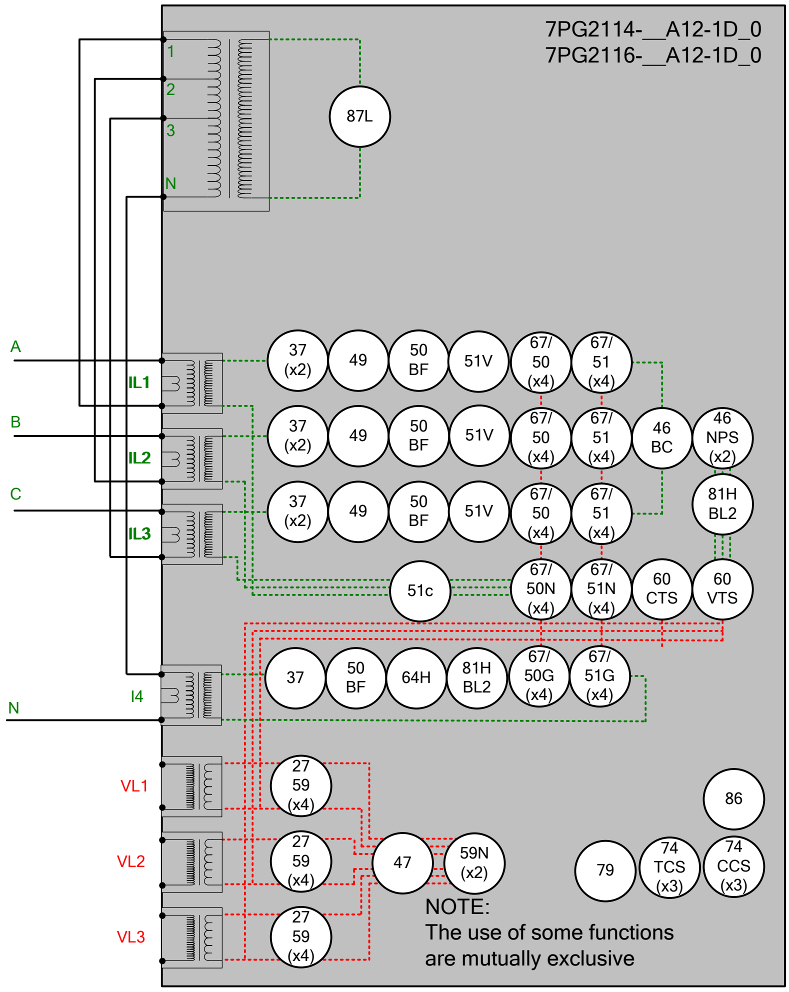


Figure 1.1-4 Functional Diagram of 7PG2114/6 Relay with Autoreclose

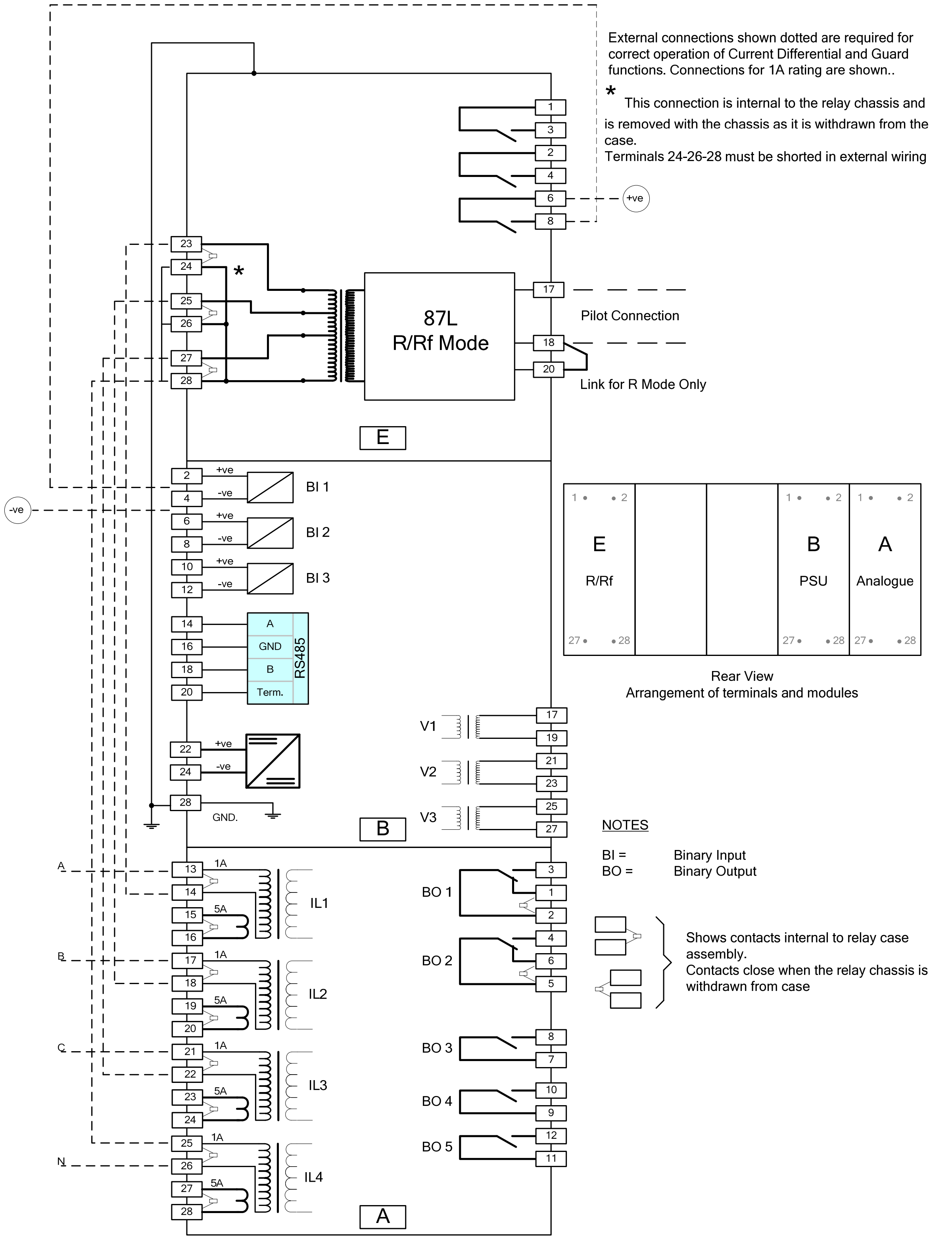


Figure 1.1-5 Connections Diagram for 7PG2114 Relay

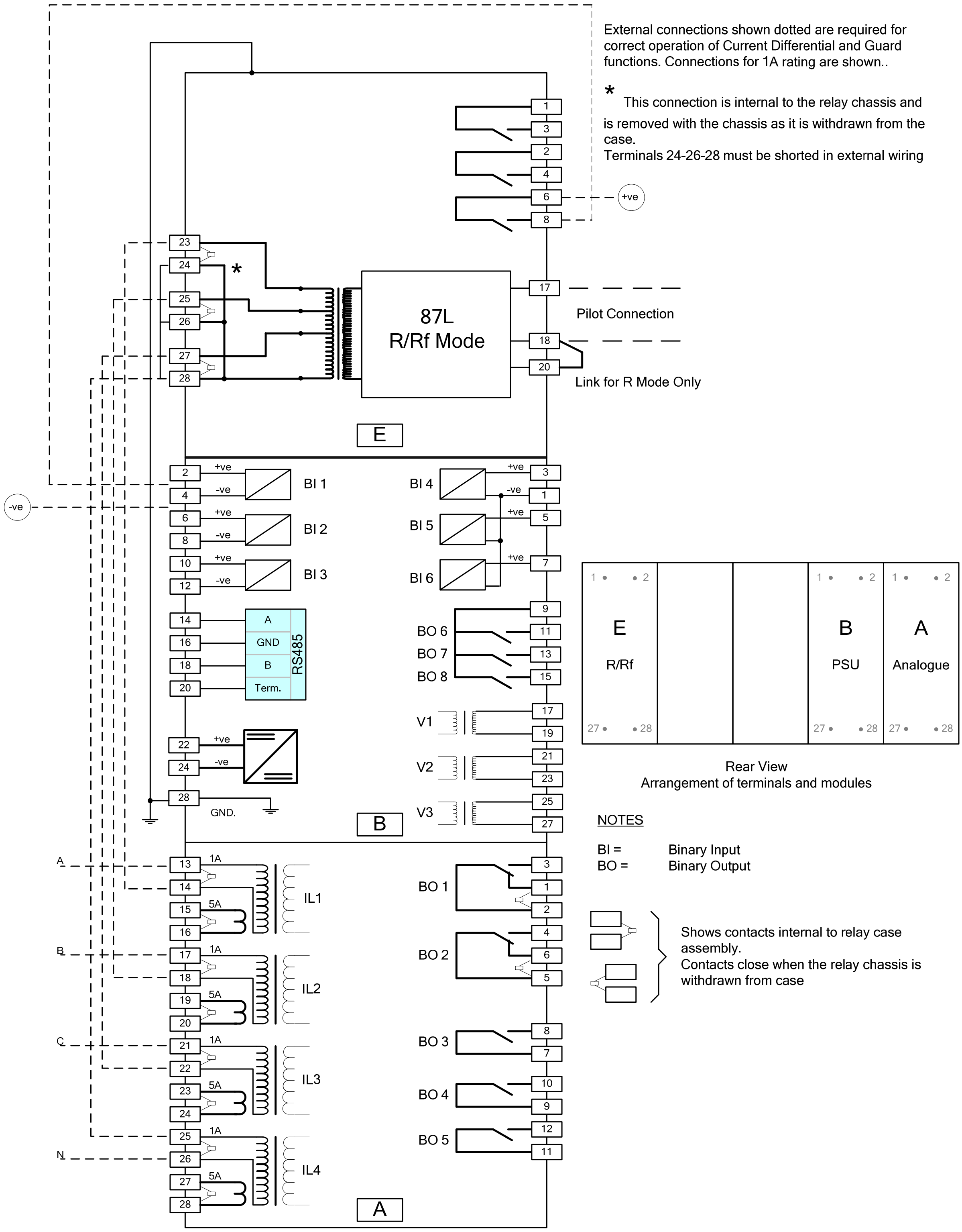


Figure 1.1-6 Connections Diagram for 7PG2116 Relay

Section 2: Hardware Description

2.1 General

The relay combines the Current Differential function of a Solkor R/Rf relay with the functions and flexibility of a modern numeric protection device.

Solkor R & Rf are well established Pilot Wire Current Differential Protection for use with privately owned 2 core pilots with relatively high core resistance.

Solkor R/Rf protection benefits from the following main features:

- High transient stability
- High speed operation (<60ms)
- Little or no variation of settings with pilot length
- Up to 20% of rated load can be tapped off from inside of the protection zone.
- Easy to install, commission and maintain
- 15kV pilot isolation option
- Easily reconnected as either Solkor Rf or Solkor R
- Pilot wire supervision schemes available
- Remote end injection intertripping via pilot cores available

The structure of the numeric guard module is based upon the Reyrolle Compact hardware platform. The combined relay is supplied in a size E10 case (where 1 x E = width of approx. 26mm). The hardware design provides commonality between products and components across the Reyrolle Compact range of relays.

Table 1-3 Summary of Compact Relay Configurations

Relay	Current Inputs	Voltage Inputs	Binary Inputs	Programmable Binary Outputs	Fixed 87L Binary outputs	LEDs
7PG2113	4	0	3	5	3	10
7PG2115	4	0	6	8	3	10
7PG2114	4	3	3	5	3	10
7PG2116	4	3	6	8	3	10

Numeric modules are assembled from the following printed circuit boards:

1) Front Fascia with 9 configurable LEDs and 1 Relay Healthy LED.

2) Processor module.

3) Current Analogue / Output module

4 x Current + 5 x Binary Outputs (BO)

4) Voltage Analogue / Input / output module

3 x Voltage (7PG2114)

3 x Voltage + 3 x Binary Input and 3 x Binary Output Module. (7PG2116)

5) Power Supply and 3 x Binary Input (BI) and RS485.

2.2 Case

The relays are housed in cases designed to fit directly into standard panel racks. The case has a width of 260mm and a height of 177 mm (4U). The required panel depth (with wiring clearance) is 242 mm.

The relay modules are withdrawable from the front of the case. Contacts in the case ensure that the CT circuits and normally closed contacts remain short-circuited when the relay is removed. To withdraw the relay modules remove the front cover by rotating the six securing pins and withdraw using the module handles. The relay modules should not be carried using these handles..

Figure 2.2-1 Relay shown withdrawn

The rear terminal blocks comprise M4 female terminals for wire connections. Each terminal can accept two 4mm crimps.

Figure 2.2-2 Rear view of 7PG2113/4/5/6 Relay

Located at the top rear of the case is a screw clamp earthing point, this must be connected to terminal B28 and directly to the main panel earth. This connection point is indicated by the following symbol.

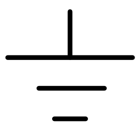


Figure 2.2-3 Earth Symbol

2.3 Front Cover

As standard the relay is supplied with a transparent front cover. The front cover is used to secure the relay modules in the case.

Figure 2.3-1 Relay with standard transparent cover

2.4 Power Supply Unit (PSU)

The relay can be ordered with two different nominal power supply ranges, 24V to 60V and 80V to 320V dc. The Solkor R/Rf module does not require an auxiliary supply and is universal for all DC ratings.

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

2.5 Operator Interface/ Fascia

The operator interface is designed to provide a user-friendly method of controlling, entering settings and retrieving data from the relay. Links are provided to allow setting of pilot padding resistance and test points are provided to allow operating spill current to be measured.

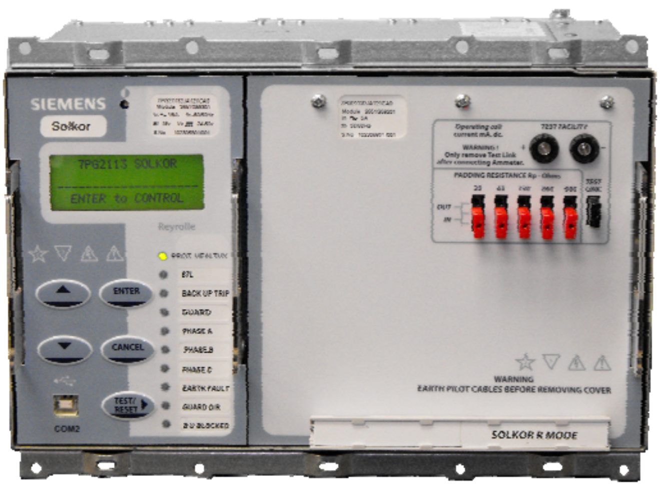


Figure 2.5-1 Relay with Transparent cover removed

The fascia is an integral part of the relay modules. Handles are located on the modules which allow them to be withdrawn from the relay case. The relay should not be carried by these handles.

Relay Information

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

1) Product Information & Rating Label, containing

MLFB ordering code

Nominal current rating

Rated frequency

Voltage rating

Auxiliary supply rating

Binary input supply rating

Serial number

2) Purpose inscription label marked ‘Solkor’.

Figure 2.5-2 Close up of typical relay labels

A ‘template’ is available in Reydisp Software to allow users to create and print customised purpose inscription labels.

For safety reasons the following symbols are displayed on the fascia

Dielectric Test Voltage 2kV

Impulse Test Above 5kV

Caution: Refer to Equipment Documentation

Caution: Risk of Electric Shock

Liquid Crystal Display (LCD)

A 4 line by 20-character alpha-numeric 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. The ‘backlight timer’ 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 indentifying 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.

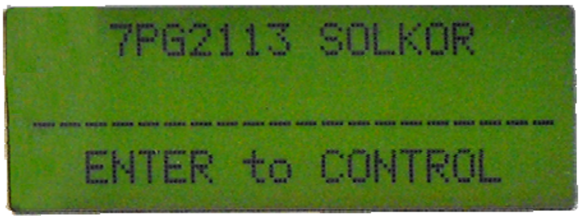


Figure 2.5-3 Close up of Relay Identifier

LCD Indication

General Alarms are user defined text messages displayed on the LCD when mapped to binary or virtual inputs. Up to six general alarms of 16 characters can be programmed, each triggered from one or more input. Each general alarm will also generate an event.

If multiple alarms are activated simultaneously the messages are displayed on a separate page in a rolling display on the LCD.
All general alarms raised when a fault trigger is generated will be logged into the Fault Data record.

Standard Keys

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

NOTE: All settings and configuration of LEDs, BI and BO can be accessed and set by the user using these keys. Alternatively configuration/settings files can be loaded into the relay using 'Reydisp'. When the System Config>***Setting Dependencies*** is ENABLED, only the functions that are enabled will appear in the menu structure.

'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.

Indication LEDs

Relays have 9 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. The same LED can be assigned two different colours dependent upon whether a Start/Pickup or Operate condition exists. LED's can be assigned to the pick up condition and colour selected in the OUTPUT CONFIG>LED CONFIG menu.

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 in the Reydisp software tool 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.

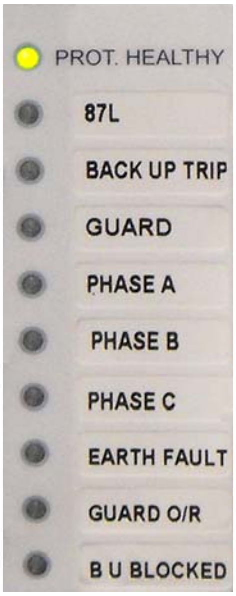


Figure 2.5-4 LED Indication Label

2.6 Current Inputs

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

The correct connections must be applied to suit the fixed 1A or 5A rating of the Solkor R/Rf module.

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.

2.7 Voltage Inputs

Three voltage inputs are provided on the Analogue Input module of the 7PG2114/6 relays.

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 or 6 binary inputs (BI) depending on the variant. One BI should be wired externally to the Solkor R/Rf module to take advantage of the recording and indication functions of the numeric module. The user can assign any binary input to any of the available functions (INPUT CONFIG > INPUT MATRIX).

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.

Each binary input is set by default to be read when the relay is in both the local or remote condition. A setting is provided to allow the user to select if each individual input shall be read when the relay is in the local or remote condition in the INPUT CONFIG > BINARY INPUT CONFIG menu.

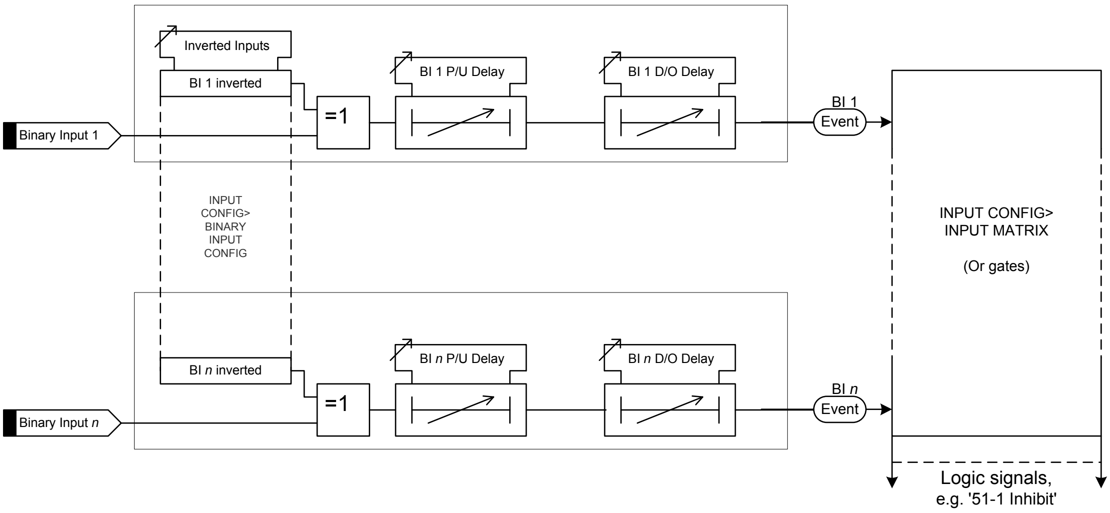


Figure 2.8-1 Binary Input Logic

2.9 Binary Outputs (Output Relays)

The Solkor R/Rf module provides 3 segregated voltage free normally open contacts. The functionality of these contacts is fixed. One contact must be wired externally to the numeric module to take advantage of the recording and indication functions of that module. Numeric modules are fitted with 5 or 8 binary outputs (BO). All outputs of the numeric module are fully user configurable and can be programmed to operate from any or all of the available functions.

In the default mode of operation the binary outputs of the numeric module are self reset and remain energised for a user configurable minimum time of up to 60 seconds. If required, these outputs can be programmed to operate as ‘hand reset’ or ‘pulsed’. If the output is programmed to be ‘hand reset’ and ‘pulsed’ then the output will be ‘hand reset’ only.

The output contacts 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. It is recommended that the trip signal to the circuit breaker is wired directly from the Solkor R/Rf module rather than via the numeric module for maximum speed and simplicity.

Any BO can be assigned as a ‘Trip Contact’ in the OUTPUT CONFIG>TRIP CONFIG menu. Operation of a ‘Trip Contact’ will operate any LED or virtual assigned from the trip triggered feature in the same menu and will initiate the fault record storage, actuate the ‘Trip Alert’ screen where enabled and CB Fail protection when enabled.

The following notes refer to the binary outputs of the numeric module:

Notes on Pulsed Outputs

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

Notes on Self Reset Outputs

Self reset operation has a minimum reset time of 100ms

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

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.

Binary Output Test

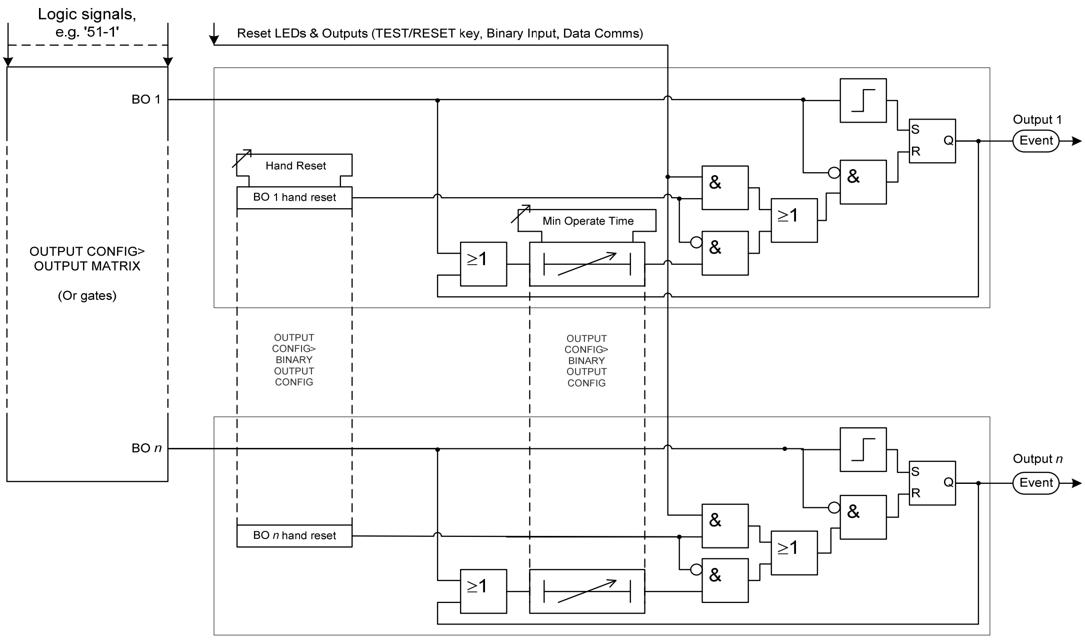


Figure 2.9-1 Binary Output Logic

2.10 Virtual Input/Outputs

The relays have 8 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.

The status of the virtual inputs and outputs is volatile i.e. not stored during power loss.

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

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

If the relay is withdrawn from the case, the case shorting contact will make across the normally closed contacts to provide and external alarm.

Section 3: Current Differential Protection Function

3.1 Description

Conjunctive operation of the Current Differential function and the Overcurrent and Earth Fault Guard functions is described in the Applications section of this manual.

The Solkor Rf protection system (excluding current transformers) is shown below. The alternative basic Solkor R protection circuit is also shown.

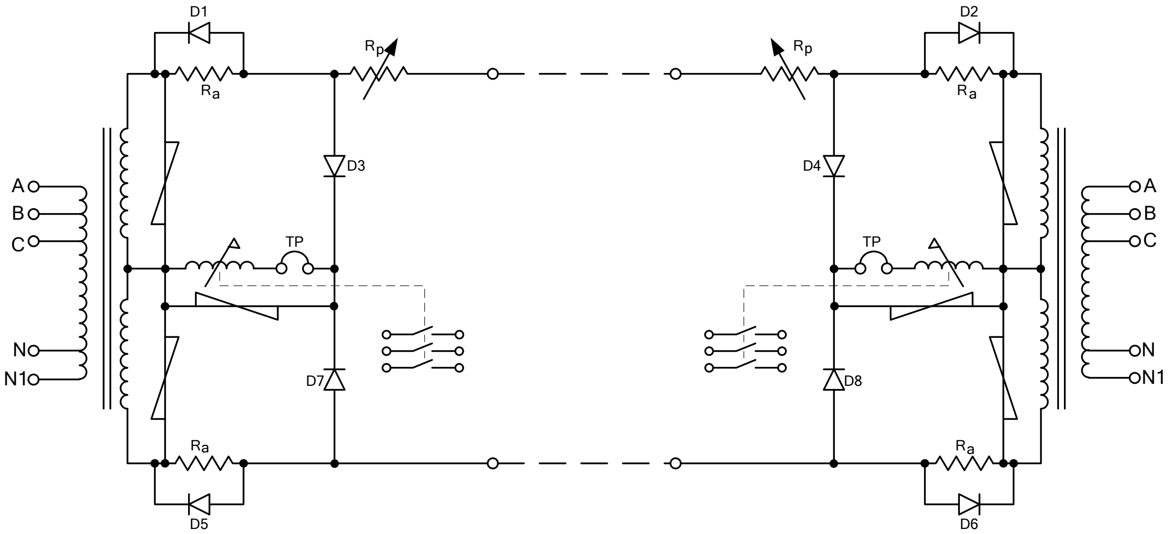


Figure 3.1-1 Solkor Rf schematic

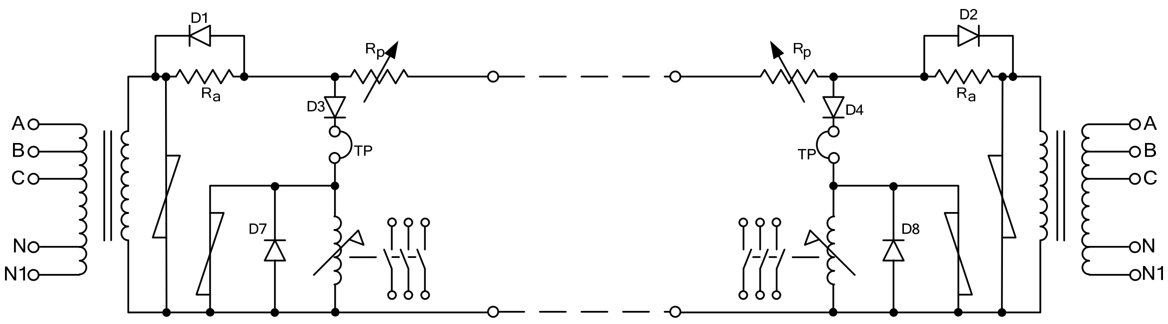


Figure 3.1-2 Solkor R schematic

Selection of the Solkor Rf or Solkor R operating mode is arranged by wire links, internal to the relay.
The relay contains an 8-way internal terminal block. 4 wires marked 1-4 must be moved from 4 terminals marked ‘Solkor Rf’ to 4 adjacent terminals marked ‘Solkor R’. Additionally a wire link must be fitted, externally to the relay on the rear terminal block to use the relay in Solkor R mode.

In addition to the basic components there are at each end, three non-linear resistors, a tapped ‘padding’ resistor and three diodes. The non-linear resistors are used to limit the voltage appearing across the pilots and the operating element. The purpose of the ‘padding’ resistors at each end is to bring the total pilot loop resistance up to a standard value. The protection is therefore always working under constant conditions and its performance is to a large extent, independent of the resistance of the pilot cable’ The ‘padding’ resistors comprise five series connected sections, each section having a short circuiting link. The values of the resistance on the sections are 35 ohms, 65 ohms, 130 ohms, 260 ohms and 500ohms.

For Solkor R the value chosen should be as near as possible to ½(1000-R_p) ohms, where R_p is the pilot resistance. The 500 ohm resistor should therefore never be fitted for the Solkor R and the link will always be fitted for this mode.

For Solkor Rf without isolating transformers the value chosen should be as near as possible to ½(2000-R_p) ohms.

For Solkor Rf with isolating transformers the value chosen should be as near as possible to

½(SV-R_p)/T ohms.

where T = Isolating transformer tap.

& SV = Standard resistance value for tap on transformers,

1780Ω for tap1, 880Ω for tap 0.5 & 440Ω for tap 0.25

The operating element is of the attracted armature type with three contacts, each pair being brought out to separate terminals. The inherent advantages of such a relay are robustness and simplicity and since the contacts are suitable for direct operation of a circuit breaker trip coil, no repeat relay is necessary.

A 5kV insulation level is provided between the secondary winding of the summation transformer and its primary winding. The core and the relay coil is also insulated at 5kV.

Since the only external connections to the relay are those to; the current transformers, the pilots and the tripping and alarm circuits, the installation and commissioning of the equipment is extremely simple. To check the current in the operating element, a test point is provided.

The 15kV arrangement is for applications where the voltage across the pilot insulation due to induction or a rise in station earth potential are excessive and where, consequently, the normal 5kV insulation level is not considered adequate.

The complete protection scheme is shown in figure below.

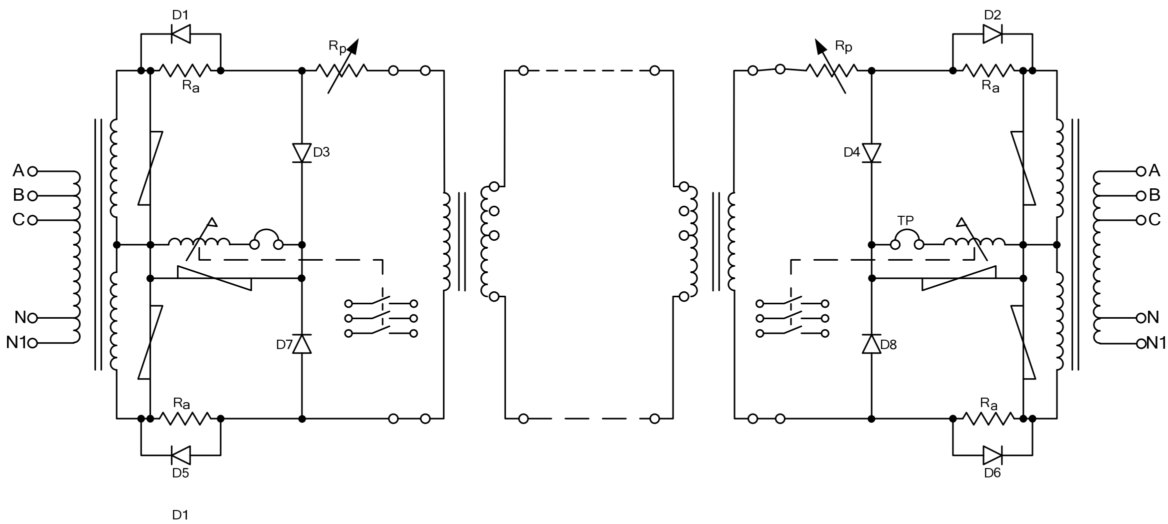


Figure 3.1-3 Solkor Rf 15kV schematic

The difference between this circuit and that shown previously is that the pilots are connected via interposing transformers which incorporate 15kV insulation barriers between windings to isolate the pilot circuit. The introduction of the isolating transformer does not modify the basic principle of operation of the protection but allows greater range of pilot coverage by the use of taps on the isolating transformer secondary windings.

3.2 Operation

Solkor R belongs to the circulating current class of differential protections which can be recognised by two main features. Firstly, the current-transformer secondaries are arranged to produce a current circulating around the pilot loop under external fault conditions. Secondly, the protective relay operating coils are connected in shunt with the pilots across points which have the same potential when the current circulates around the pilot loop. In this particular scheme equipotential relaying points during external fault conditions exist at one end during one half cycle of fault current, and at the other end during the next half cycle. During half cycles when the relay at either end is not at the electrical midpoint of the pilot system the voltage appearing across the relay is in the reverse direction to that required for operation.

At each end of the feeder the secondaries of the current transformers are connected to the primary of the summation transformer – see section 3.3 Theory of Summation Transformer. For various types of current distribution in the three current transformers, a single phase quantity appears in the summation transformer secondary winding and is applied to the pilot circuit. By this means a comparison between the currents at each end of a three phase line is effected over a single pair of pilot wires on an equivalent single phase basis. The tappings on the summation transformer primary have been selected to give an optimum balance between the demands of fault setting and stability.

The pilot is shown as a 'lumped' resistor R_P. The rest of the pilot loop is made up of four resistors R_a and four diodes D1, D2, D5 and D6. The operating elements, which are made unidirectional by diodes D3, D4, D7 and D8 are connected in shunt with the pilots.

During an external fault condition, an alternating current circulates around the pilot loop. Thus on successive half cycles one or other of the resistors R_a at the two ends of the pilot is short circuited by its associated diode D1 or D2. The total resistance in each leg of the pilot loop at any instant is therefore substantially constant and equal to R_a+R_p. The effective position of R_a however, alternates between ends, being dependent upon the direction of the current. The change in the effective position of R_a makes the voltage distribution between the pilot cores different for successive half-cycles of the pilot current.

In other words stability is achieved by current balance using the Solkor R principle of establishing the electrical centre point geographically within the end which has positive polarity so that the positively polarised measuring elements remain in the negative part of the circuit and are thus biased against operation.

Referring to the basic circuit of Solkor Rf as shown in Figure 3.1-2, the circulating current will flow from the summation transformer through the diode or the resistor depending on the polarity of the summation transformer output. Thus the circuit may be redrawn to suit the polarities of summation transformer output as shown in Figure 3.2-1 & Figure 3.2-2 below.

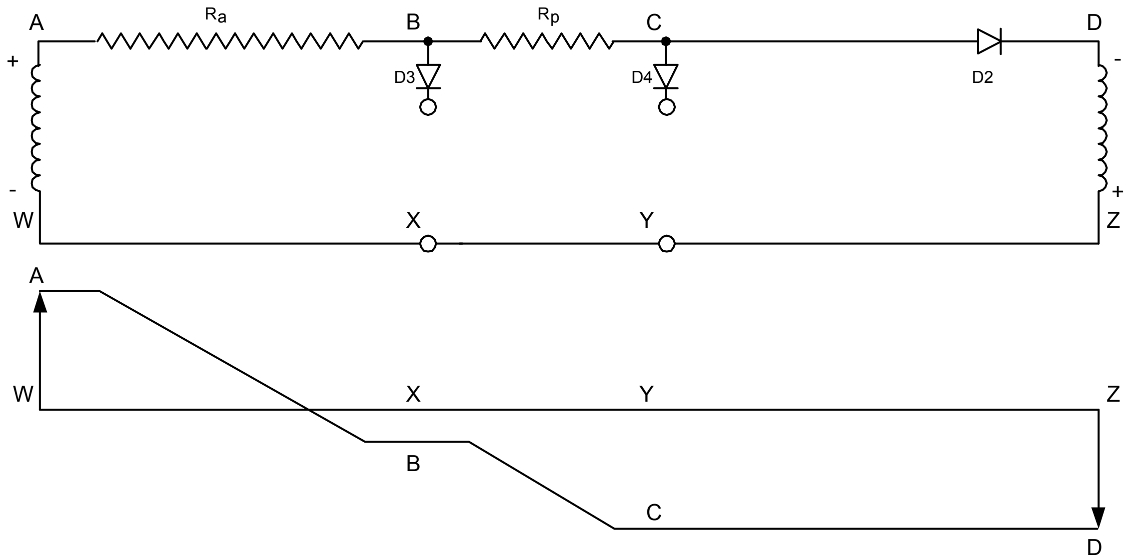


Figure 3.2-1 Through Fault, zero ohm pilots, Positive half cycle.

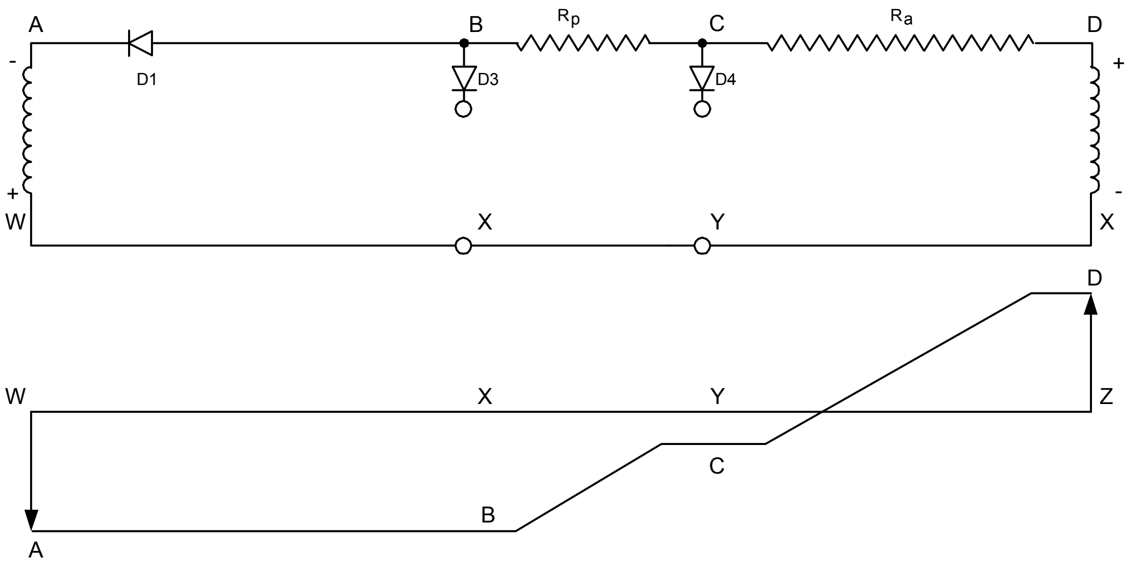


Figure 3.2-2 Through Fault, zero ohm pilots, Negative half cycle.

Figure 3.2-1 & Figure above represents the operations of Solkor R protection with zero ohm pilots so that the loop resistance is represented entirely by the 500 ohm padding resistor in each relay and the 1000ohm sum in the pilot circuit is in one leg of the pilot circuit as shown, R_P.

Resistors R_a are of greater resistance than the pilot loop resistance R_p and this causes the point of zero potential to occur within the resistors R_a, as shown in Figure 3.2-1. The voltage across each relaying point (B-X and C-Y) throughout the cycle is now always negative. This voltage bias must be overcome before operation can take place; consequently the effect is to enhance the stability of the protection against through faults.

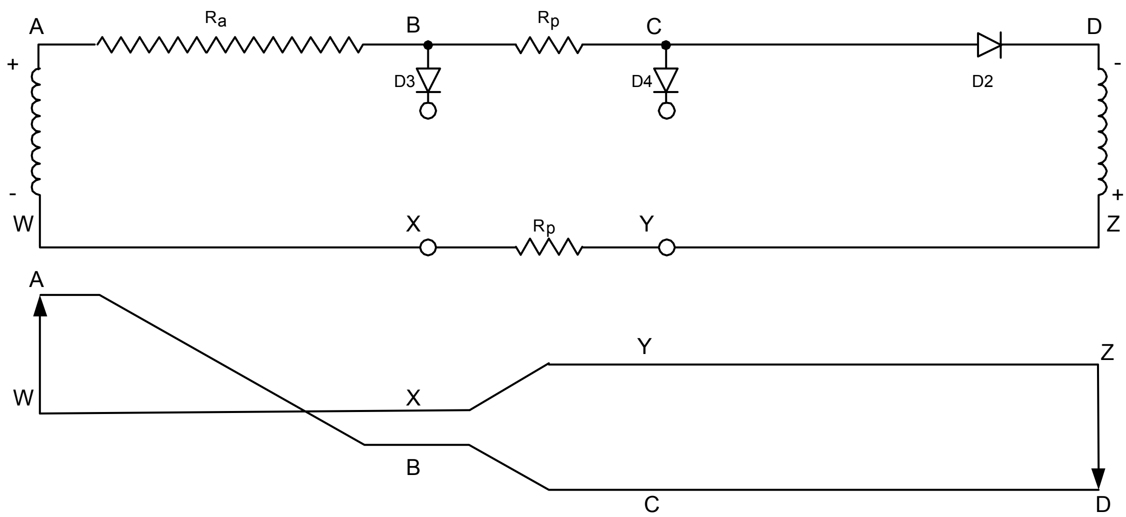


Figure 3.2-3 Through Fault, 1000 ohm pilots, Positive half cycle.

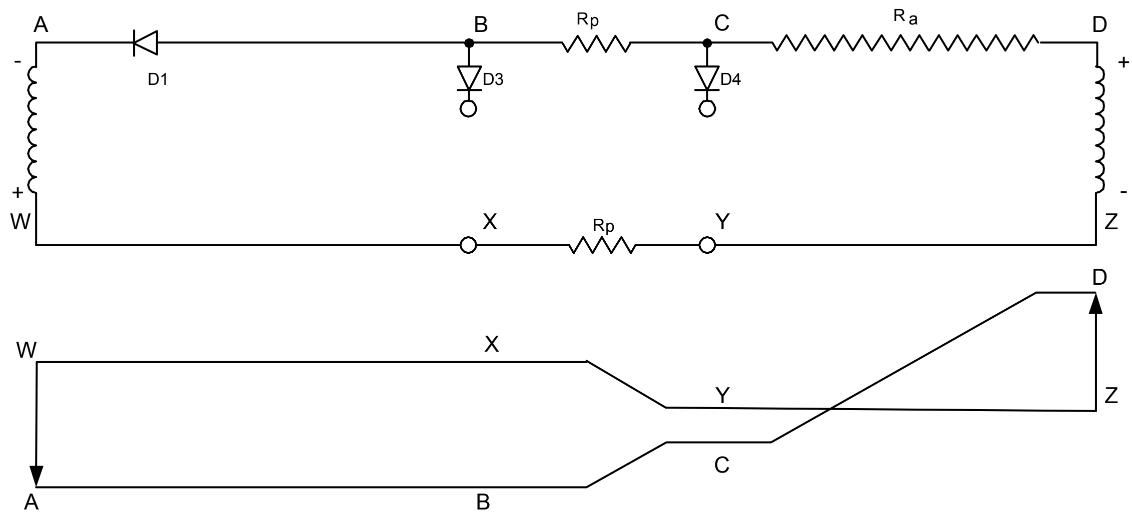


Figure 3.2-4 Through Fault, 1000 ohm pilots, Negative half cycle.

At the other limiting condition the pilot resistance is a 1000 ohms loop and the circuit will be as shown in Figure 3.2-3 & Figure 3.2-4. with 500 ohms in each leg of the pilot circuit and zero padding resistors. As shown in Figure 3.2-3 & Figure 3.2-4 the resultant voltage distribution of this maximum pilot arrangement gives identical voltages across the relay points B-X and C-Y.

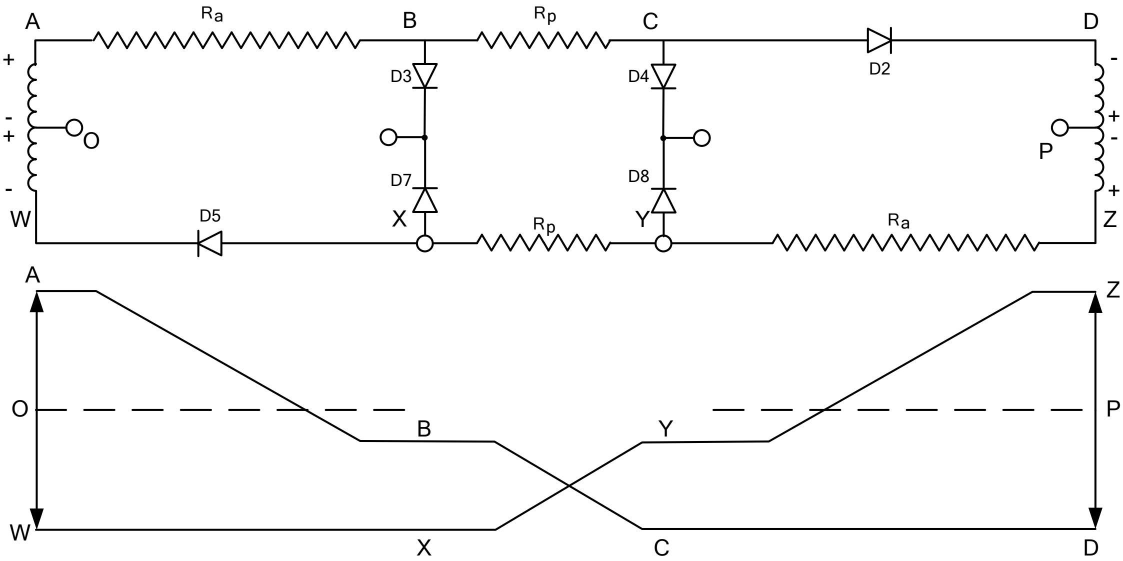


Figure 3.2-5 Through fault Rf mode, positive half cycle

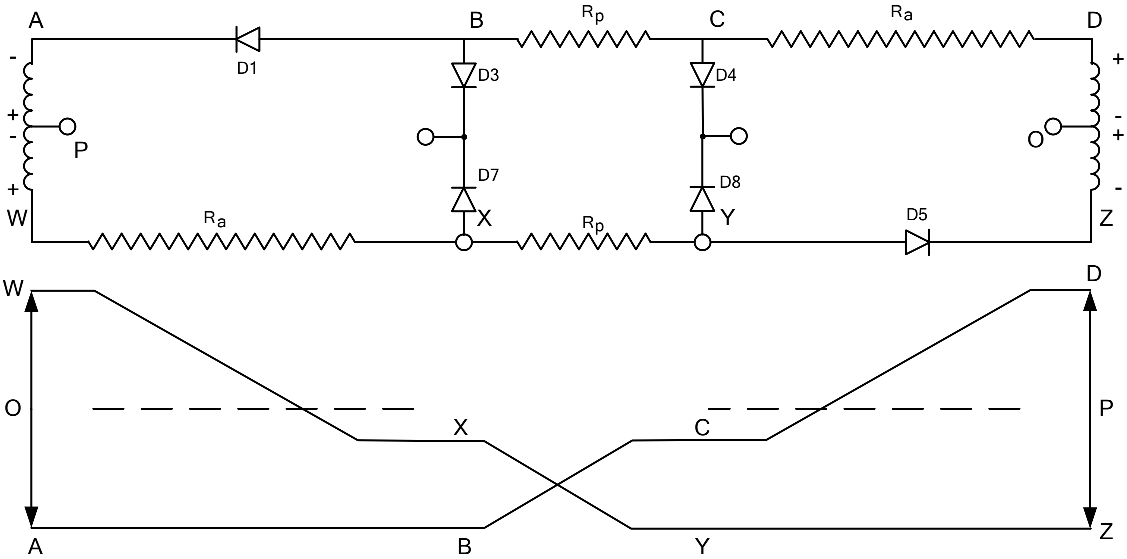


Figure 3.2-6 Through fault Rf mode, negative half cycle

Considering now the equivalent Solkor Rf circuit with 1000 ohms in each leg of the pilots as shown in Figure 3.2-5. the voltage distribution shows that the bias voltage across the polarising diodes (D3, D4, D7 and D8) with this arrangement are effectively identical with the minimum values obtained in the Solkor R arrangement. In other words, the balance of the full wave comparison gives the same value of bias for each polarity of half-cycle.

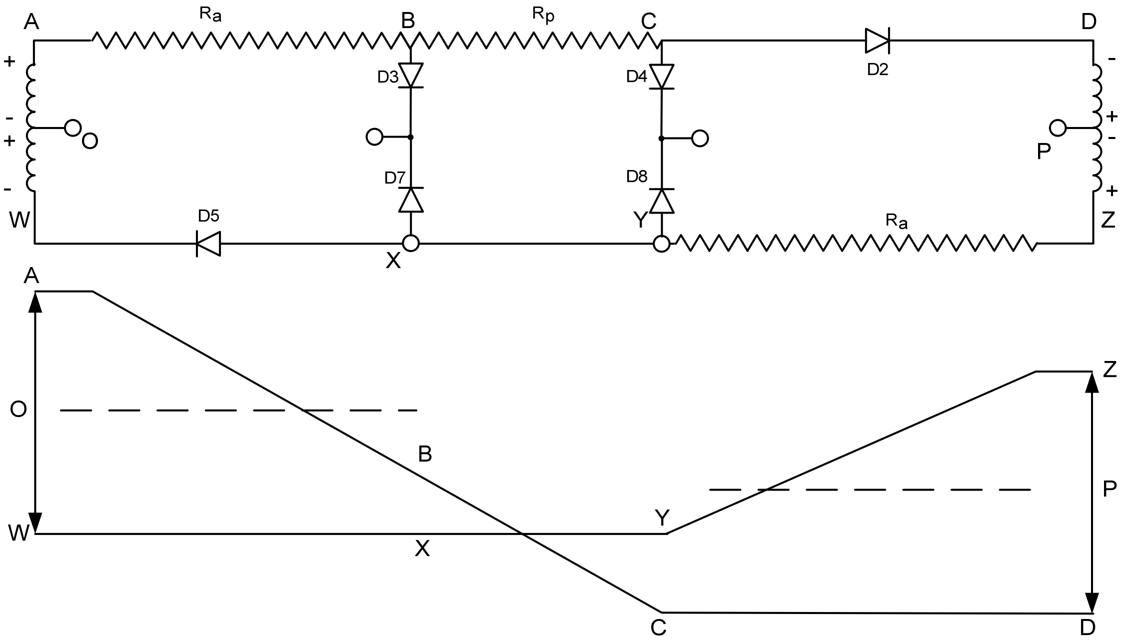


Figure 3.2-7 Through fault Rf mode, positive half cycle

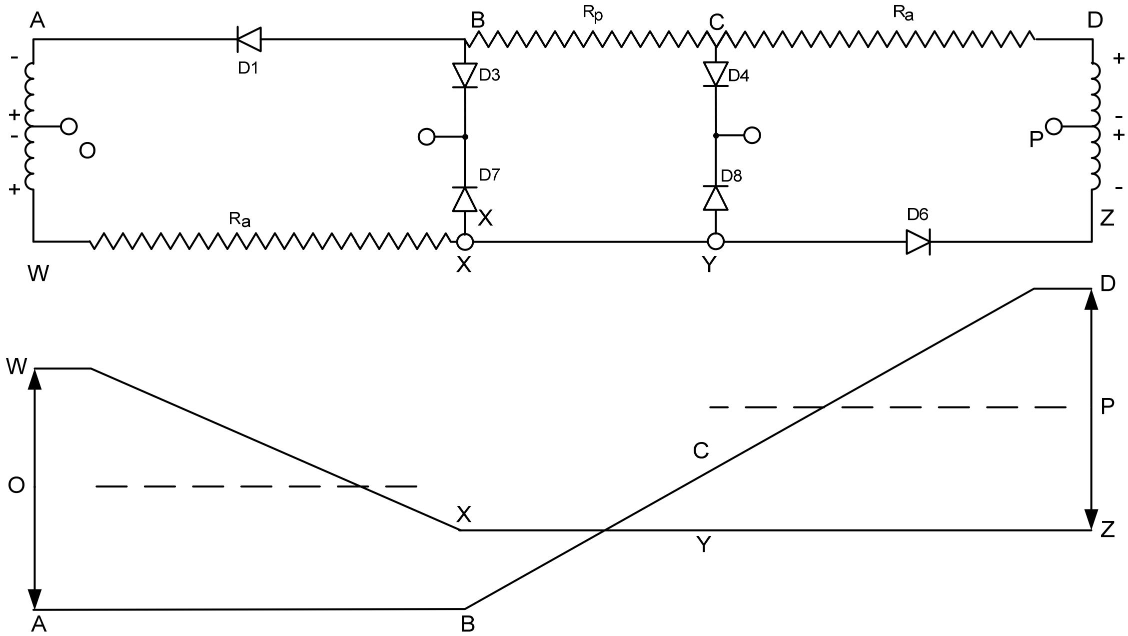


Figure 3.2-8 Through fault Rf mode, negative half cycle

If the condition of zero pilots is then considered for Solkor Rf (i.e. with 1000 ohms padding in each relay), the circuit and voltage distribution are as shown in Figure 3.2-7 & Figure 3.2-8. This shows that the same bias voltages are as obtained in Figure 3.2-5 & Figure 3.2-6

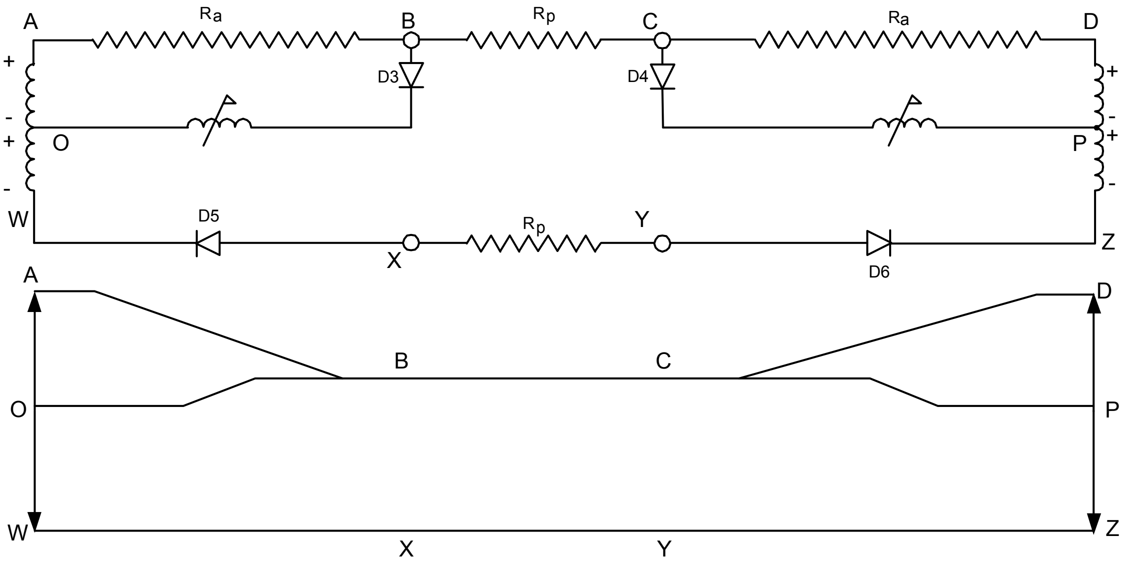


Figure 3.2-9 Internal fault Rf mode, positive half cycle

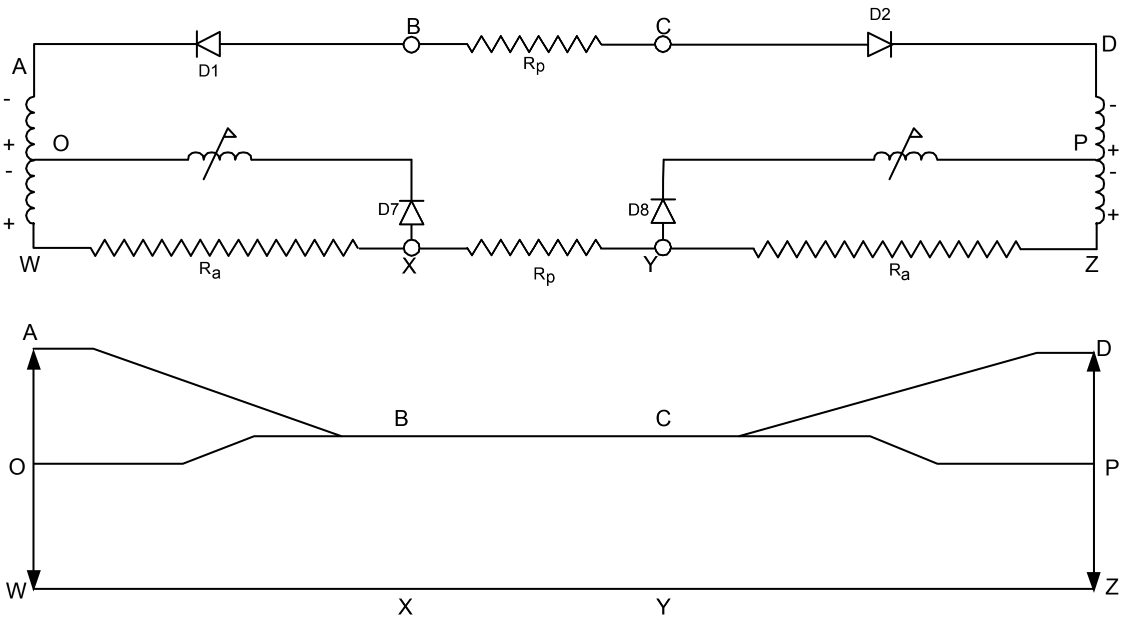


Figure 3.2-10 Internal fault Rf mode, negative half cycle

The application of pilot wire protection is generally in interconnected power systems so that it is reasonable to consider double end fed faults. For simplicity in explaining the basic principles, it may be assumed that the infeeds at both ends have the same magnitude and relative phase angle. The Solkor Rf circuit is then effectively as shown in Figure 3.2-9 & Figure 3.2-10 because the diodes in series with the pilots on the positive leg of the circuit will be out of circuit and the measuring element polarising diodes on this leg will be conducting. The voltage distribution fore this arrangement shows how, with the assumed balanced infeeds, no current flows in the pilots and each measuring element is energised via the resistor R_a.

The single end fed internal fault operates both measuring elements from the one end so that the setting level is twice that of the double end fed arrangement. However, both ends operate at this level (which is the normal setting claim) so that the intertripping is not required for internal faults even those which may be fed from one end or have low infeed at one end.

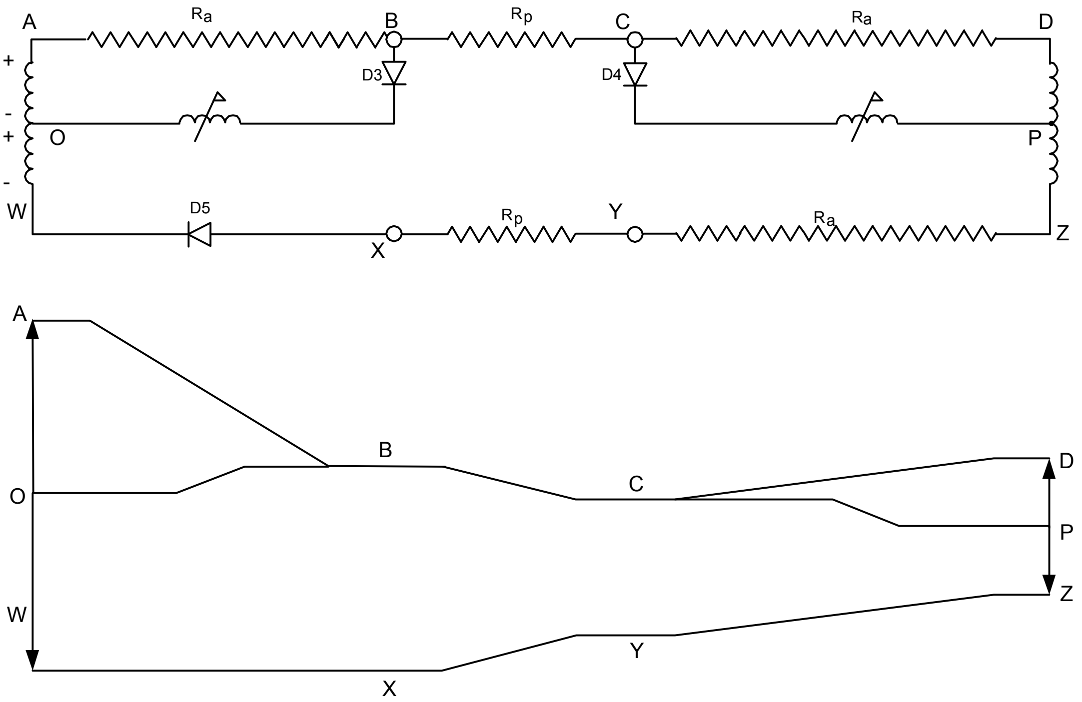


Figure 3.2-11 Single End Fed fault Rf mode, positive half cycle

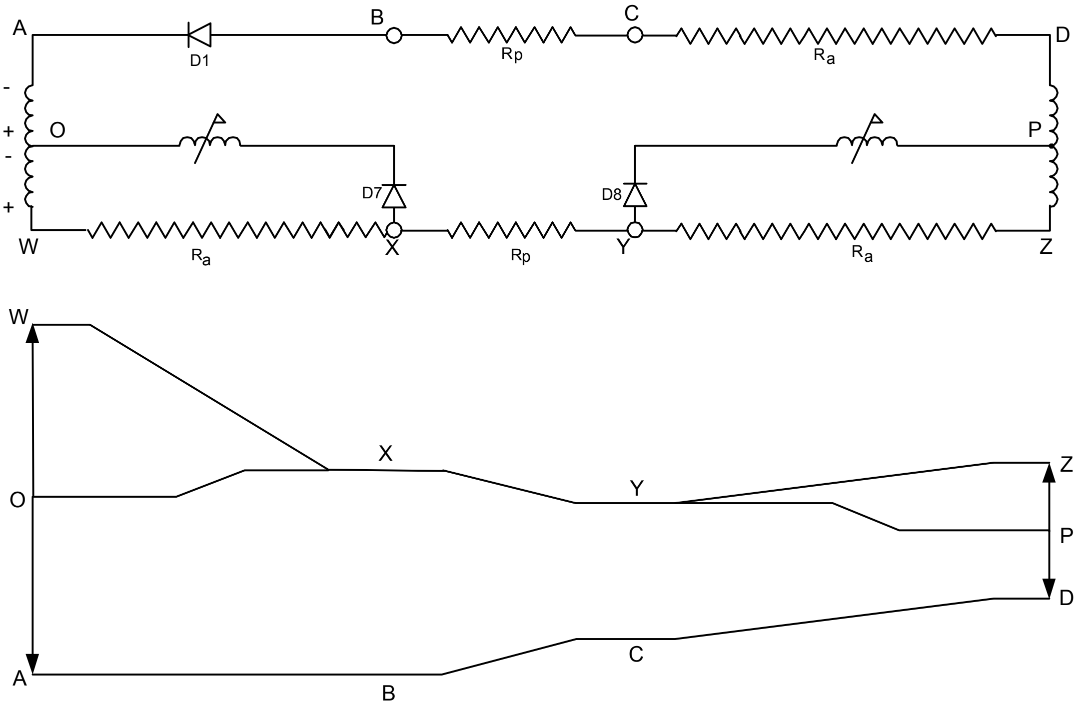
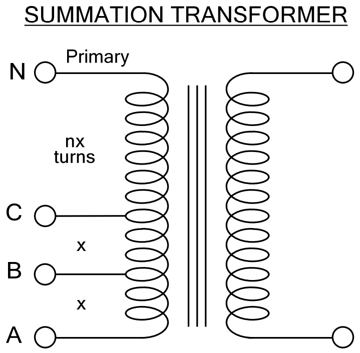


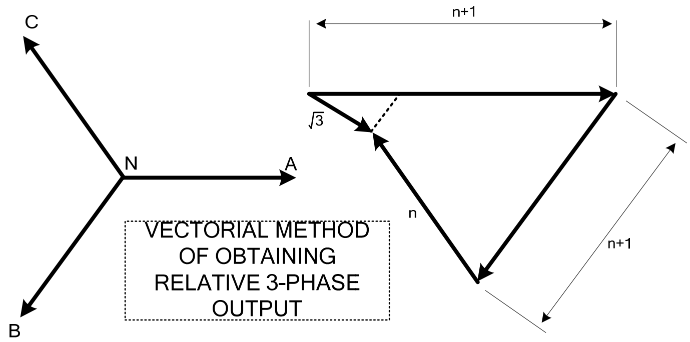
Figure 3.2-12 Single End Fed fault Rf mode, negative half cycle

The single end fed internal fault conditions configure the circuit in a similar way to the double end fed internal fault but only one summation transformer has any output. Thus the other summation transformer acts only as an equalising transformer, re-circulating current through the measuring element as indicated in Figure 3.2-11 & Figure 3.2-12. The voltage distribution shows diagrammatically how, in each half cycle, the measuring elements are energised via R_a at the energised end and the action of the remote end summation transformer re-circulating current via the polarising diodes D4 on one half-cycle and D8 on the other half-cycle.

3.3 Theory of Summation Transformer

The main purpose of the summation transformer is to enable either balanced or unbalanced three phase currents to be re-produced as a single phase quantity. This makes it possible in a feeder protection to compare the various fault currents on a single phase basis over only two pilot cores. As this device is essentially a transformer it can also be used to reduce the burden imposed by the pilot circuit on the current transformers by changing the impedance levels. In addition, it provides isolation between the current transformers and the pilot circuit and makes it possible to have the current transformers earthed and the pilots unearthed.





Fault Type	Effective Primary Ampere-turns	Relative Output
A-N	I(nx + x + x) = Ix. (n+2)	n+2
B-N	I(nx + x) = Ix. (n+1)	n+1
C-N	I(nx) = Ix. (n)	n
A-B	I(x) = Ix. (1)	1
B-C	I(x) = Ix. (1)	1
C-A	I(2x) = Ix. (2)	2
3P	I(√3x) = Ix. (√3)	√3

Table 3-1 Summation Transformer Output

Section 4: Numeric Protection Module Functions

4.1 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**

4.1.1 Directional Control of Overcurrent Protection (67) – 7PG2114/6

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

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

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

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

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

The characteristic angle can be user programmed to any angle between -95° and +95° using the ***67 Char Angle*** setting. The voltage is the reference phasor (Vref) 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 (Vref Angle + ***67 Char Angle***) and should be set to correspond with Ifault Angle for maximum sensitivity i.e.

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

OR

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

Two-out-of-three Gate

When the ***67 2-Out-Of-3 Logic*** setting is set to **Enabled**, the directional elements will only operate for the majority direction, e.g. if I_{L1} and I_{L3} are detected as forward flowing currents and I_{L2} is detected as reverse current flow, phases L_1 and L_3 will operate forwards, while phase L_2 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 control signal 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.

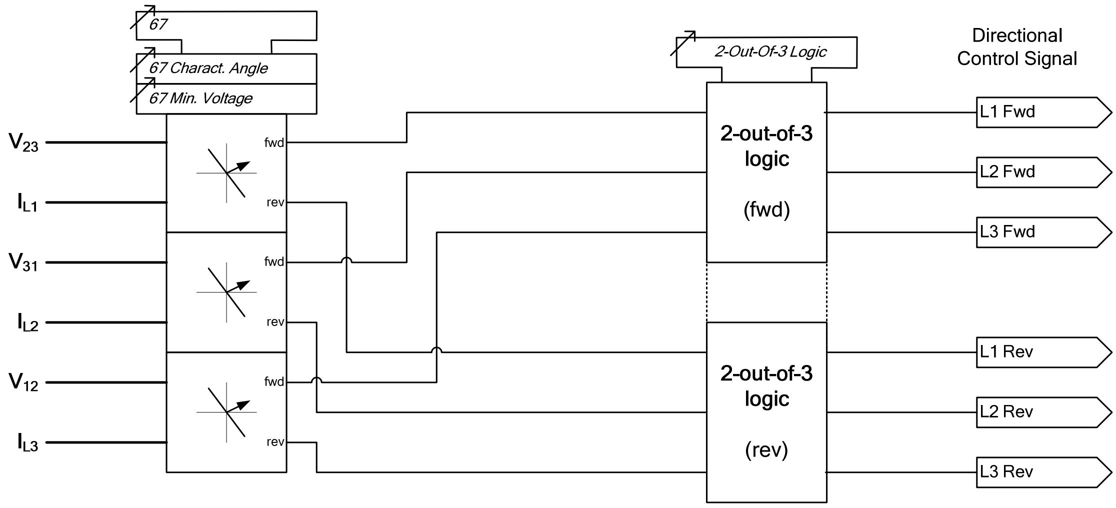


Figure 4.1-1 Logic Diagram: Directional Overcurrent Element (67)

4.1.2 Instantaneous Overcurrent Protection (50)

Two Instantaneous overcurrent elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

50-1, 50-2, (50-3 & 50-4 – 7PG2114/6)

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, e.g. giving the option of using two elements set to forward and two to reverse.

Operation of the instantaneous overcurrent elements can be inhibited from:

Inhibit 50-n	A binary or virtual input.
***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:* Block**	Operation of the inrush current detector function.
***50-n VTS Action:* Inhibit**	Operation of the VT Supervision function (7PG2114/6).

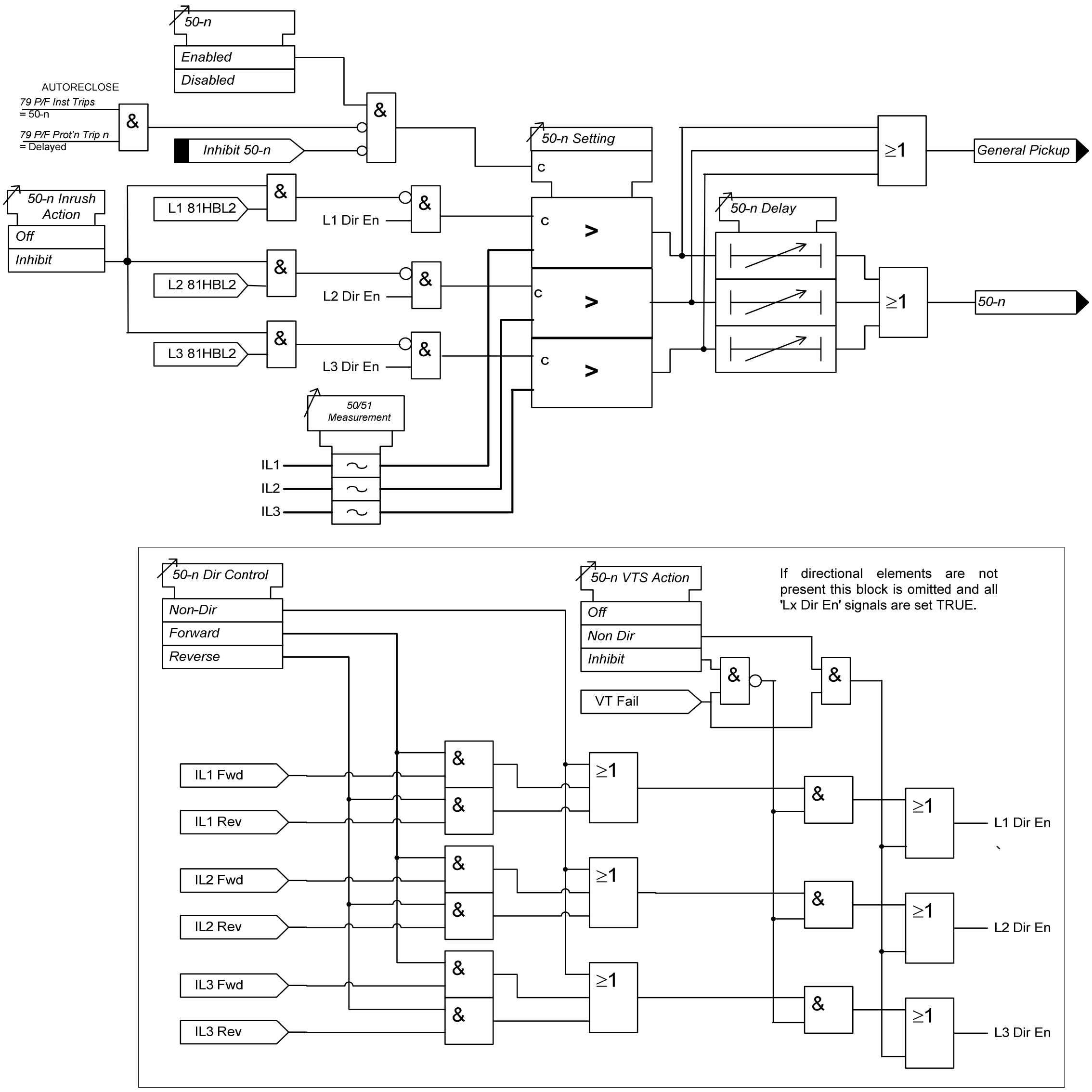


Figure 4.1-2 Logic Diagram: Instantaneous Over-current Element

4.1.3 Time Delayed Overcurrent Protection (51)

Two time delayed overcurrent elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

51-1, 51-2, (51-3 & 51-4 –7PG2114/6)

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

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

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

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

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

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

Inhibit 51-n	A binary or virtual input.
79 P/F Inst Trips: **51-n**	When 'delayed' trips only are allowed in the auto-reclose sequence (***79 P/F Prot'n Trip n*** = **Delayed**).
51c	Activation of the cold load settings.
51-n Inrush Action: **Block**	Operation of the inrush current detector function.
51-n VTSAction: **Inhibit**	Operation of the VT Supervision function (7PG2114/6).

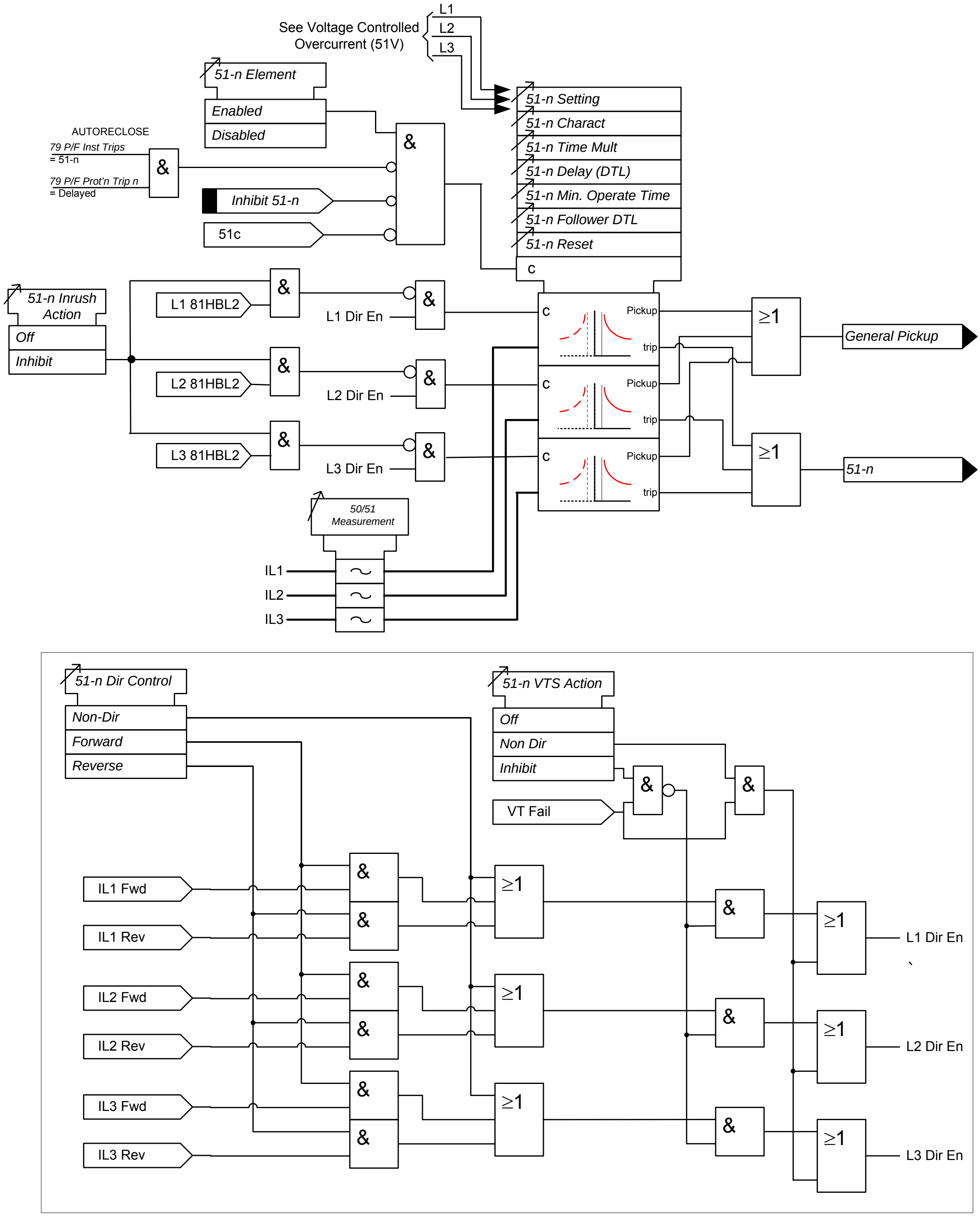


Figure 4.1-3 Logic Diagram: Time Delayed Overcurrent Element

4.1.4 Current Protection: Voltage Controlled Overcurrent (51V) – 7PG2114/6

Voltage controlled overcurrent is only available in relays with four current inputs.

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.

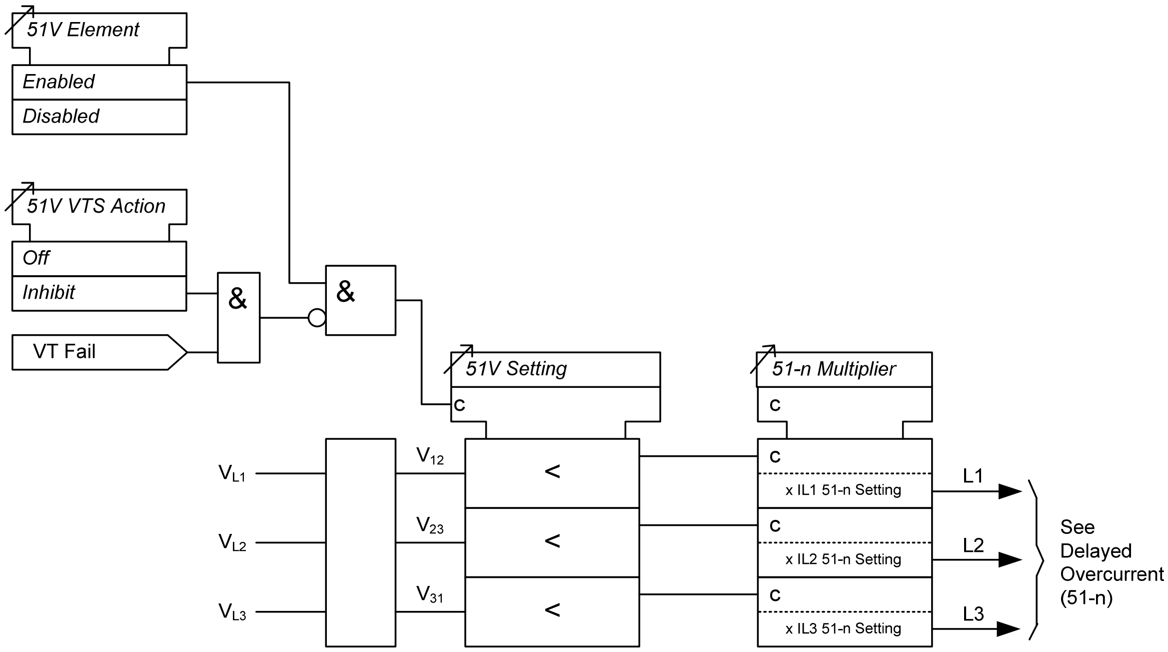


Figure 4.1-4 Logic Diagram: Voltage Controlled Overcurrent Protection

4.2 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.

4.2.1 Directional Control of Derived Earth Fault Protection (67N) – 7PG2114/6

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° and +95° using the ***67N Char Angle*** setting. The voltage is the reference phasor (Vref) 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 (Vref Angle + ***67N Char Angle***) and should be set to correspond with Ifault Angle for maximum sensitivity e.g.

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

OR

For fault current of -45° (I lagging V by 45°) a ***67 Char Angle*** of **-45°** 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.

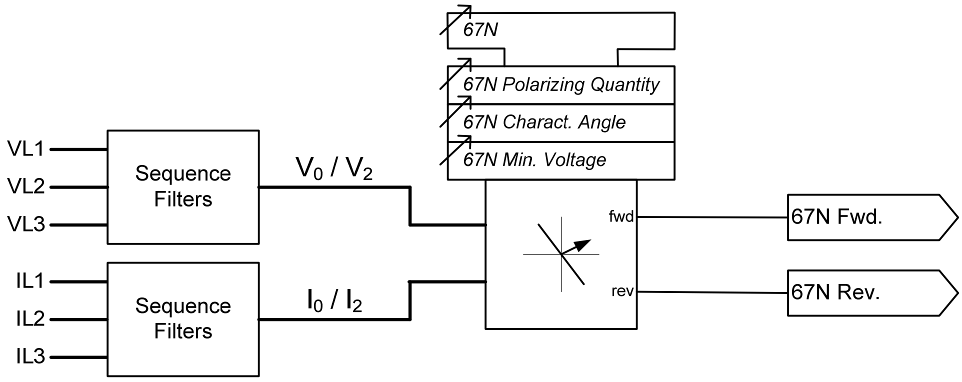


Figure 4.2-1 Logic Diagram: Derived Directional Earth Fault Element

4.2.2 Instantaneous Derived Earth Fault Protection (50N)

Two instantaneous derived earth fault elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

50N-1, 50N-2, (50N-3 & 50N-4 – 7PG2114/6)

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:

Inhibit 50N-n	A binary or virtual input.
79 E/F Inst Trips: **50N-n**	When ‘delayed’ trips only are allowed in the auto-reclose sequence (***79 E/F Prot’n Trip n*** = **Delayed**).
50-n Inrush Action: **Block**	Operation of the inrush current detector function.
50N-n VTSAction: **Inhibit**	Operation of the VT Supervision function (7PG2114/6).

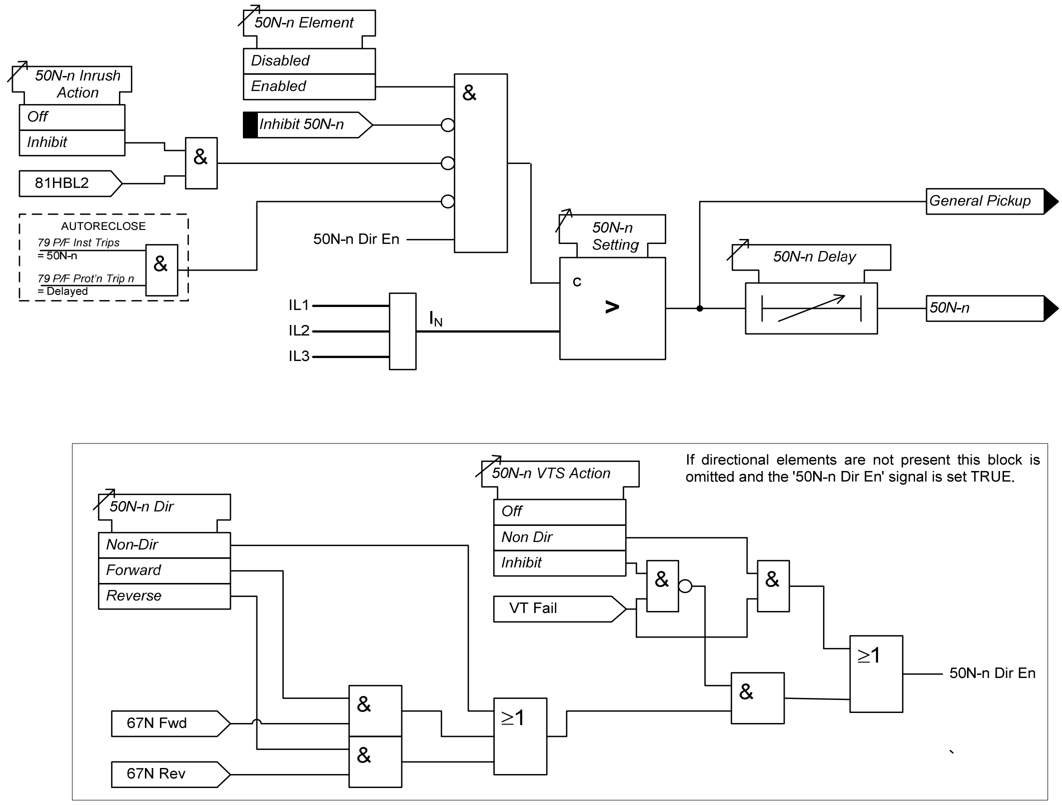


Figure 4.2-2 Logic Diagram: Derived Instantaneous Earth Fault Element

4.2.3 Time Delayed Derived Earth Fault Protection (51N)

Two time delayed derived earth fault elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

51N-1, 51N-2, (51N-3 & 51N-4 – 7PG2114/6)

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 definite time lag (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:

Inhibit 51N-n	A binary or virtual input.
79 E/F Inst Trips: **51N-n**	When ‘delayed’ trips only are allowed in the auto-reclose sequence (***79 E/F Prot’n Trip n*** = **Delayed**).
50-n Inrush Action: **Block**	Operation of the inrush current detector function.
51N-n VTSAction: **Inhibit**	Operation of the VT Supervision function (7PG2114/6).

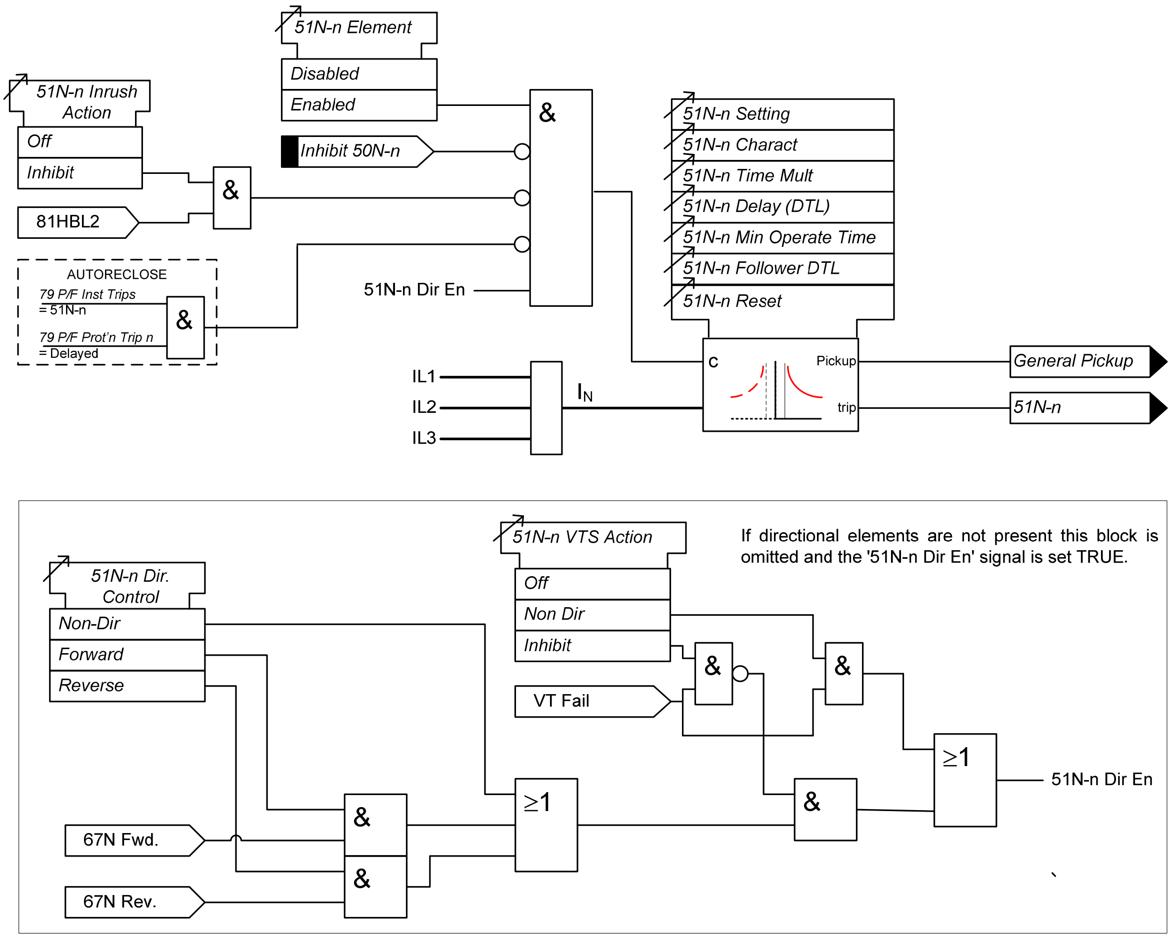


Figure 4.2-3 Logic Diagram: Derived Time Delayed Earth Fault Protection

4.3 Current Protection: Measured Earth Fault (67G, 51G, 50G)

The earth current is measured directly via a dedicated current analogue input, IL4.

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**

4.3.1 Directional Control of Measured Earth Fault Protection (67G) – 7PG2114/6

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

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

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

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

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

$I_0 \sim V_0$

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

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

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

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

Minimum Polarising Voltage

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

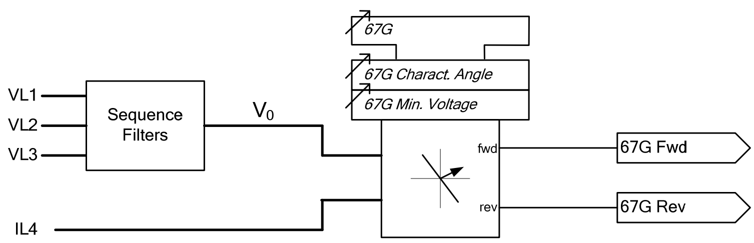


Figure 4.3-1 Logic Diagram: Measured Directional Earth Fault Protection

4.3.2 Instantaneous Measured Earth Fault Protection (50G)

Two instantaneous derived earth fault elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

50G-1, 50G-2, (50G-3 & 50G-4 – 7PG2114/6)

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

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

Inhibit 50G-n	A binary or virtual input.
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**).
50-n Inrush Action: **Block**	Operation of the inrush current detector function.
50G-n VTSAction: **Inhibit**	Operation of the VT Supervision function (7PG2114/6).

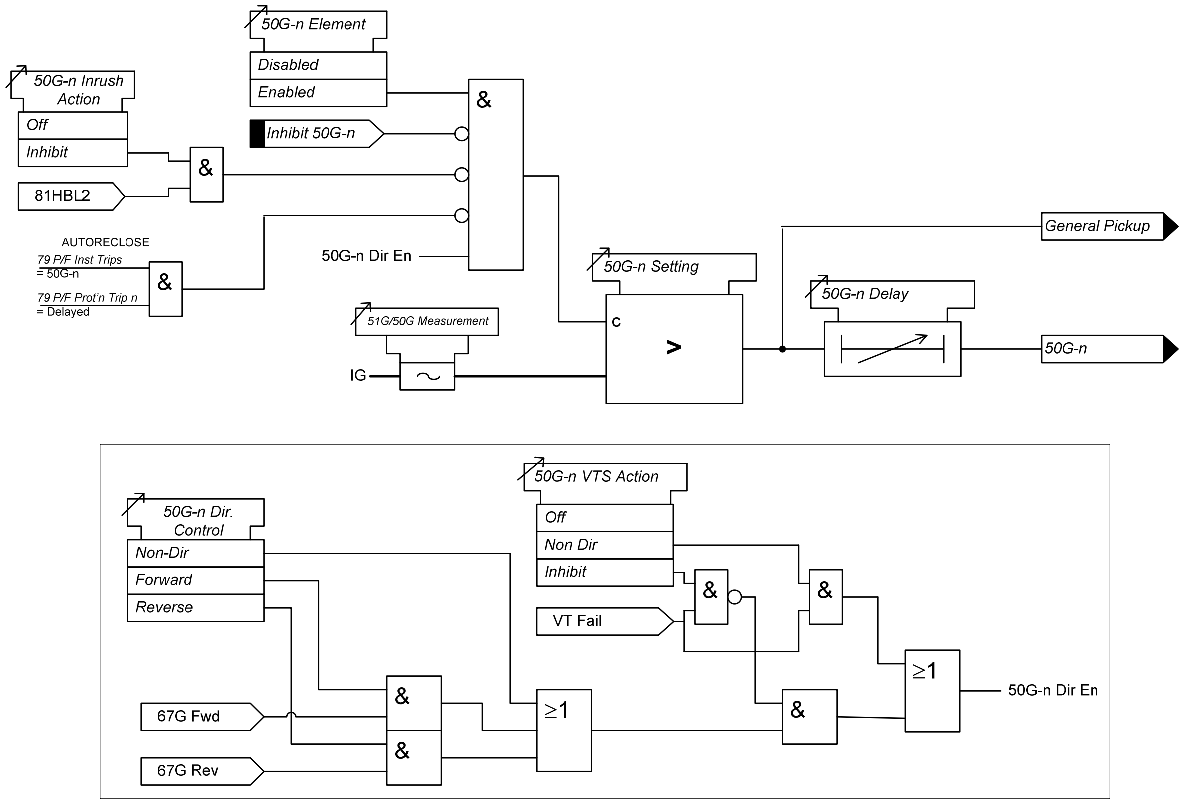


Figure 4.3-2 Logic Diagram: Measured Instantaneous Earth-fault Element

4.3.3 Time Delayed Measured Earth Fault Protection (51G)

Two instantaneous derived earth fault elements are provided in the 7PG2113/5 relay and four elements are provided in the 7PG2114/6 relay.

51G-1, 51G-2, (51G-3 & 51G-4 – 7PG2114/6)

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

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

The ***51G-n Reset*** setting can apply a **definite time delayed** reset**,** or when configured as an ANSI characteristic an **ANSI (DECAYING)** reset. If ANSI (DECAYING) 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 e.g. giving the option of using two elements set to forward and two to reverse.

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

Inhibit 51G-n	A binary or virtual input.
79 E/F Inst Trips: **51G-n** (***79 E/F Prot'n Trip n*** = **Delayed**).	When 'delayed' trips only are allowed in the auto-reclose sequence
50-n Inrush Action: **Block**	Operation of the inrush current detector function.
51G-n VTSAction: **Inhibit**	Operation of the VT Supervision function (7PG2114/6).

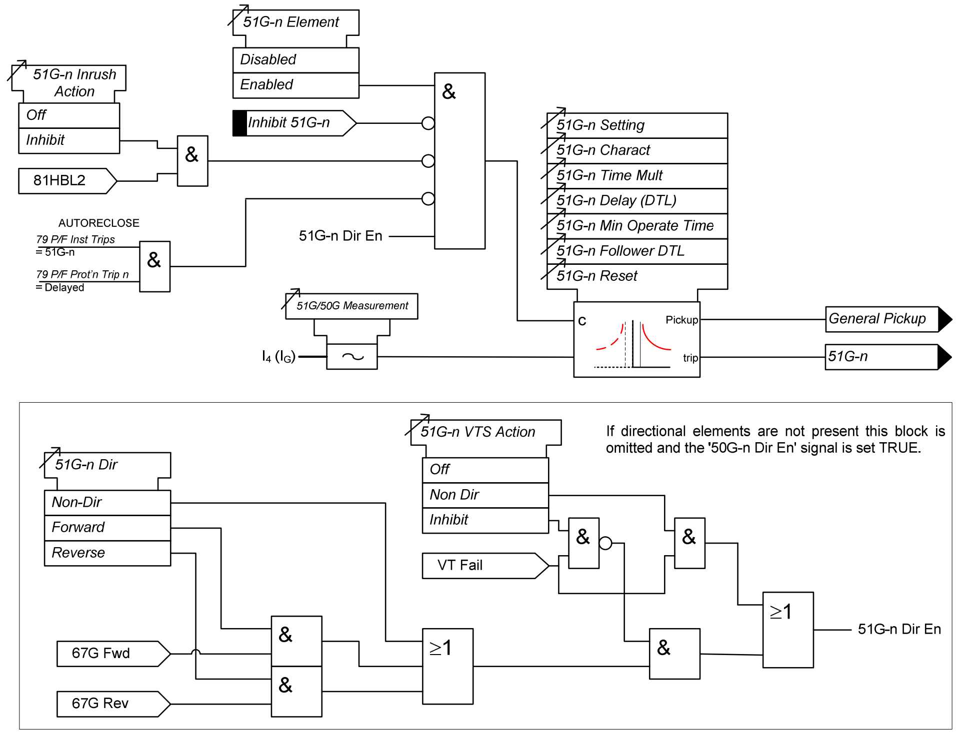


Figure 4.3-3 Logic Diagram: Measured Time Delayed Earth Fault Element (51G)

4.4 Current Protection: High Impedance Restricted Earth Fault - (64H)

One high impedance Restricted Earth Fault (REF) element is provided ***64H-1***.

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.

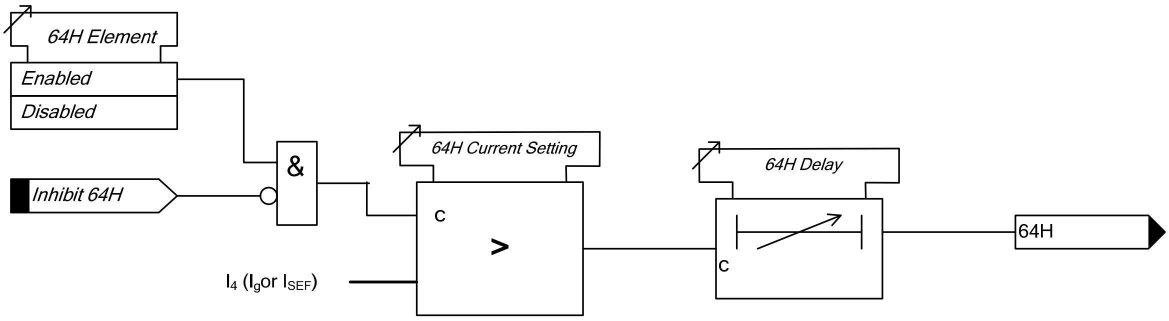


Figure 4.4-1 Logic Diagram: High Impedance REF (64H)

4.5 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) alarm condition, see 5.3 CIRCUIT BREAKER (CB), 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.

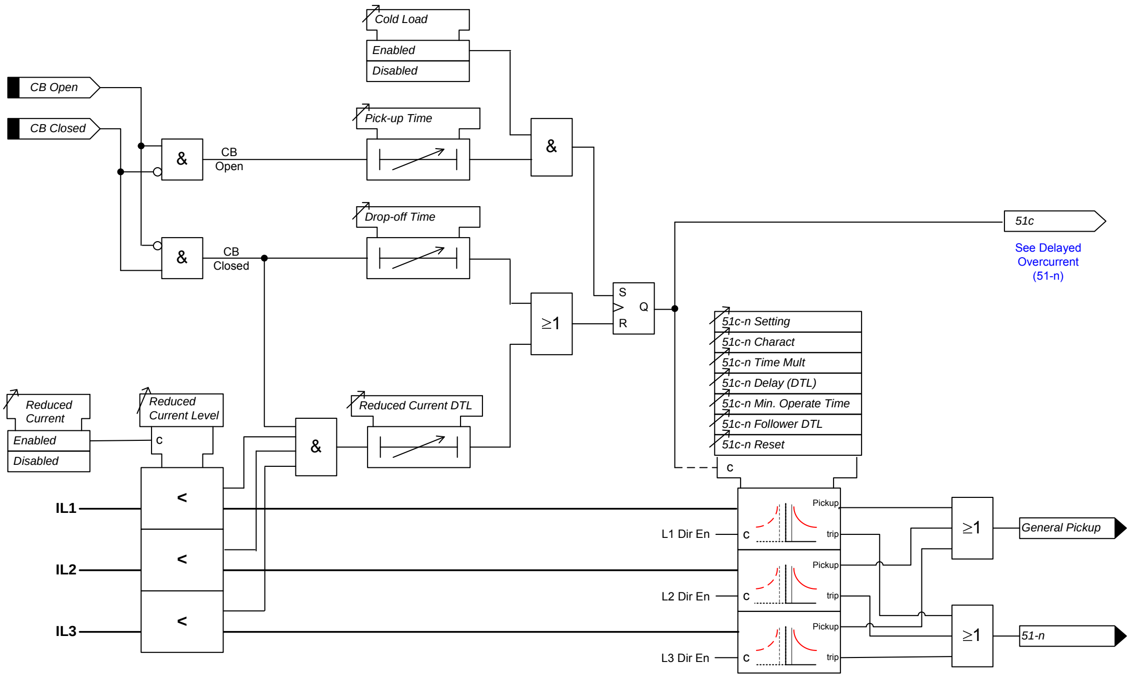


Figure 4.5-1 Logic Diagram: Cold Load Settings (51c)

4.6 Current Protection: Negative Phase Sequence Overcurrent - (46NPS)

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

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 Definite Time Lag (DTL) is selected the time multiplier is not applied and the ***46IT Delay (DTL)*** setting is used instead.

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

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

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

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

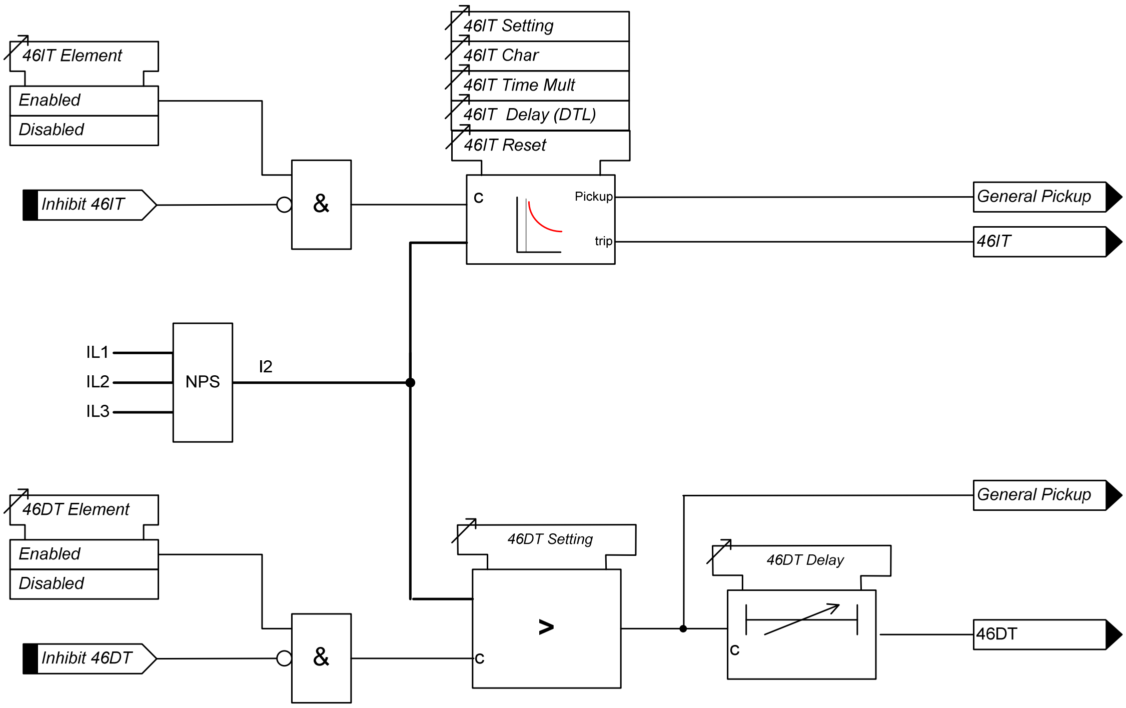


Figure 4.6-1 Logic Diagram: Negative Phase Sequence Overcurrent (46NPS)

4.7 Current Protection: Under-Current (37)

Two under-current elements are provided ***37-1 & 37-2***.

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

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

Inhibit 37-n A binary or virtual input.

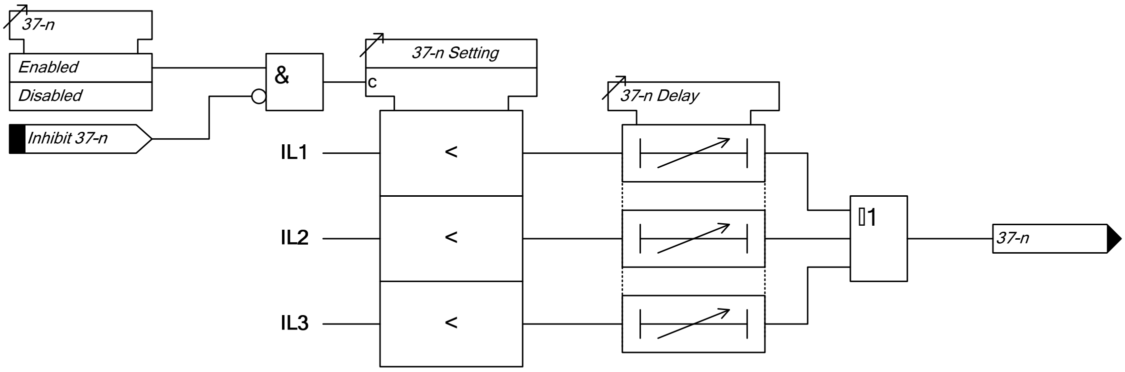


Figure 4.7-1 Logic Diagram: Relays with 4 Current Inputs Undercurrent Detector (37)

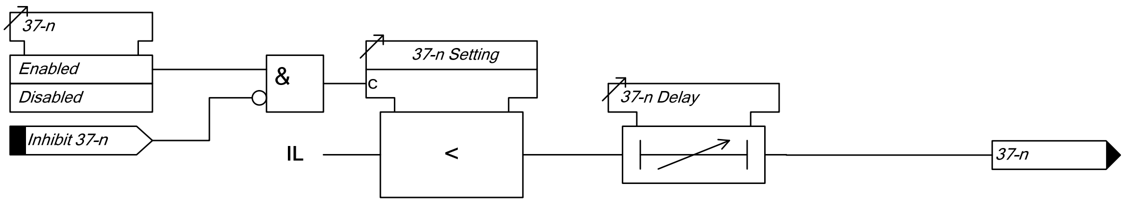


Figure 4.7-2 Logic Diagram: Relays with 1 Current Inputs Undercurrent Detector (37)

4.7.1 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. The operating time is a function of thermal time constant ***49 Time Constant*** and previous current levels.

Operate Time (t):-

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

Where

T = Time in minutes

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

In = Log Natural

I = measured current

IP = Previous steady state current level

k = Constant

IB = Basic current, typically the same as In

k.IB = ***49 Overload*** Setting (Iθ)

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

For the heating curve:

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

Where: θ = thermal state at time t

I = measured thermal current

Iθ = ***49 Overload*** setting (or k.IB)

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

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

Where: θF = final thermal state before disconnection of device

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

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

Thermal overload protection can be inhibited from:

Inhibit 49 A binary or virtual input.

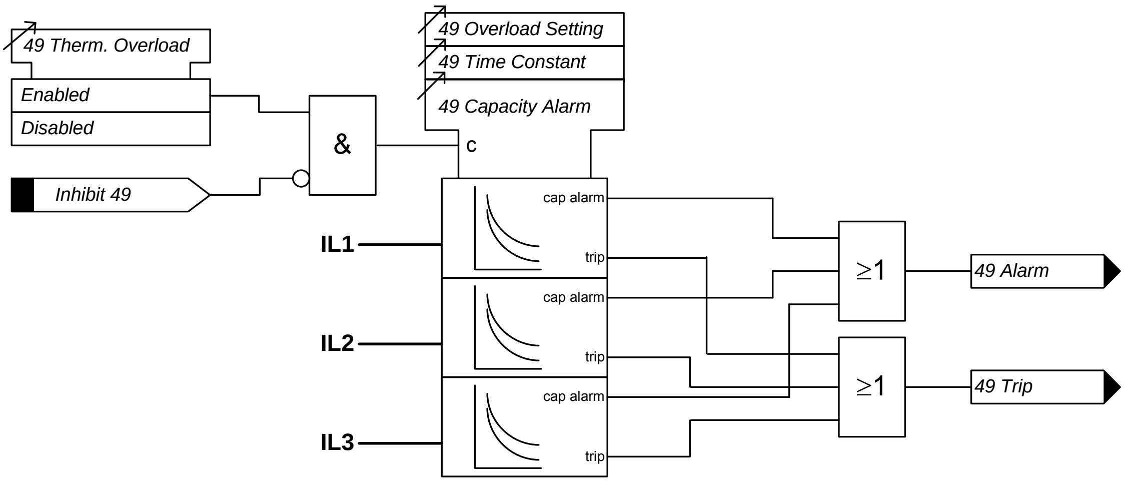


Figure 4.7-3 Logic Diagram: Thermal Overload Protection (49S)

4.8 Voltage Protection: Phase Under/Over Voltage (27/59) – 7PG2114/6

In total four under/over voltage elements are provided ***27/59-1, 27/59-2, 27/59-3 & 27/59-4.***

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 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*** 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*** setting.

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

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

Inhibit 27/59-n	A binary or virtual input.
***27/59-n VTSInhibit:* Yes**	Operation of the VT Supervision function (7PG2115/6).
27/59-n U/V Guarded	Under voltage guard element.

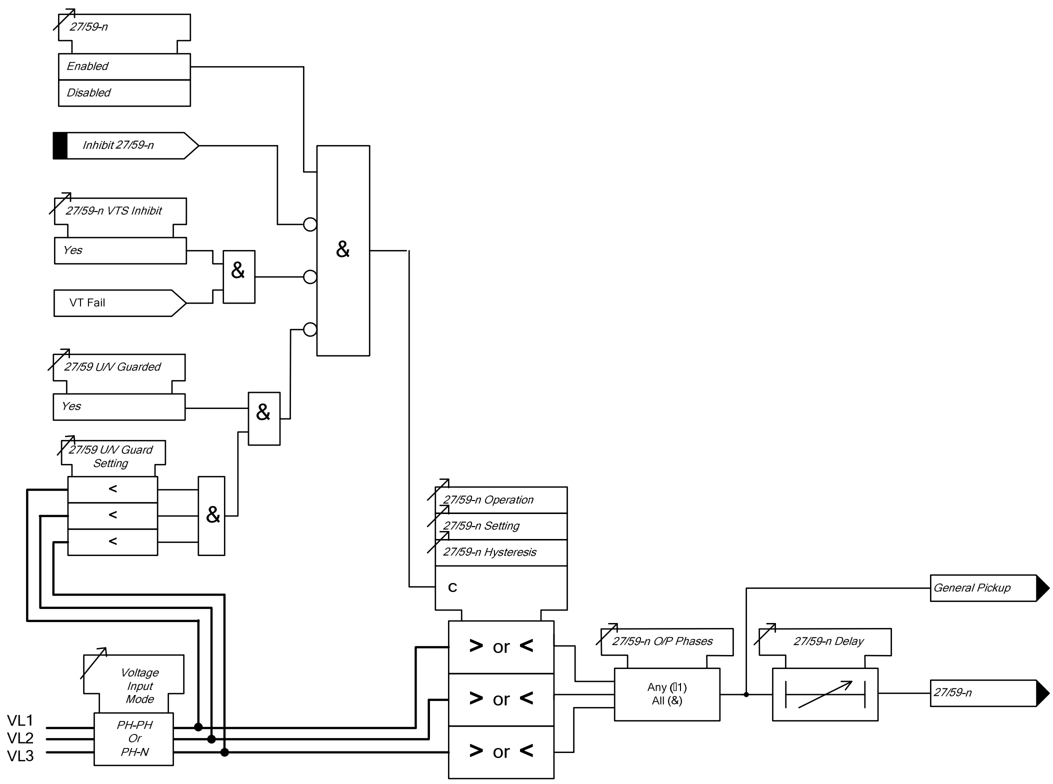


Figure 4.8-1 Logic Diagram: Under/Over Voltage Elements (27/59)

4.9 Voltage Protection: Negative Phase Sequence Overvoltage (47) – 7PG2114/6

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

Two elements are provided ***47-1 & 47-2.***

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

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

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

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

Inhibit 47-n	A binary or virtual input.

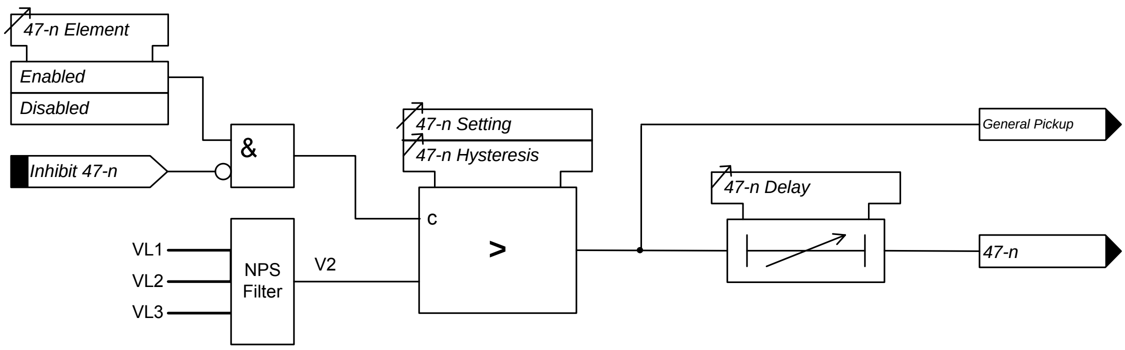


Figure 4.9-1 Logic Diagram: NPS Overvoltage Protection (47)

4.10 Voltage Protection: Neutral Overvoltage (59N) – 7PG2114/6

Two Neutral Overvoltage (or Neutral Voltage Displacement) elements are provided ***59NIT & 59NDT***.

The relay utilises fundamental voltage measurement values for this function.

The 59NIT element can be configured to be either definite time lag (DTL) or inverse definite minimum time (IDMT),

59NIT Setting sets the pick-up voltage level (3V0) 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):

$$t_{op} = \left[\frac{1000 * M}{\left[\frac{3Vo}{Vs}\right] - 1} \right] ms$$

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 59NDT element has a DTL characteristic. ***59NDT Setting*** sets the pick-up voltage (3V0) and ***59NDT Delay*** the follower time delay.

Operation of the neutral overvoltage elements can be inhibited from:

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

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

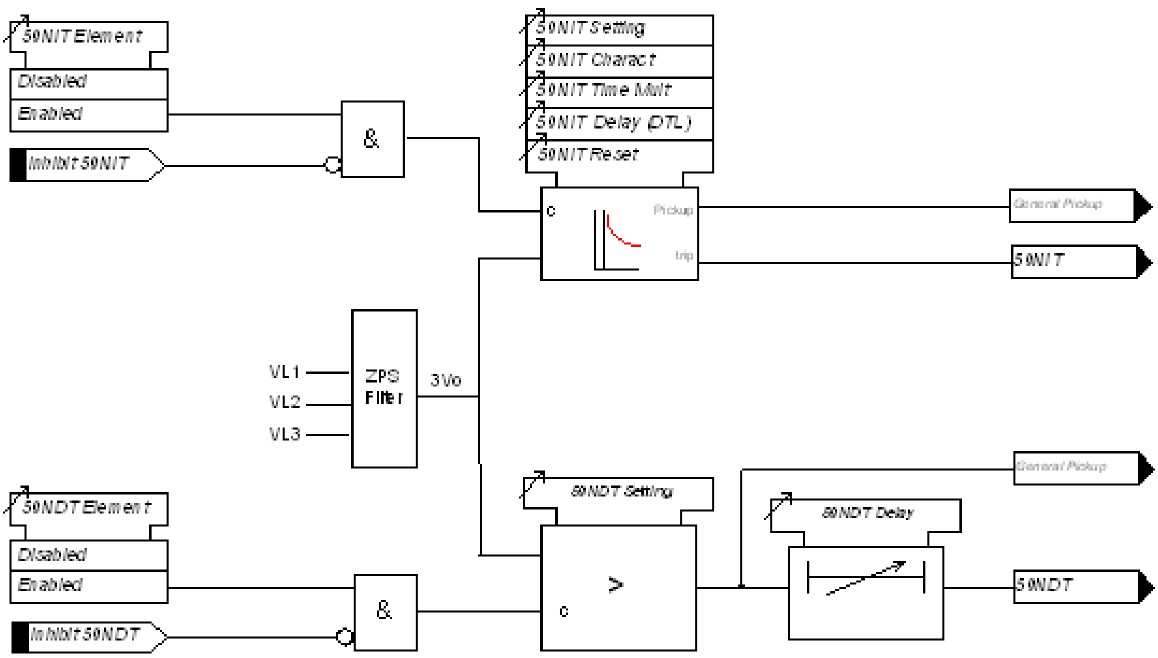


Figure 4.10-1 Logic Diagram: Neutral Overvoltage Element (59N)

Section 5: Control & Logic Functions

5.1 Auto-Reclose (79) Optional Function

5.1.1 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 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 (shot) 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 Instantaneous/Highset+1Delayed/HighSet Trips with 1 sec & 10 sec dead times.

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

Changing Relay Setting ***79 Autoreclose*** **ENABLE/DISABLE** (AUTORECLOSE CONFIG menu)

Enable/Disable in the CONTROL MODE accessed from the fascia

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: -

Status of the AR sequence

AR Shot Count.

CB Open Countdown Timer

CB Close Countdown Timer

Inputs

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

79 Out (edge triggered)

79 In (level detected)

CB Closed

CB Open

79 Ext Trip

79 Ext Pickup

79 Block Reclose

Block Close CB

Close CB

Open CB

79 Trip & Reclose

79 Trip & Lockout

79 Line Check

79 Reset Lockout

79 Lockout

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

Manual Close CB

79 Successful AR

79 Lockout

79 Close Onto Fault

79 CB Fail to Close

79 Trip & Reclose

79 Trip & Lockout

79 Block External

Successful Manual Close

5.1.2 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 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.

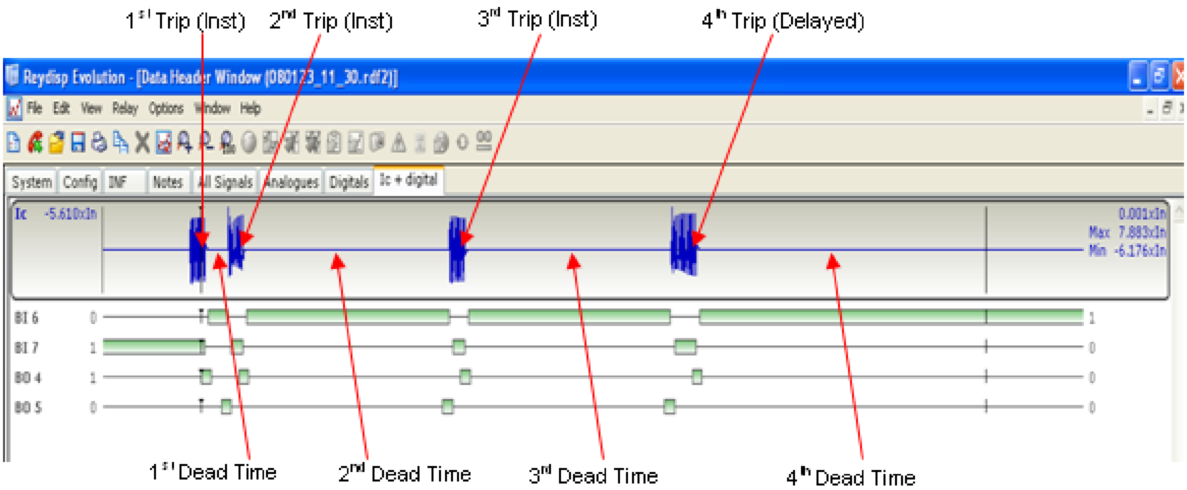


Figure 5.1-1 Typical AR Sequence with 3 Inst and 1 Delayed trip

5.1.3 Autoreclose Prot'n Menu

This menu presents the Overcurrent Protection elements available for each type of Fault i.e. P/F, E/F (N/G) 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.

5.1.4 Autoreclose Config Menu

This menu allows the following settings to be made:-

79 Autoreclose	**Enabled** turns ON all AutoReclose Functions.
79 Num Shots	Sets the allowed number of AutoReclose attempts in a sequence.
79 Retry Enable	**Enabled** configures the relay to perform further attempts to automatically Close the Circuit Breaker where the CB has initially failed to close in response to a Close command. If the first attempt fails the relay will wait for the ***79 Retry Interval*** to expire then attempt to Close the CB again.
79 Retry Attempts	Sets the maximum number of retry attempts.
79 Retry Interval	Sets the time delay between retry attempts.
79 Reclose Blocked Delay	If the CB is not ready to receive a Close command or if system conditions are such that the CB should not be closed immediately e.g. a close-spring is not charged, then a Binary input mapped to **Reclose Block** can be raised and the Close pulse will not be issued but will be held-back. The ***79 Reclose Blocked Delay*** sets the time **Reclose Block** is allowed to be raised, if this time delay expires the Relay will go to Lockout. If Reclose Block is cleared, before this time expires, then the CB Close pulse will be issued at that point in time. Dead Time + Reclose Blocked Delay = Lockout.
79 Sequence Fail Timer	Sets the time that 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 of 2s. The Lockout condition can not be reset if there is an active lockout input.

5.1.5 P/F Shots sub-menu

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

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

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

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

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

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

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

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

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

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

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

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

5.1.6 E/F Shots sub-menu

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

As above but E/F settings.

5.1.7 SEF Shots sub-menu

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

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

5.1.8 Extern Shots sub-menu

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

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

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

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

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

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

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

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

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

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

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

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

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

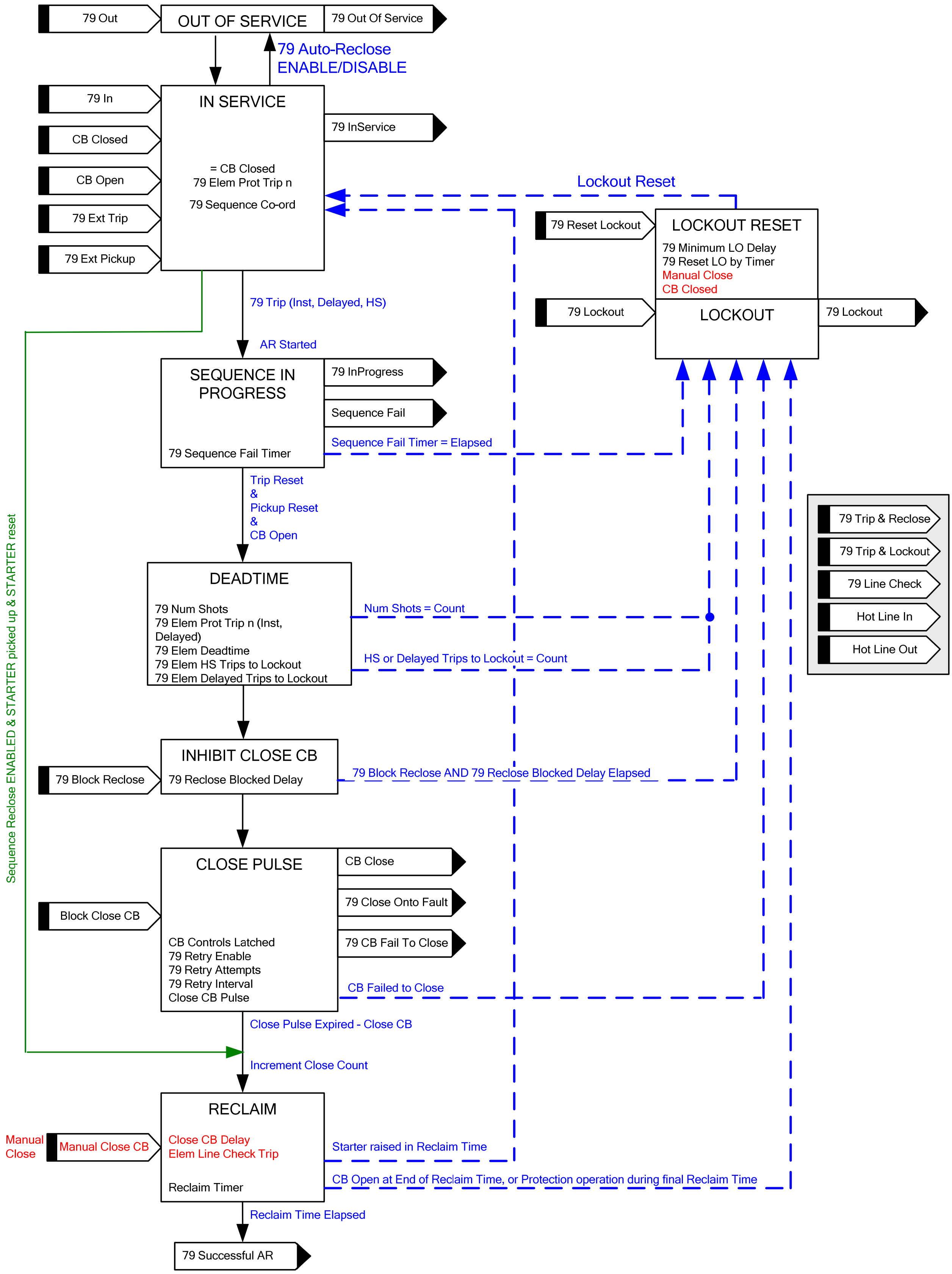


Figure 5.1-2 Basic Auto-Reclose Sequence Diagram

5.2 Manual Close

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 DAR 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. Where ***Line Check*** = **DELAYED** then instantaneous protection is inhibited until the reclaim time has elapsed.

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

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

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

5.3 Circuit Breaker (CB)

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.

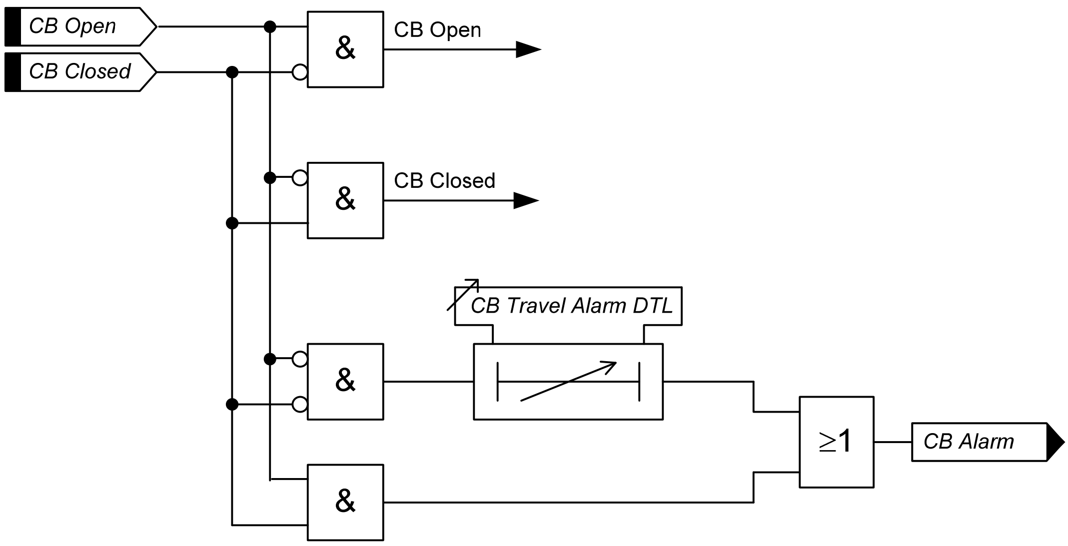


Figure 5.3-1 Logic Diagram: Circuit Breaker Status

5.4 Quick Logic

The 'Quick Logic' feature allows the user to input up to 4 logic equations (E1 to E4) in text format. Equations can be entered using Reydisp or at the relay fascia.

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

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

Example Showing Use of Nomenclature

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

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

OR

LED 1

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

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

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

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

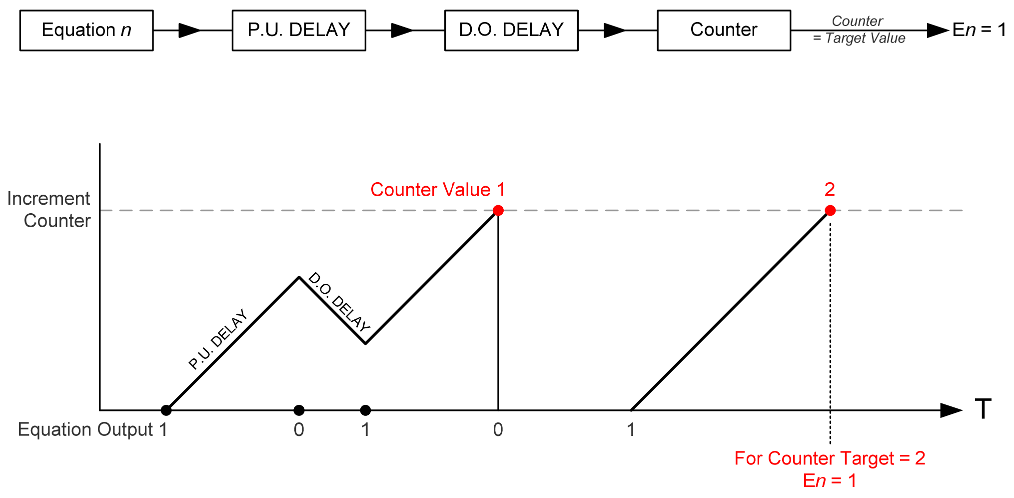


Figure 5.4-1 Sequence Diagram: Quick Logic PU/DO Timers (Counter Reset Mode Off)

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

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

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

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

Section 6: Supervision Functions

6.1 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\TRIP 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\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.

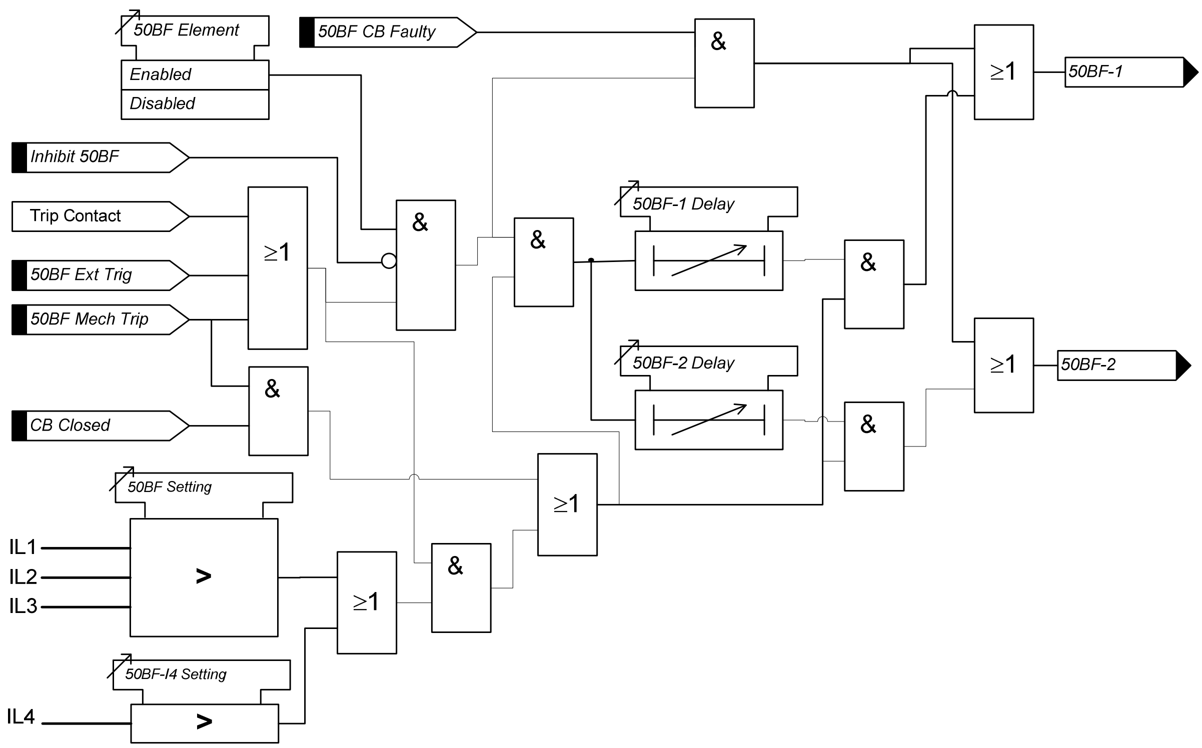


Figure 6.1-1 Logic Diagram: Circuit Breaker Fail Protection (50BF)

6.2 VT Supervision (60VTS) – 7PG2114/6

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 VPPS*** setting, an ***60VTS IPPS Load*** setting and a setting for ***60VTS IPPS Fault***. A VT is considered to have failed where positive sequence voltage is below ***60VTS VPPS*** while positive sequence current is above ***IPPS Load*** and below ***IPPS Fault*** level for more than ***60VTS Delay***.

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 ***VPPS*** setting while NPS voltage is below ***VNPS*** setting.

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

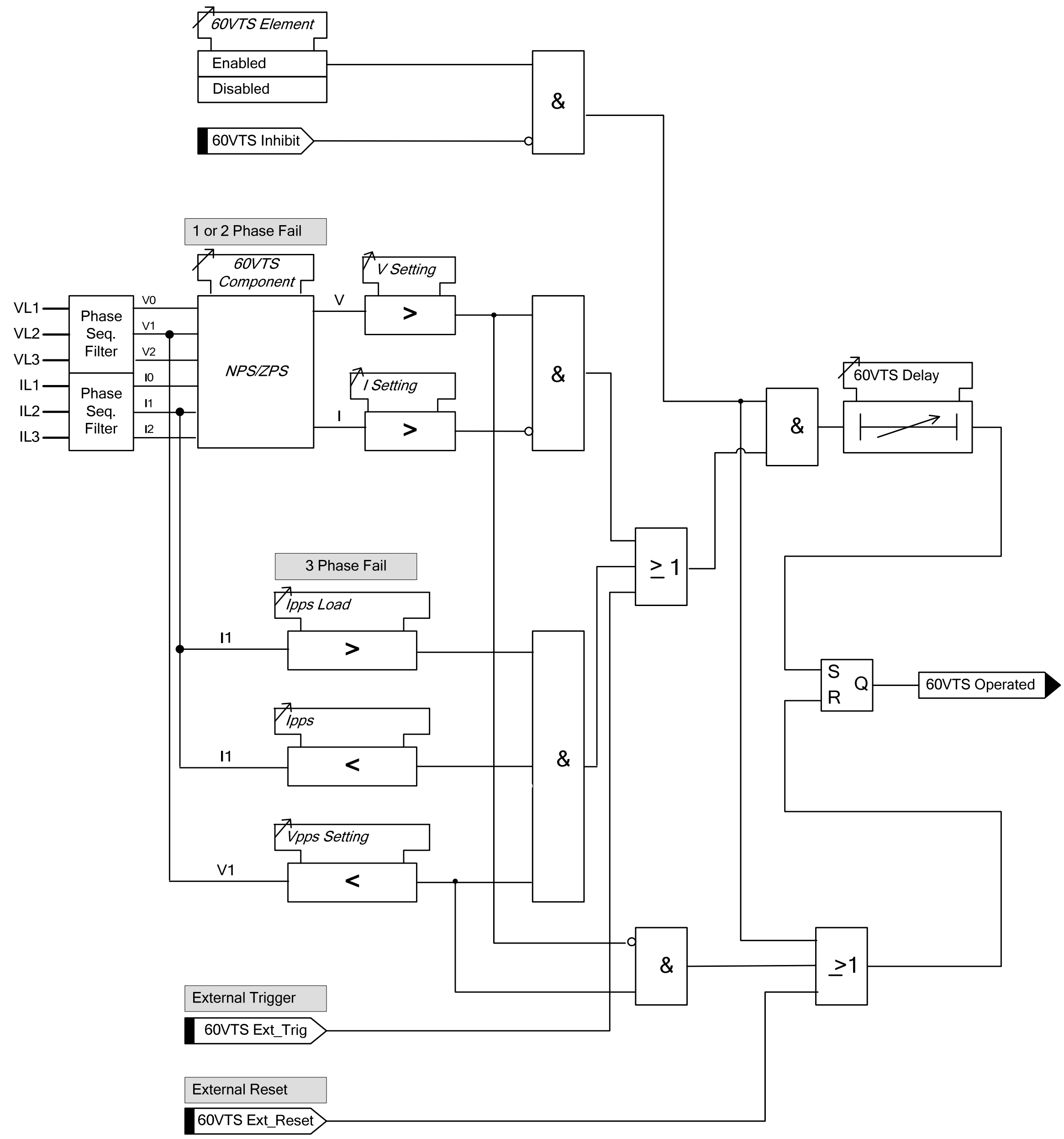


Figure 6.2-1 Logic Diagram: VT Supervision Function (60VTS)

6.3 CT Supervision (60CTS)

The relay has two methods of detecting a CT failure, depending on the relay model. CT Supervision is only available in relays with four current inputs.

6.3.1 60CTS – 7PG2113/5

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 Delay*** then a CT failure output (***60CTS 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:

Inhibit 60CTS A binary or virtual input.

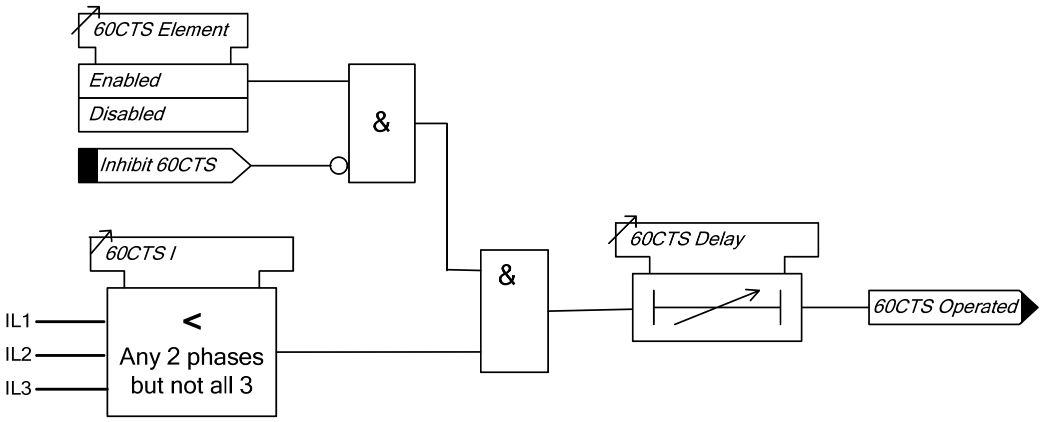


Figure 6.3-1 Logic Diagram: CT Supervision Function (60CTS) – 7PG2113/5

6.3.2 60CTS – 7PG2114/6

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:

Inhibit 60CTS A binary or virtual input.

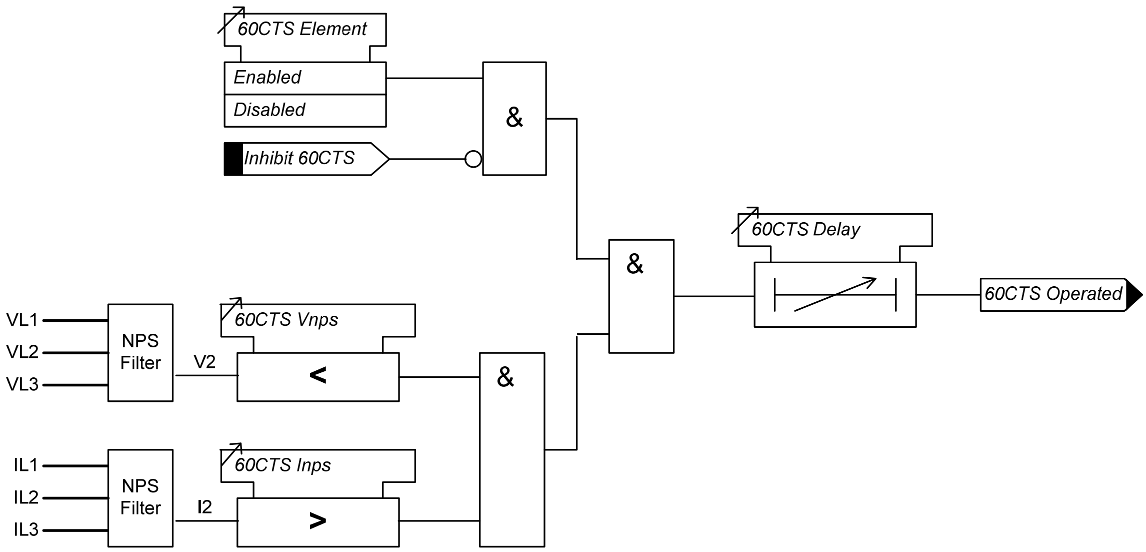


Figure 6.3-2 Logic Diagram: CT Supervision Function (60CTS) – 7PG2114/6

6.4 Broken Conductor (46BC)

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

The Broken Conductor function can be inhibited from

Inhibit 46BC	A binary or virtual input.

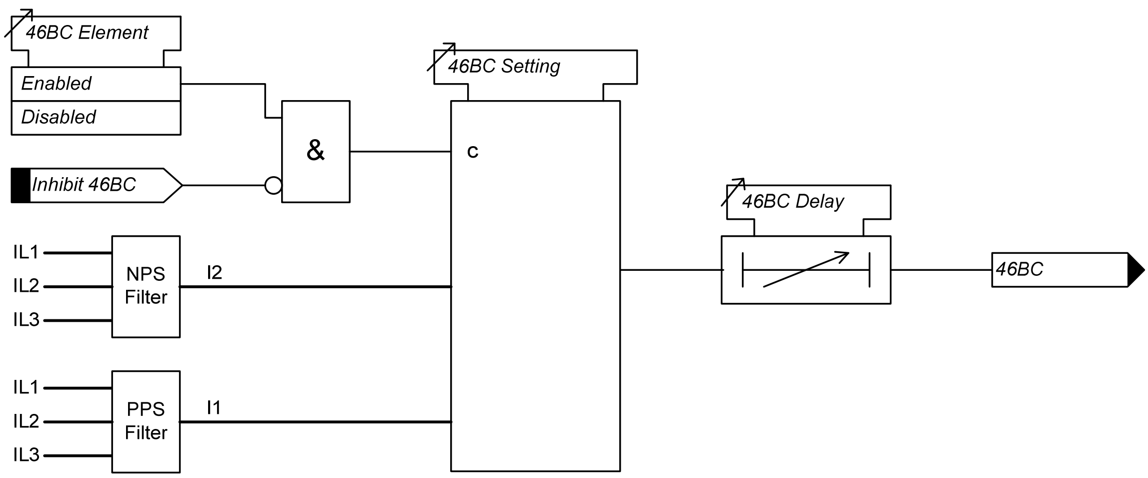


Figure 6.4-1 Logic Diagram: Broken Conductor Function (46BC)

6.5 Trip/ Close Circuit Supervision (74TCS & 74CCS)

The relay provides three trip and three close circuit supervision elements, all elements are identical in operation and independent from each other allowing 3 trip and 3 close circuits to be monitored.

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'.

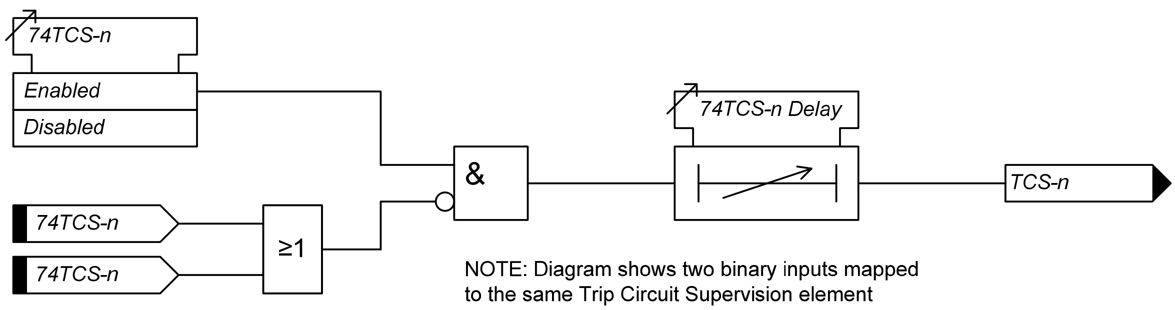


Figure 6.5-1 Logic Diagram: Trip Circuit Supervision Feature (74TCS)

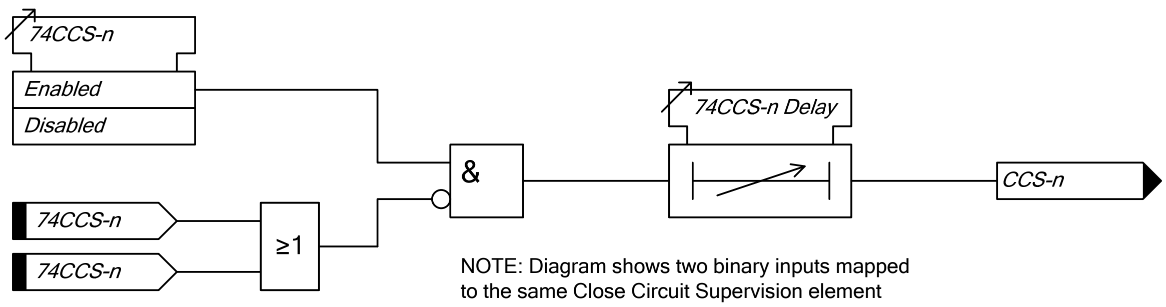


Figure 6.5-2 Logic Diagram: Close Circuit Supervision Feature (74CCS)

6.6 2nd Harmonic Block/Inrush Restraint (81HBL2) phase elements only

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.

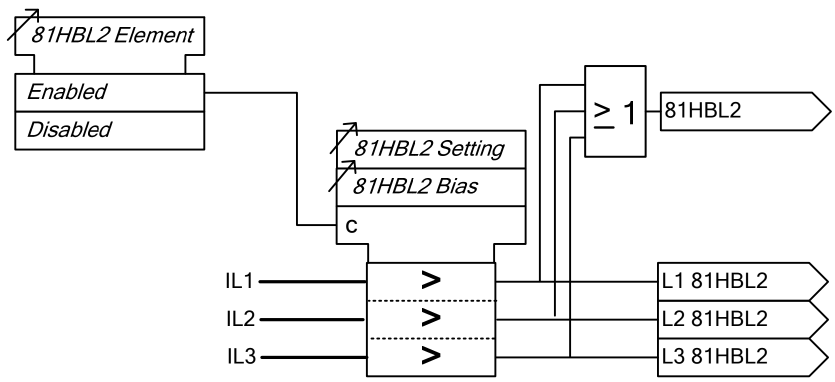


Figure 6.6-1 Functional Diagram for Harmonic Block Feature (81HBL2)

6.7 Demand

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

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

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

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

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

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

Section 7: Other Features

7.1 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.

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, is available to allow transfer of relay settings, waveform records, event records, fault data records, Instruments/meters and control functions. Reydisp is compatible with IEC60870-5-103.

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

7.2 CB Maintenance

7.2.1 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.

7.2.2 CB Counters

The following CB maintenance counters are provided:

CB Total Trip Count:	Increments on each trip command issued.
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 before the AR is blocked. 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.

A CB Trip Time meter is also available, which measures the time between the trip being issued and the auxiliary contacts changing state.

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.

Table 7-1 CB Counters

7.2.3 I_2t CB Wear

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***.

7.3 Data Storage

7.3.1 General

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

7.3.2 Event Records

The event recorder feature allows the time tagging of any change of state (Event) in the relay. As an event occurs, the actual event condition is logged as a record along with a time and date stamp to a resolution of 1 millisecond. There is capacity for a maximum of 1000 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 or from Reydisp.

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 uploaded over the data communications channel(s) and can be displayed in the ‘Reydisp’ package in chronological order, allowing the sequence of events to be viewed. Events can be selected to be made available spontaneously to an IEC 60870-5-103, Modbus RTU or DNP 3.0 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’.

7.3.3 Waveform Records.

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

In total the relay provides 10 seconds of waveform storage, this is user selectable to 1 x 10second, 2 x 5 second, 5 x 2 second or 10 x 1 second records. 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 from Reydisp.

7.3.4 Fault Records

Up to ten fault records can be stored and displayed on the Fascia LCD. Fault records can be triggered by user selected relay operations or via a suitably programmed binary input.

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 from Reydisp.

7.4 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.

7.5 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 7-2 Operating Modes

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

7.6 Control Mode

This mode provides convenient access to commonly used relay control and test functions. When any of the items listed in the control menu 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.

7.7 Real Time Clock

Time and date can be set either via the relay fascia using appropriate commands in the System Config menu or via the data comms channel(s). 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 communications interface, or a 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.

7.7.1 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.

7.7.2 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 vale when the BI is energised. This input is leading edge triggered.

7.8 Settings Groups

The relay provides four groups of settings – Group number (Gn) 1 to 4. 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**).

Settings are stored in non-volatile memory.

7.9 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.