Reyrolle
Protection
Devices

7SG16 Ohmega 408

Protection Relays

Answers for energy

SIEMENS

Contents

Technical Manual Chapters

7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

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Contents

1 General

The relays provide high speed Distance protection and have independent measuring elements for each fault condition and zone of operation. This gives a true full scheme operation. The impedance measurement is a continuous process therefore under impedance starting elements are not required. The relays can include a complete range of feeder protection features supplemented by control, metering, data storage and fibre optic data communication capabilities.

Supervisory components and self-monitoring features give a high confidence of full serviceability. A menu-based interface facilitates user friendly access to relay settings, meters and stored fault data. The relay can be easily incorporated into substation control and automation systems.

2 Protection Functions

Table 1 illustrates the standard functions and Table 2 shows the standard schemes available in all relay models;

Mho Characteristics	High Set Overcurrent
3 Zone	A.C. Line Check (SOTF)
Residual Compensation	D.C. Line Check (SOTF)
3 Pole Tripping	V.T. Supervision
Power Swing Blocking	Voltage Memory

Table 1 – Standard Protection Functions

Time Stepped Distance	Blocked Overreach
Permissive Underreach	Permissive Overreach

Table 2 – Standard Schemes

In addition to these standard features, different model numbers are available which have extended functionality. These extended features are detailed in Section 12 of this manual.

3 Output Contacts

The basic relay model provides 5 output relays, three of which energise changeover contacts, the remaining two energise normally open contacts. The number of output contacts can be increased by groups of 8, to give a maximum of 29 output contacts.

Outputs are user programmable to operate from any or all of the protection functions. In addition they can be programmed to generate outputs for alarm conditions or operate on the energisation of a status input. The relay “Protection Healthy” output is energised whenever the relay is powered-up and working correctly. If the self monitoring feature of the relay detects a hardware fault, or the relay power supply is lost, this contact will drop off.

In their normal mode of operation, output contacts remain energised for at least 100ms, or for the duration of fault. Alternatively, outputs can be programmed to operate as latching contacts if required. Latched output relays can be reset either by pressing the TEST/RESET button, by sending an appropriate data communications command or electrically via a status input.

4 Status Inputs

3 plant status inputs are provided in the basic relay, this can be increased in groups of 8, using additional modules to give a maximum of 27 inputs. The inputs can be mapped to dedicated functions within the relay or can be mapped to functional logic blocks or to user defined logic. The inputs can be configured to be high speed signal channels or have a time delayed pickup or drop off function.

5 Multiple Setting Groups

The relays provides up to eight alternative settings groups, making it possible to edit one group while the relay protection algorithms operate using another ‘active’ group. The relay can be switched from one group of settings to another to suit alterations in the power system configuration. The process of changing the settings takes place changed sequentially, and may take up to 2s to update all the settings, during which time the relay remains operative.

A change of group can be achieved either locally at the relay fascia, remotely via a communications interface command or automatically by the energising of a status input. In the case of the last method, the ‘Status Configuration’/‘Settings Group Select’ setting is used to configure any one (or more) of the status inputs to select a settings group. The selected group is then made active if the status input is energised and remains active for as long as the input remains energised. When the input is de-energised the relay returns to the original settings group.

All Settings are stored in non-volatile memory.

6 Instrumentation and Metering

6.1 Metering

The metering features provide continuous data accessed either from the relay fascia in “**Instruments Display Mode**” or via the data communications interface. While in the display mode pressing the ⇩ key accesses the following metering data:

6.2 Secondary Values

RMS values for the secondary I_A, I_B, I_C, V_A, V_B, V_C values measured by the relay.

6.3 Primary Values

RMS values for the primary I_A, I_B, I_C, V_A, V_B, V_C values on the system.

6.4 Phase Sequence Currents and Voltages

RMS value for the secondary phase sequence quantities measured by the relay. Positive, negative and zero sequence current and voltage are all measured.

6.5 Watts

Three phase exported primary power.

6.6 VArs

Three phase exported primary VArs.

6.7 Power Factor

Cosine of ϕ measured on phase A.

6.8 Load Direction

Forward, Reverse on each phase.

Indications showing the condition of the status input signals and the output contacts are available. Where the display indicates a **I** then that position is shown to be active.

The time and date is also displayed.

Where appropriate, additional meter displays are available depending upon the functions supplied with the relay. These will be described in the relevant sections.

7 Data Storage

Data records are available in three forms, namely fault records, waveform records and event records. All records are stamped with time and date. The relay incorporates a real time clock feature which keeps time even when the relay is de-energised.

Time and date can be set either via the relay fascia using appropriate commands in the System Configuration Menu, or via the communications interface. In the latter case, relays in a communications network can be synchronised by a global command. Alternatively, time can be synchronised via the IRIG B-12x interface in the relay.

7.1 Fault Records

When issuing a trip output under fault conditions, the relay illuminates the relevant LED(s) and, stores a fault record.

This fault record contains the date and time of the occurrence, the active setting group, the flags raised and the distance to fault (if fault location is enabled).

The fault record is viewed in the '**Fault Data Display** Mode' of the menu display system and can be viewed again at a later date. Records are stored for up to 10 faults, the older records being viewed by pressing the ⇩ button. The displays are numbered from 1 to 10 with fault 1 indicating the most recent record. When each record is viewed the LED's which were indicating at the time of the fault are re-displayed.

The relay triggers the fault recorder (and waveform storage) when the internal logic detects a fault trip condition.

Fault records are stored in capacitor backed memory.

7.2 Waveform Records

The waveform record feature stores analogue and digital information for all current inputs, voltage inputs, status inputs and output relays. Waveform storage is triggered by operation of any internal trip function.

In addition, the waveform records can be triggered remotely via a status input or via the serial communications interface.

Waveforms are stored in a rolling 'time window'. The memory is configured for a default of 10 x 1s records but can be set to 5 x 2s, 2 x 5s or 1 x 10s. The pre-trigger can be set in 10% steps over the record length.

Any new record over-writes the oldest when the data memory is full. All records are time and date stamped.

Waveform records are stored in RAM with a capacitor providing back-up during breaks in auxiliary supply.

The waveform records can only be examined once they have been downloaded into a suitable data analysis package such as Reydisp Evolution.

7.3 Event Records

The event recorder feature allows the time tagging of any change of state of the relay. Each event is logged with the full date and time and actual event condition every 2.5ms. The following events are logged:-

- Change of setting (though not the actual setting changes). Also indication of which group of settings is active.
- Change of state of Output Relays
- Change of state of Status Inputs
- Change of state of any protection characteristic
- Main Trip

Other events are available depending upon the features included in the relay -they are described with the relevant feature.

The event storage buffer holds at least 500 records. When the event buffer is full, then any new record over-writes the oldest.

Event records are stored in RAM with a capacitor providing back-up during breaks in auxiliary supply.

The event records can only be examined once they have been downloaded into a suitable data analysis package such as Reydisp Evolution or by interrogation of the SCADA system.

8 Communications

A front mounted RS232 port and two rear fibre optic communication ports are provided. Communication is compatible with the IEC60870-5-103 transmission and application standards. The fibre optic interface gives superior EMC performance. A user friendly software package (Reydisp Evolution) is available to allow transfer of the following:

- Relay settings
- Waveform records
- Event records
- Instruments and meters
- Control Functions

Communications operation is described in detail in the Communication Interface Manual

9 Self Monitoring

The relay incorporates a number of self-monitoring features. Each of these initiates a reset sequence, which can be used to generate an alarm output. In addition, the Protection Healthy LED gives visual indication.

A watchdog feature monitors the microprocessor while the relay has a self-check feature for the program memory, which is continuously checked for data corruption.

The power supply is continuously supervised. Any failure is detected with sufficient time warning so that the microprocessor can be shut down in a safe and controlled manner.

10 Password Feature

The programmable password feature enables the user to enter a 4 character alpha-numeric code. The relay is supplied with the password function disabled. To enable the password feature the user must first enter a password. Verification of this is asked for and then this becomes the valid password.

As soon as the user attempts to change a setting the password is requested before any setting alterations are allowed. Once the password has been validated, the user is said to be "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 out", re-enabling the password feature.

Note that the password validation screen also displays a numerical code. If the password is lost or forgotten, this code can be communicated to Siemens by authorised personnel, and the password can be retrieved.

The relay is supplied with the password set to "NONE" which means the feature is de-activated.

To de-activate the password change the password to “NONE” the function will now be disabled.

11 User Interface

The user interface is designed to provide a user-friendly method of entering settings and retrieving data from the relay. The HMI is shown in 1.

11.1 General Arrangement

All relay fascia includes a liquid crystal display, 33 light emitting diodes, 5 push buttons and an RS232 data communications socket.

The LCD has a 20 character by 2 line display which is backlit.

11.2 Liquid Crystal Display

The liquid crystal display is used to present settings, instruments and fault data in a textual or graphical format.

The contrast of the display may be changed by pressing TEST/RESET and either the up or down key simultaneously.

The display back lighting is turned off to conserve power if no pushbuttons are pressed for a set time delay (the backlight timer which is set to 5 minutes by default). After a further delay (Default screens timer, default 60 minutes), the display will revert to the defaults screen(s). The relay will then cycle through screens selected in the defaults screen list, changing screens every few seconds (unless the default screens timer setting is set to OFF). The defaults screen list always includes the ‘RELAY IDENTIFIER’ screen. Additional instruments screens can be added to the defaults screens list by pressing the ENTER key when the required screen is being viewed. A ’D’ symbol appears on the screen to show that the screen is now in the list.

11.3 LED Indications

The following indications are provided:

Protection Healthy - Green LED.

This LED indicates that DC volts have been applied to the relay and that the relay is operating correctly. If a permanent fault is detected by the internal supervision, then this LED will continuously flash.

Red LED –

These LED's indicate that a trip or protection operation as defined by customer setting has occurred. Such an operation may have been issued by any of the relays functions or by a change of state of a status input - all red LEDs are user programmable and can be assigned to any output function. Any of the red LEDs can be defined as self reset as opposed to the default of latched such that the led will be extinguished when the output stimulus is removed.

Listed below in Table 3 is an example of indications provided by the LEDs. Some of these will not be applicable when the relay is not provided with the relevant associated feature. Note a full list of the LED indications available in the particular model of the relay is provided in Section 4 of this manual.

Zone 1	Carrier Receive 2
Zone 2	DEF Aided Trip
Zone 3	Carrier Receive Guard
Zone 4	Switch onto Fault
Zone 5	VT Fail
Phase "A"	Overcurrent Highset
Phase "B"	Power Swing alarm
Phase "C"	Power Swing trip
Earth	Broken Conductor
Carrier Receive 1	Stub Protection
Aided Trip	Autoreclose in progress
DEF Forward	Autoreclose lockout
DEF Reverse	CB open

Table 3 – Typical LED Indications

11.4 Keypad

Five push buttons are used to control the functions of the relay by moving around the menu display. They are labelled ⇩ ⇧ ⇨ **ENTER** and **CANCEL**. Note that the ⇨ button is also labelled **TEST/RESET**.

Only two push buttons are accessible when the front cover is on. These are the ⇩ and ⇨ buttons, allowing read access to all displays.

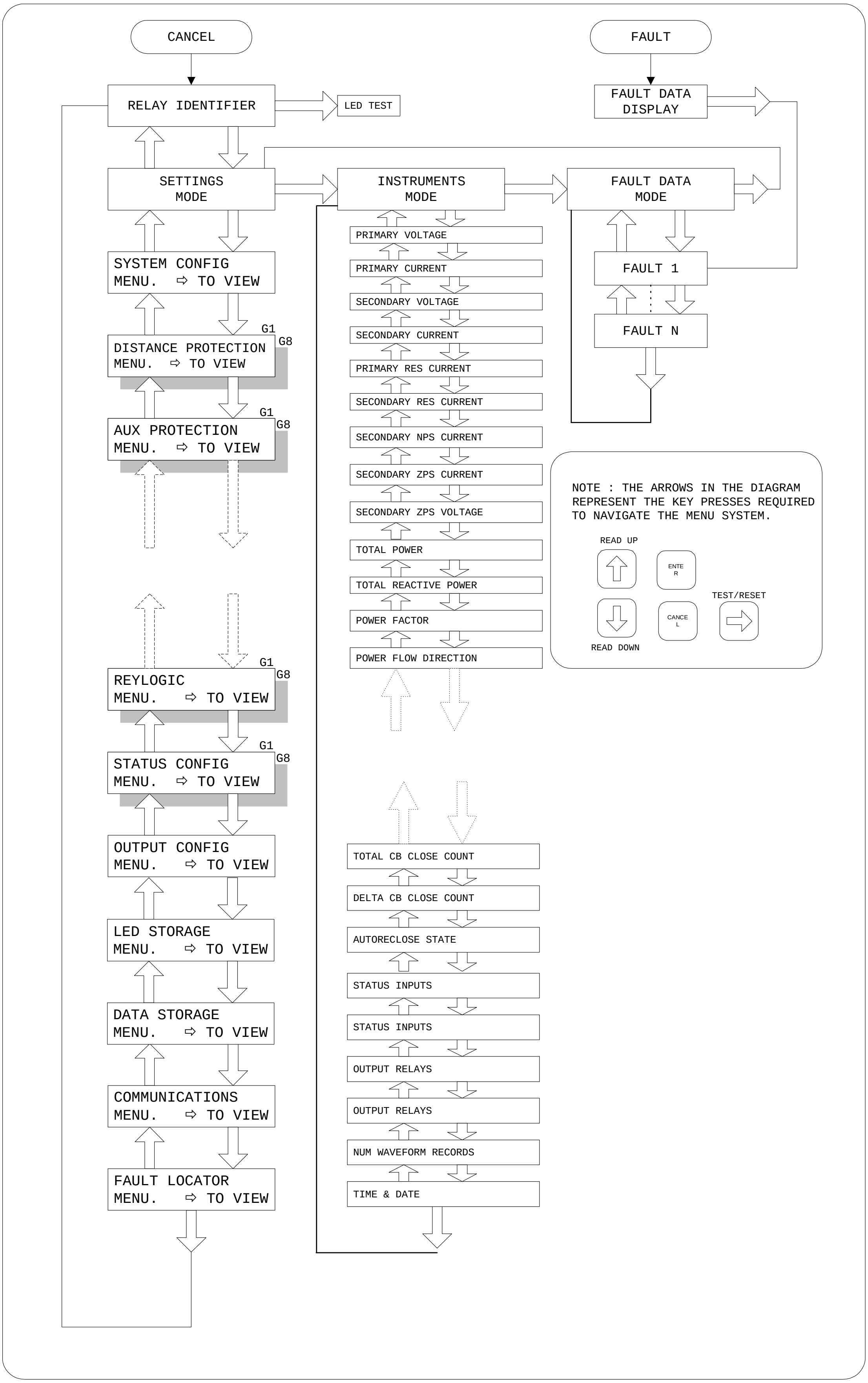
12 Settings and Displays

The model specific settings/displays flow diagram is shown in the settings section of this manual, section 4. The diagram below shows the basic structure for demonstration purposes. This diagram shows the three main modes of display, the SETTINGS DISPLAY MODE, the INSTRUMENT DISPLAY MODE and the FAULT DATA DISPLAY MODE.

On relay start up, the user is presented with a default relay identifier. This can be changed (In the SYSTEM CONFIG MENU) to some user-definable identifier or code if the user prefers.

Settings display mode is entered by scrolling down from the relay identifier display. The ⇨ key can then be used to move to the INSTRUMENT and FAULT DATA DISPLAY MODES in turn.

The settings display mode contains all the menus which hold the programmable settings of the relay. It contains a series of sub-menus with typical title displays as follows:



A sub-menu is opened by pressing the ⇨ key when viewing one of the above title screens. The settings within the sub-menu can then be viewed in turn. Leaving a sub-menu, by scrolling either upwards or downwards, causes it to be automatically closed. It must be re-opened in order to view its settings again.

(1) Pressing ⇧ / ⇩ scrolls up / down, viewing the screens. All screens can be viewed even if the password is not known - the password only protects the relay against unauthorised changes.

(2) While viewing an editable screen, ENTER allows the user to change the displayed data, indicated by flashing character, as long as the changes are authorised via password verification. Pressing ⇧ / ⇩ increments / decrements that particular character, while ⇨ moves right along the edit field or fields. If ⇧ or ⇩ are held pressed while scrolling through a range of numerical settings then the rate of scrolling increases.
CANCEL returns the screen to view mode and restores the most recently stored setting.

(3) If changes are made, pressing ENTER alters the values on that screen and immediately stores the changes into non-volatile memory. This also returns the screen to view mode and allows ⇧ / ⇩ to move to the previous / next screen.

There are eight separate 'Settings Groups. The different settings groups can be viewed or edited independently and indication of which group is presently being viewed is given by the 'G?' character in the top left of the display.

The setting selections, setting ranges and default values can be found at the end of each relevant section in the technical manual.

13 Relay Hardware

The range of relays are housed in the Epsilon case - size 16.

The relay hardware is illustrated in 1.

The build consists of up to eight internal hardware modules as well as the fascia module. All relay models are supplied with the following modules:

Module A	Power supply + basic I/O
Module E	Voltage inputs
Module F	Current inputs
Module G	Analogue input processing
Module H	Protection processor and controller

Modules B, C and D are optional giving additional input/output capability.

The fascia PCB includes the human machine interface (HMI), with pushbuttons for entering settings, an LCD for displaying alphanumeric and optionally graphical information and LEDs for indication. A 25 pin RS232 D type connector is located on the front plate to allow local data communications.

Current and voltage input signals are carried from the input modules via the data acquisition bus (DAQ) to the analogue input processor card for processing. The processed inputs are in turn carried to the protection processor/controller module via the expanded I/O bus.

Two remote data communications interfaces - fibre optic - and an IRIG-B connector are located behind module H and connected into the controller card.

A 34 way ribbon cable connects the I/O and fascia modules to the processing and protection processor /controller modules and a 26 way ribbon cable connects the analogue modules to their processor and another 26 way ribbon cable connects the processors together.

13.1 Internal Construction

The design for the internal arrangement of each module has been chosen to provide a high level of EMI screening, using multi-layer PCBs with ground planes, RFI suppression components and earthed metal screens.

The case is segregated internally into electrically noisy and quiet areas in order to improve noise immunity and reduce RFI emissions. The only direct connection from the quiet components to the external environment is via the serial communication interfaces. The optical interfaces are immune to radiated or conducted interference.

13.2 Front Cover

After the relay has been commissioned, a clear plastic front cover is fitted. This allows the user to see the entire front of the relay, but only allows access to the ⇩ and ⇨ buttons, allowing all of the menus discussed previously to be viewed but not changed. The only ‘action’, which is permitted, is to reset the Fault Data Display, latched output relays and the latched LEDs by using the **TEST/RESET** function of the ⇨ button.

13.3 Terminal Blocks

These are of the standard Epsilon design, consisting of six blocks - behind modules A to F - with 28 terminals per block. All inputs and outputs (except for the serial communications interface) are made through these connectors. Where CT’s and normally closed output contacts are fitted the terminals are provided with CT shorting contacts to provide system integrity when these modules are removed.

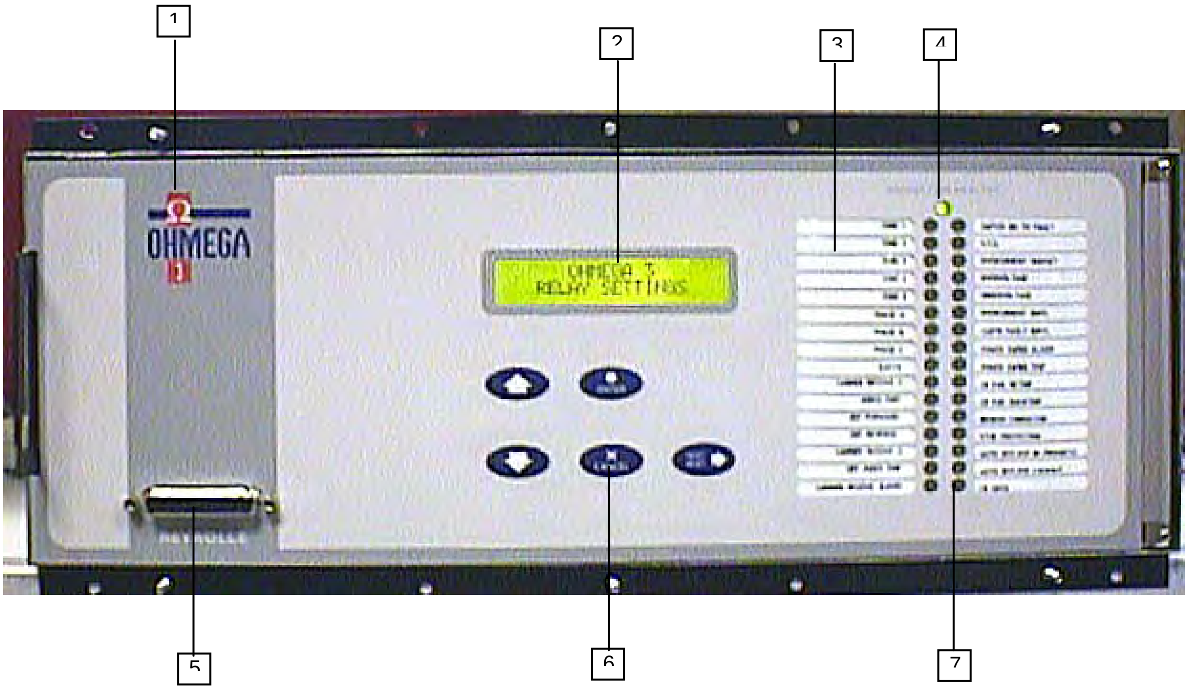


Figure 1 –Human Machine Interface (HMI)

Features

1 Relay type
2 2 line 20 character back lit L.C. display
3 Alarm description
4 Protection healthy L.E.D.
5 Local RS232 port
6 Five button key pad
7 32 programmable alarm and trip L.E.D's

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7SG164 Protection Relay

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Contents

1 DISTANCE PROTECTION FUNCTIONS

1.1 POLARISED MHO CHARACTERISTIC

1.1.1 Cross-Polarised Mho

It is fundamental to the requirements of discrimination that distance protection Zone 1 and 2 measuring characteristics for direct tripping are directional since they are required to detect faults in the forward direction only.

As with any measuring device, operation on, or very close to, the boundary of operation will be less decisive than that further inside the characteristic. It can be seen that the characteristic for Zones 1 and 2 pass through the origin, and thus, faults occurring very close to the relaying point will represent a boundary condition. In order to improve the operating speed, and to ensure correct directional response for such faults, a method known as cross-polarising is used.

A proportion (30%) of the voltage measured on a phase (or phases) not involved in the fault is added to the fault voltage used by the comparator (after being shifted 90º to bring it into phase with the fault voltage). The polarising voltage used will be different for each fault comparator, i.e. red-earth for a yellow-blue fault, red-blue for a yellow earth fault. For balanced (three-phase) faults the voltage in each phase will be equal, and so this will have no effect. For unbalanced faults, however, this ”cross-polarising” changes the overall shape of the characteristic into a circle of diameter $Z_F - kZ_S$ as shown in figure 1, when the current is flowing in the forward direction. It can be seen from this diagram that the reach along the line angle is unaffected, but off angle, the characteristic expands. This expansion gives an increasing coverage of the resistive axis, and allows detection of higher resistance faults than the unpolarised mho characteristics. The healthy phase voltage, and thus the degree of expansion will depend largely on the source impedance, and thus the shape of the characteristic will depend upon the System Impedance Ratio (SIR). The higher the SIR, the greater the expansion. When current flow is in the reverse direction, the shape of the characteristic will change again to give a small circle of operation in the forward direction (i.e. in the opposite direction from the fault). This ensures the stability of the relay for close-up reverse faults.

This expansion will only apply for unbalanced conditions. Some models of the relay employ a feature known as Voltage Memory. This provides a polarising vector derived from the pre-fault voltage which is applied for a limited time, after which the protection is inhibited. This provides a similar expansion for three-phase faults. Full details about voltage memory are given in later in this section.

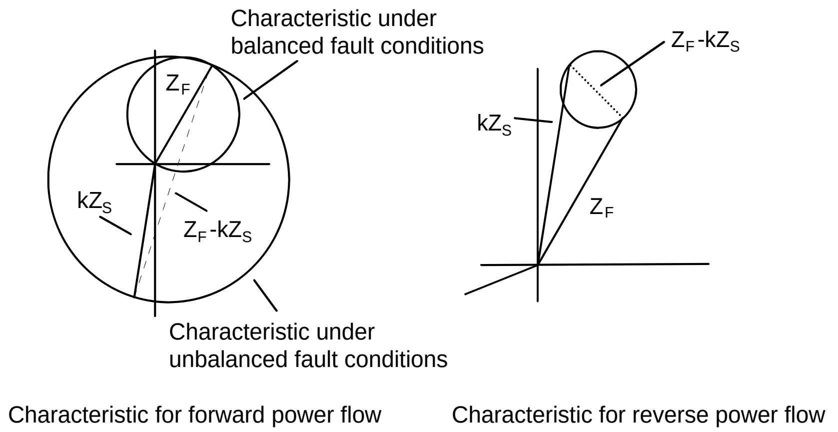


Figure 1, Cross-Polarised Mho Characteristic

1.1.2 Offset Mho Characteristic

The offset Mho characteristic is shown in figure 2. The characteristic is set with a forward reach, Z_F and a reverse reach, Z_R. This type of characteristic may be selected for Zone 3, and it provides time delayed back-up for faults behind the relaying point.

In addition to this, the origin is not a boundary condition as it is for zones 1 and 2, so the offset zone can be used in schemes to provide positive operation for marginal conditions (see Switch-onto-fault logic).

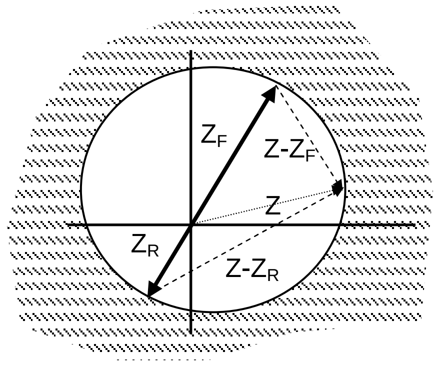


Figure 2 Offset Mho Characteristic

1.1.3 Fault Configuration

A distance relay must measure the impedance correctly for all types of power system faults (single-phase, two-phase and three phase). For each fault type the effective impedance at the relaying point will be different because the path that the current takes will be different in each case, as illustrated in figure 3 below ;

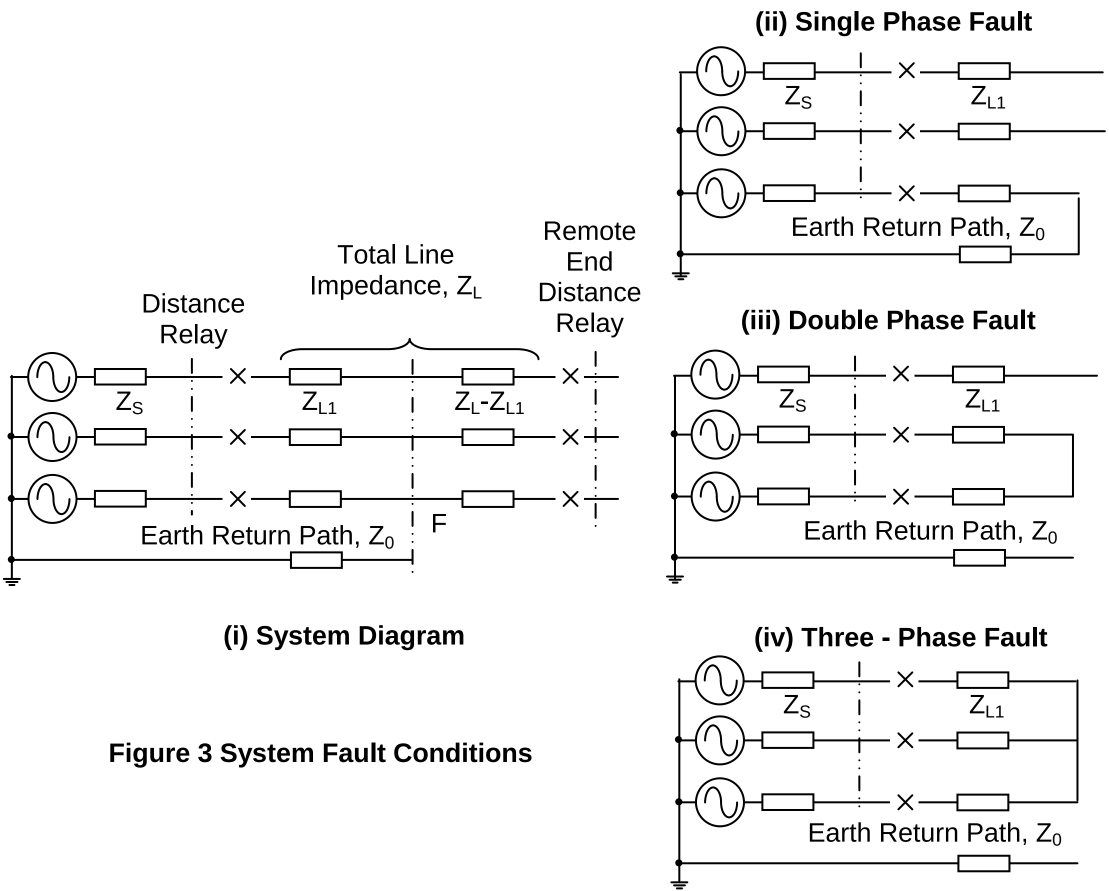


Figure 3 System Fault Conditions

To correctly measure the impedance to the fault point, the correct current and voltage must be applied to the relay. The relay impedance setting is made in terms of the positive sequence impedance to the point of reach which means that the relay setting is the same for all types of fault.

The relay uses discrete measuring elements for each fault type in each zone. The quantities measured by each of these element s are described in the following sections.

1.1.3.1 Phase Faults

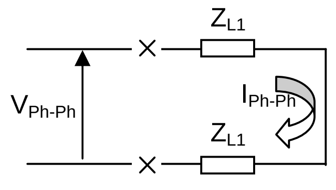


Figure 4 Fault Loop for Phase-Phase faults

There are three phase fault elements in each zone looking at red-yellow, yellow-blue, and blue-red phase faults respectively. These elements measure the phase-phase voltage, and phase-phase current for their particular phases. As can be seen from figure 4, this leads to a loop impedance of $2Z_L$.

1.1.3.2 Earth faults

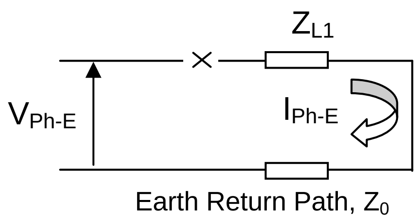


Figure 5 Fault loop for earth faults

When considering earth faults, the relay is actually presented with a loop impedance of $Z_L + Z_N$, where Z_L is the impedance in the line to the fault and Z_N is the earth return path, as shown in figure 5. This can also be compensated for by using a combination of the current flowing in the line and neutral circuit but the problem is that the complex impedance Z_N is not known and is not readily available by measurement.

Conventionally the known parameter available for the line is the zero sequence impedance. (If it is not known, it can be measured for any particular line). The zero sequence impedance, like the positive sequence impedance is proportional to the line length.

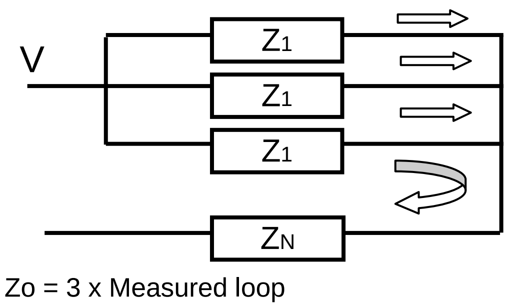


Figure 6 Sequence impedance diagram for an earth fault

Figure 6 shows the method utilised to measure the zero sequence impedance of a line that gives the expression.;

$$Zo = 3\left(\frac{Z_1}{3} + Z_N\right)$$

or $$Z_N = \frac{(Z_O - Z_1)}{3}$$

and the ratio $$\frac{Z_N}{Z_1} = \frac{1}{3}\left(\frac{Z_O}{Z_1} - 1\right)$$

$$Z_N = \frac{1}{3}\left(\frac{Z_O}{Z_1} - 1\right)Z_1$$

hence $Z_N = K_o Z_1$

where $K_O = \frac{1}{3}\left(\frac{Z_O}{Z_1} - 1\right)$

This is a convenient factor to use in the phase comparison logic as the actual value of Z_0 is not required provided the ratio Z_0 / Z_1 and the phase angles of Z_0 and Z_1 are available. The K_0 factor described above must of course take into account the phase angles of Z_1 and Z_0 in the calculation for K_0.

The advantage of using the method described above is that the ratio Z_0/Z_1 is a relatively simple calculation and can be obtained using any convenient dimensions (e.g. Primary Ohms, Secondary Ohms, Ohms/Km etc) provided the zero phase sequence value and the positive phase sequence value are expressed in the same units.

When the reach setting Z_1, the ratio Z_0/Z_1, the line angle, and the angle of Z_0 are entered the relay calculates the composite value.

$K_0 = 1/3\ (Z_0/Z_1 - 1)$

and this value is taken into account for a polarised mho characteristic using the complex expression.

$(IZ + K_0 I_N Z_1) - V$ within 90° of $V + Vp$ where I = Phase current

Z_1 = Positive phase sequence impedance of zone setting
$K_0 = 1/3\ (Z_0/Z - 1)$
I_N = Earth fault current
V = Phase-earth fault voltage
Vp = Polarising voltage

1.1.4 Zone 3 Shaped Characteristics

In circumstances where the zone conditions come within the reach of the Zone 3 Characteristic blinders can be applied to prevent load encroachment (See figure 7a, below).

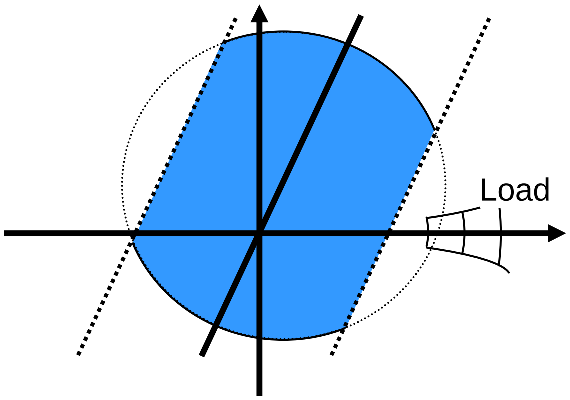


Figure 7a - Shaped Mho Zone 3

Obviously, this presents no problem for the Quad characteristic, since the reach along the resistive axis can be limited. But the resistive reach of the Mho will depend upon it's impedance reach and the degree of offset used.

The method of shaping the mho Zone 3 is to use adjustable blinders. With a value of 1.0 the blinders are tangential to the circular characteristic & have no shaping effect. Two settings are available Shaping factor 1 adjusts the local end of the boundary characteristic & shaping factor 2 adjusts the remote end of the characteristic. A value of 1.0 is equivalent to the radius of the total Zone 3 setting. If a lower value is used for factor 1 than factor 2 the characteristic is narrower near the origin allowing for a more flexible load encroachment characteristic.

1.1.4.1 Setting of Shape Factors.

The positions of the blinders are set using the shape factor 1 (SF1) and shape factor 2 (SF2) settings which appear in the distance protection setting menu as part of the zone 3 settings. Each of these settings has a range from 0.00 to 1.00 in 0.01 steps. Normally, both shape factors would be set to the same value.

The shape factors control the ratio between the minor and major axes of the shaped characteristic, the major axis being along the direction of the line angle, and the minor axis being at ninety degrees to the line angle.

Selecting both SF1 and SF2 to a value S would result in a pair of blinders being placed parallel to the line angle and equidistant from the protected line. The distance between the blinders in impedance terms would be SZt, where Zt is the total impedance cover along the line, i.e. the forward impedance setting Zf plus the reverse impedance setting Zr.

For example, if the relay was set to protect 24Ω in the forward direction and 8Ω in the reverse direction, and the shape factors were both set to 0.5, then the blinders would be positioned so that the characteristic had a width of 0.5*(24+8)Ω = 16Ω.

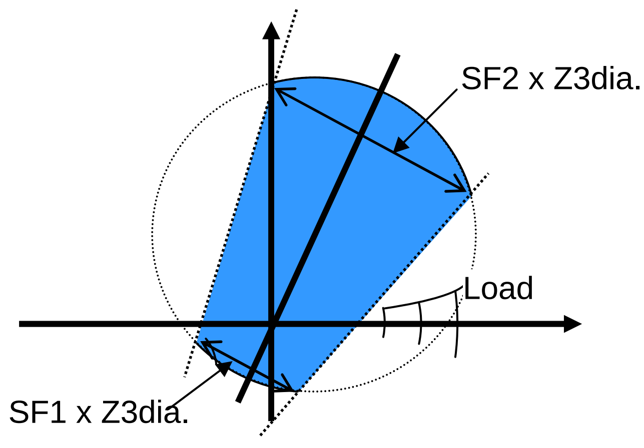


Figure 7b - Unequal Shape Factors

The above figure shows the position of blinders if different values are chosen for SF1 & SF2.

1.1.5 Comparison of Setting with THR Relay

In order to ease application of the characteristic, it is recommended that the same ratios of minor to major axis are used as were provided with the THR relay. These are given in the table below.

The method of achieving the THR shaped characteristic resulted in the characteristic shape being “waisted” with two distinct lobes. As a result, these lobes did have a reach slightly beyond the minor axis width calculated from the shape factors. These values (ratios) are given below for reference.

Ratio of minor to major axis a/b	THR maximum lobe width (as ratio)
0.36	0.38
0.5	0.52
0.6	0.62
0.75	0.752

Selecting different link positions on THR resulted in unequal lobe widths, giving an asymmetrical characteristic. This could be advantageous for some applications, and this effect can be achieved by selecting unequal values for SF1 and SF2. The value of SF1 controls the width of the “lobe” at the local (relay) end of the characteristic, i.e. that part of the characteristic with reverse reach, and SF2 controls the width of the remote part of the characteristic. Selecting values from the above table will result in similar profiles.

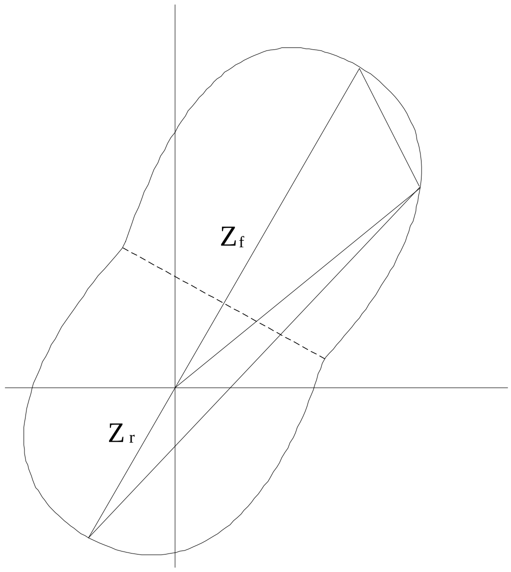


Figure 7b THR shaped characteristic showing waisting.

1.2 QUADRILATERAL CHARACTERISTIC

In addition to MHO characteristics, some models of the relay have the option of quadrilateral characteristics for earth fault coverage. The quadrilateral characteristic can be set according to resistive coverage, reactive coverage and the line angle. The resistive cut off blinder is set to the same angle as the line angle.

1.2.1 Cross-polarised Quadrilateral

A typical polarised quadrilateral characteristic, as would be used for Zones 1 and 2, and the reverse looking Zone 4 is shown below. This characteristic is constructed using two directional characteristics (hence the need for polarising), a reactance characteristic and a resistance characteristic.

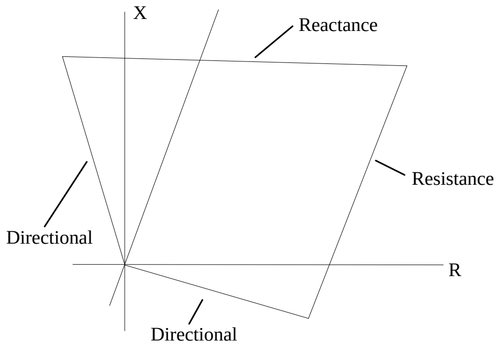


Figure 8 Forward-looking Quadrilateral Characteristic.

Because of the polarising quantities, the directional lines will exhibit a shift toward the source during unbalanced faults, ensuring operation for close up forward faults, and stability for close up reverse faults.

A self-polarised directional characteristic is given by the vector equation

$$IZ_F \equiv V$$

Dividing through by *I* gives

$$Z_F \equiv Z$$

In other words, we compare the angle of the fault impedance with the angle of the forward replica impedance, as shown below. If the two angles are within 90°, then the comparator operates.

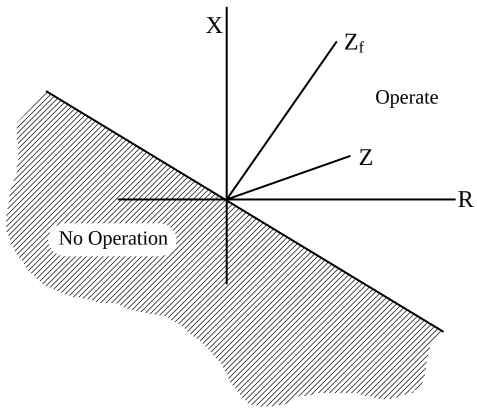


Figure 9

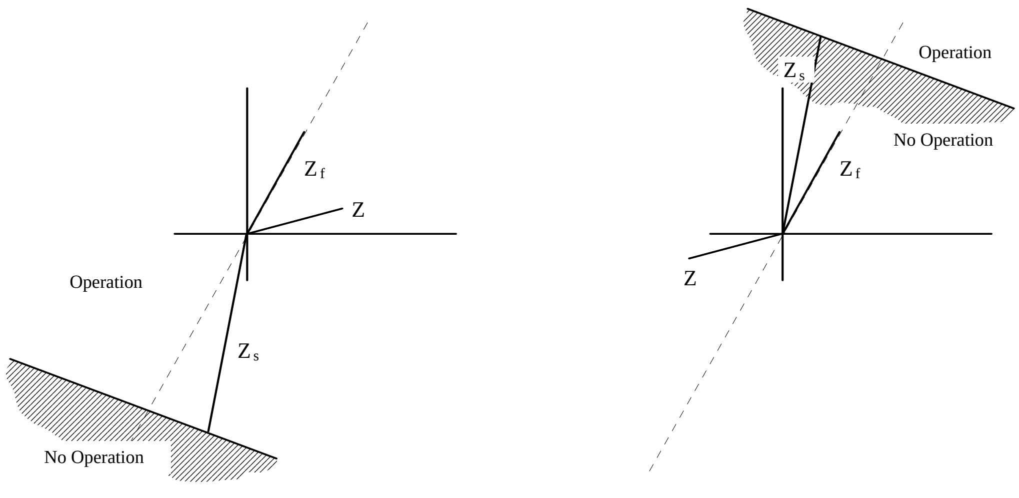
In order to obtain more reliable operation for close up fault conditions, the directional characteristic is polarised from a source other than the fault voltage, which will allow accurate determination of the fault direction for close-up faults. The vector equation for the polarised characteristic is

$$IZ_F \equiv V_P$$

The magnitude and angle of V_P will depend on a combination of factors, but for unbalanced fault conditions it will be related to the source impedance Z_S. For convenience the vector equation is

$$Z_F \equiv Z_S$$

The characteristic is shown below.



Characteristic for forward power flow   Characteristic for reverse power flow

Figure 10 Polarised Directional Characteristic

As can be seen, the characteristic moves behind the origin for forward faults, and forward of it for reverse faults. In addition, as the SIR level increases (Z_S increases relative to *Z*) the characteristic moves further from the origin. This ensures operation for close-up forward faults and stability for reverse faults.

The Reactance Characteristic is shown in Figure 11, and consists of a straight line which cuts the reactive axis at a value X_F. This requires a replica impedance Z_F of magnitude $X_F \cos \Phi_X$ and angle Φ_X. If the reactive component of the fault impedance is less than this value, the comparator operates. The angle Φ_X is normally set at about -3° to the horizontal, so that the characteristic slopes in order to ensure that with increasing resistance, the relay will not overreach beyond setting. This angle is referred to as the reactive drop angle.

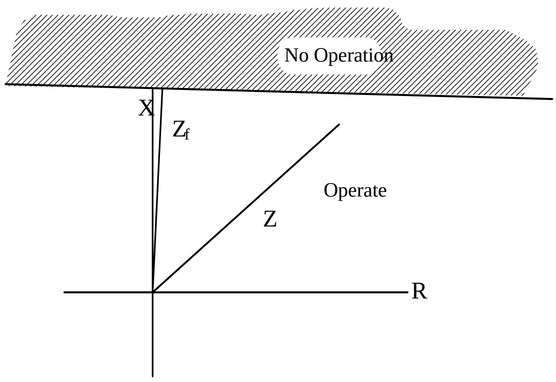


Figure 11 Reactance Characteristic

The vector equation for the reactance characteristic is

$$IZ_F - V \equiv IZ_F$$

which becomes

$$Z_F - Z \equiv Z_F.$$

If the angle between Z_F and $Z_F - Z$ is less than 90°, the comparator will operate.

The Resistive Characteristic is shown below, and is identical in nature to the reactance characteristic, except for the choice of replica impedance. This gives a characteristic which is inclined at the line angle, but crosses the resistive axis at a value R_F, giving increased resistive coverage over the entire line length. The vector equation is again

$$IZ_F - V \equiv IZ_F$$

which becomes

$$Z_F - Z \equiv Z_F.$$

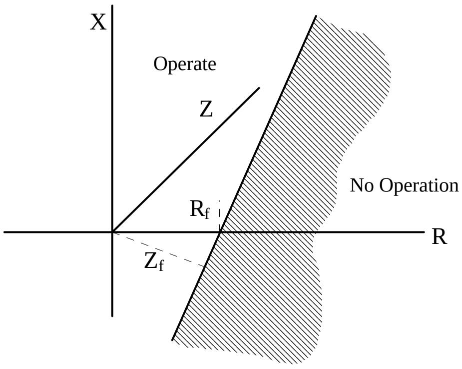
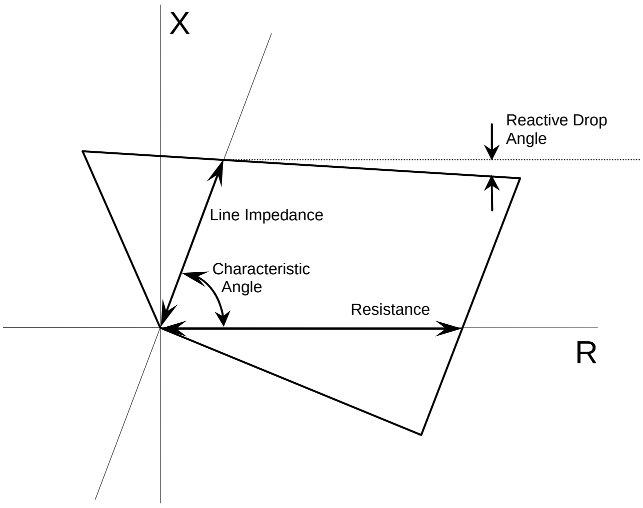


Figure 12 Resistance Characteristic

The replica impedance Z_F has magnitude $R_F \cos(\Phi_L - 90)$ and angle $\Phi_L - 90°$.

The relay is set using parameters for the line impedance, resistive reach and characteristic angle as shown below:



1.2.2 Offset Quadrilateral Characteristic

A typical offset quadrilateral characteristic is shown below. This is constructed using forward and reverse resistance characteristics, and forward and reverse reactance characteristics. This would be used for the offset zone 3 characteristic.

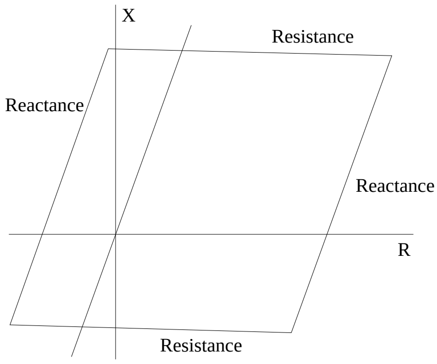


Figure 13 Typical offset quadrilateral distance characteristic

1.3 VOLTAGE MEMORY

The relay incorporates a voltage memory feature. This ensures directional security under close-in three phase fault conditions when there is little or no healthy phase voltage available for cross-polarising.

The relay monitors the positive sequence voltage of the system, and under fault conditions it adds a replica of this voltage to the polarising voltage of each comparator, suitable phase-shifted to align it with the ideal polarising voltage. 100% memory polarising is used, and is applied in conjunction with cross-polarising.

Voltage memory is applied for a maximum of 200ms, after which time the zone 1 and, where fitted, zone 4 comparators will be either inhibited from operating or have their operation latched until the fault is cleared. Zone 2 and Zone 3 continue to operate to provide backup protection.

1.4 IMPEDANCE ZONES

The relay has three zones of protection as standard; zone 1 & 2 are polarised to operate in the forward direction while zone 3 can be set as either forward, reverse or as an offset zone. If the zone 3 is set as an offset zone then the minimum reverse reach is the same as the minimum forward reach. A fourth zone is available as an option in some models. This is a reverse-looking polarised characteristic. It is commonly used as a non-tripping zone in conjunction with a blocking scheme.

The accuracy of the relay is ±5% or 0.1Ω, whichever is larger. The range for each of the impedance elements is from 0.1Ω to 250Ω, regardless of the output of the current transformers. Obviously, the settings used for 5A CTs will be smaller than those used for 1A CTs, on an equivalent circuit.

With 5A CTs the minimum advisable setting is 0.1Ω.
With 2A CTs the minimum advisable setting is 0.2 Ω.
With 1A CTs the minimum advisable setting is 0.5Ω.

For 2A and 1A, the settings can be reduced below these minimums, but the relay accuracy will be reduced.

1.5 SINGLE POLE/THREE POLE TRIPPING(406/408 only)

As the distance relay has separate comparators for each fault type there is an option for single pole tripping. The tripping actions are determined by a choice of auto-reclose settings. There are three auto-reclose actions available.
None
Internal
External
When **none** is selected then the relay will only issue a three pole trip. Regardless of fault type. With **Internal** selected the relay allows either single pole or three pole trip dependent on the auto re-close scheme settings. When **external** is selected the relay issues a single pole trip unless the three pole trip select input is energised.
Single pole tripping only operates for a Zone 1 or aided trip fault. All other trips are always three pole.

1.6 POWER SWING CHARACTERISTICS

1.6.1 Applications

A power swing is the result of a change in angle between two power systems. Each system can be subjected to disturbances such as faults, loss of load, loss of large generation, etc. which in turn, may result in excursions of generator rotor angles. Assuming a two-machine model, one generator working at local end of the line will rotate with different angular velocity with reference to the remote generator until reaching a new stability point.

This phenomenon can result in oscillating power between two ends of the protected line. At the relaying point, a distance element measures these as impedance oscillations which may encroach a set protection impedance characteristics and trip a line. In order to prevent from mal-tripping, a power swing blocking function may be implemented.

There are various methods detecting power swings encroaching impedance measuring elements. The most common practice is to plot an impedance curve which encloses tripping impedance characteristics. The relay employs two different shapes of characteristics for this purpose i.e. polygonal and circular.

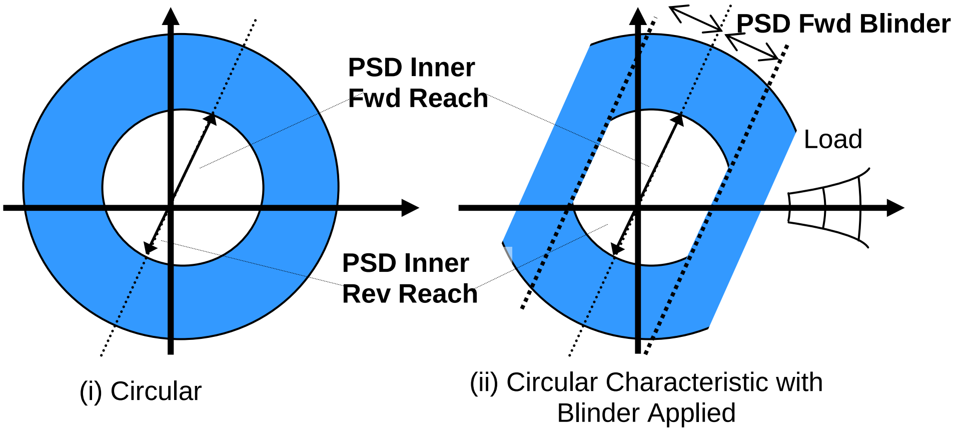


Figure 14 Power Swing Detection Zones

It is possible to apply forward and reverse resistance blinders to the circular characteristic, to separate it from the load impedance if necessary. The user can enable or disable these blinders to achieve the best-tailored shape with reference to load and tripping zones.

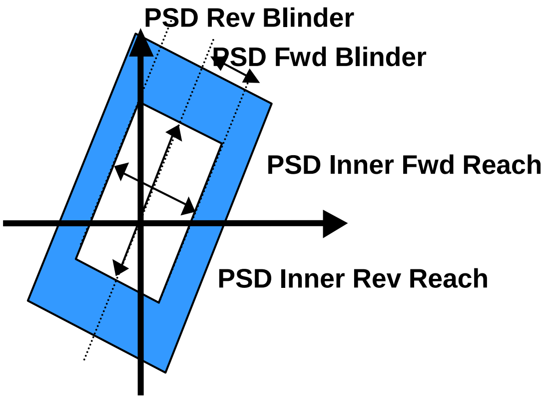


Figure 15
Rectangular Power Swing Detection Zones

The rectangular power swing detection characteristic (see Figure 15) is designed for use with quadrilateral characteristics – this is simply set in terms of forward and reverse reach (giving the reactive reach) and forward and reverse blinders (giving the resistive reach)

1.6.2 Description of Operation

1.6.2.1 Power Swing Detection.

The relay uses 2 zones of protection to detect a power swing condition, defined as the inner and the outer zones. Each of these zones consists of a phase to phase fault comparator applied to the Yellow-Blue phase. Upon operation of the outer zone, a timer is started. If the time between the operation of the outer zone and the inner zone is greater than the relay PSD Transit time, the relay will raise the power swing alarm.

The reach of the power swing detection zones are set in terms of impedance for the inner reach. The outer reach is then set by a multiplying factor, usually 1.5 times the inner reach.

$Z_{PSB(Outer)} = k.\ Z_{PSB(Inner)}$

The inner reach should be either equal to or just above the furthest reach setting of the relay, so that all zones of the relay are contained completely within the inner power swing detection zone. A check should also be made on the outer reach with reference to the maximum feeder load. The outer reach should not encroach upon the load condition under any circumstances. This check is best carried out by inspection – if necessary sketching out the characterstics to ensure correct co-ordination. The blinders can be applied to prevent load encroachment if this is a possible problem.

1.6.2.2 Power Swing Blocking.

Once a power swing has been detected it is often desirable to prevent operation of the relay during a power swing condition. The relay can be set to block operation of any combination of protection zones within the relay.

Faults can occur during power oscillations, so it is necessary to provide a mean of distinguishing between a power swing and a genuine fault condition. Because a power swing condition is always a balanced three-phase condition, the relay can use the level of negative phase sequence current on the system to determine between these two conditions.
Under balanced conditions, an untransposed transmission system can produce negative phase sequence currents of up to 14% of positive phase sequence current. Under fault conditions, however, the level of negative sequence current will be much higher. Thus, when the negative sequence current exceeds 25% of the positive sequence current, the power swing blocking will be removed, allowing the relay to operate.

1.6.3 Settings.

Power Swing detector	**Enable**/ Disable
PSD Zone Blocking	Zone 1 **Zone 2 Zone 3 Zone 4**
PSD Shape	**Circular** / Rectangular
PSD Blinders	Enable / **Disable**
Inner Forward Impedance	0.1-250 **(24)**
Inner Reverse Impedance	0.1-250 **(8)**
Inner Blinder Forward	0.1-250 **(16)**
Inner Blinder Reverse	0.1-250 **(16)**
Multiple (Outer Impedance)	1.05-2.50 x **(1.5)**
PS Timer	0-1000ms **(50)**

Status Inputs: N/A
Relay Outputs: **POWER SWING ALARM**

1.7 VOLTAGE TRANSFORMER SUPERVISION (VTS)

1.7.1 Applications.

A protection voltage transformer (V.T.) would normally be connected to the protection relay terminals via a fuse or a miniature circuit breaker. Operation of these would remove the voltage source for one or more phases. With load current flowing in the circuit the measured impedance (V/I) would be zero, thus it would appear to the relay that a fault had occurred, possibly causing a healthy system to be tripped out. The V.T.S. is used to identify this condition and in some cases prevent tripping by blocking the operation of one or more of the zones of protection.

1.7.2 Description of Operation.

1.7.2.1 Residual Current and Voltage

The following description applies if the VTS Input Source is set to Residual V and I.
In the event that one or two phases of the VT are lost, a residual voltage will be developed across the relay terminals, without a corresponding residual current being present. The relay incorporates a zero sequence overvoltage detector and a zero sequence undercurrent detector. The simultaneous operation of both of these detectors indicates a fuse failure. This generates a signal that gives an alarm and may be used to inhibit the distance protection (the relay may be set to ALARM or ALARM & INHIBIT).
If, during this voltage transformer failure, an earth fault occurs, the zero sequence current will increase which will then remove the VTS blocking and allow the relay to trip (the indication may be incorrect due to the relay not having all the voltage inputs).
If the VTS condition remains on the system for a time longer than the “VTS Latch PU Delay” time setting found in the Reylogic Configuration (5 seconds default), then the VTS condition will latch in. When latched the VTS blocking will not be removed by the presence of zero sequence current and will only be removed when the voltages are restored..
If a phase fault occurs during the voltage transformer failure there will be no zero sequence current. Thus, if a phase fault occurs during a VT failure, the zero sequence undercurrent detector will not reset itself and the relay will remain blocked.

For this reason there are two settings for the VTS mode:

VTS MODE:	ALARM ONLY / ALARM AND INHIBIT
VTS PHASE FAULT INHIBIT:	ENABLED / DISABLED

With the relay in ALARM ONLY mode, the relay will raise an alarm, when it detects a VT failure, but will not prevent the relay from tripping.
With the VTS mode set to ALARM AND INHIBIT the relay will inhibit the *earth fault elements* from causing a trip.

If VTS PHASE FAULT INHIBIT is ENABLED, the relay will remain stable during a two phase VT failure, but will not operate if a phase fault occurs while the VTS is picked-up.
If VTS PHASE FAULT INHIBIT is DISABLED, the relay will trip if the phase fault elements pick-up, regardless of whether the relay is set to ALARM AND INHIBIT or ALARM ONLY. This means that if two phases of the VT fail, the relay will trip, regardless of whether the relay is set to ALARM & INHIBIT or ALARM ONLY.

1.7.2.2 NPS Current and Voltage

Alternatively, negative phase sequence current and voltage can be used to detect the loss of a VT fuse. The operation is similar to that of the residual operation described above except that NPS current and voltage mismatch is used to detect the operation of a fuse. The main advantage of the NPS system is that during a phase to phase fault, NPS current is generated which will cause the VTS trip inhibit to be removed such that once again the relay can trip correctly for the fault. For this reason, if NPS is selected, the Phase Fault Inhibit should always be set to Enabled.
The NPS settings are scaled such that they are equivalent to the Residual settings i.e. the voltage setting $V_{op} = 3V_0$ for Residual or $3V_2$ for NPS.

1.7.3 General Operation

This arrangement is relatively simple and readily lends itself to application assessment in terms of its effect, if any, on the earth fault protection coverage. The minimum time response is arranged to be approximately 2/3 of the minimum operating time of the zone 1 to ensure an adequate time margin for blocking.

The inhibit signal is available immediately whereas the alarm signal has a time delay, which can be set from 0-60000ms to prevent nuisance alarms occurring during circuit breaker switching.

The above principle is recommended in applications for the transmission and sub-transmission system where the maximum residual current is 5% or less of the load current.

VTS ALARM contacts can be selected from the OUTPUT MENU.

In the case of loss of all three-phases of the VT, a contact should be taken from the VT MCB, and connected to the VT CCTS ISOLATED Status Input of the relay. This will energise the Status Input when the VT MCB trips.

1.7.4 Settings.

VT Supervision	Disable, **Enable**
VTS Mode	Alarm Only / **Alarm & Inhibit**
VTS Latched Operation	Disable, **Enable**
VTS Phase Fault Inhibit	Disable, **Enable**
VTS Input Source	**Res V&I**/NPS V&I
VTS Ires Level	0.05..2 **(0.3 X In)**
VTS Vres Level	1..100 **(20)**
VTS Latch PU delay	0..60000 **(5000)**
VTS Alarm delay	0..60000 **(100)**

Status Inputs: **VT CCTS ISOLATED**
Relay Outputs: **VTS ALARM**

1.8 SWITCH ON TO FAULT

1.8.1 Applications

The Zone 1 instantaneous elements of the relay distance protection are directional and rely upon polarisation from either the faulted phase and/or a healthy phase. When closing on to a bolted fault where all three-phase voltages are extremely low, the Zone 1 instantaneous elements may not operate. Time delayed operation would occur from either the zone 3 offset element or the high set overcurrent. This is not acceptable and special precautions are necessary to ensure high-speed clearance for this condition.

The Switch-On-To-Fault feature ensures that for a short period of time after a CB is closed, the offset Zone 3 elements and the overcurrent elements are allowed to trip at high speed.

1.8.2 Description of Operation

The mode of Switch-on-to-fault logic required can be selected as either AC SOTF or DC SOTF. AC SOTF utilises three-phase pole dead logic, based on measured current and voltage (i.e. AC quantities), to determine the circuit breaker status. The DC SOTF uses an auxiliary contact (i.e. a DC quantity) on the CB closing handle or circuit breaker to determine when the CB is being closed.

The SOTF output is automatically configured to operate the three-phase trip output. The SOTF output can be mapped to one of the LED's and to any of the output contacts to give an alarm.

1.8.2.1 AC SOTF

The AC SOTF logic monitors the line current and voltage, and so it can only be used where the instrument transformers are placed on the line side of the circuit breaker. When the relay detects that the voltage and current are dead (i.e. voltage below 20% of the nominal, current below the
SOTF O/C Operate Level which can be set from 0.3 – 4.00xIn) on all three phases, this will start the ACSOTFTIMER. This timer has a settable delay on pickup (the AC SOTF Pickup Delay settable from 0-60000ms) which is used to ensure that the circuit breaker has been switched out for maintenance.

This delay is set by default to 10,000ms, so the breaker must have been open for at least ten seconds before the SOTF logic is initiated. Once the logic has been initiated the relay can cause a SOTF trip in one of two ways.

Firstly, after this time delay, if the voltage on one or more phases increases above 20% of the nominal voltage, the ACSOTFTIMER will reset after a fixed time delay of 200ms. This gives a fixed 200ms window of operation, during which the relay will allow the Zone 3 element to trip instantaneously.

Secondly, if the relay detects the current increasing above the SOTF O/C Operate Level without the voltage increasing above 20% the relay will allow the relay to trip on SOTF. The SOTFFLSTIMER puts an inhibit on the tripping for 25ms to ensure that there is no race condition between the voltage and current reaching the "live" levels. Also, when the voltage on all three phases rises above 20% the SOTF Overcurrent tripping criteria is removed instantaneously. This prevents the relay from tripping for high line charging currents. This overcurrent criterion is essential when a uni-directional Zone 3 is being used (i.e. No offset), because in this case the zone 3 element will suffer from the same difficulties as Zones 1 and 2.

1.8.2.2 DC SOTF

The DC SOTF logic works in much the same way as the AC SOTF, but has been specifically designed for situations where the VTs are mounted on the busbar side of the line circuit breaker. This means that the voltage input to the relay cannot be used to supervise the position of the breaker. The difference is the way in which the logic is initiated.
Two options are available depending on the particular relay model, to suit the source of the initiating signal. Manual Close DC SOTF uses a contact on the CB closing switch. DC AUX SOTF uses an auxiliary contact on the circuit breaker.
A Status Input defined as 'DC SOTF Manual Close' is connected to the Manual Close handle of the circuit breaker. This Status Input is triggered on the rising edge of the Manual Close signal, and for a settable time, 400 ms default, after this signal the relay will allow instantaneous tripping of the Zone 3 element. A longer time delay is used for the DC SOTF logic (400ms rather than 200ms) because it needs to incorporate the closing time for the circuit breaker, also.
The status input 'Start Aux DC SOTF' is connected to a CB auxiliary contact to signal CB closing. This function operates similarly to the Manual Close DC SOTF except that the CB aux contact must indicate that the CB is open for the 'Min Aux DC SOTF Dead Time' (default -= 10secs). This assures that the SOTF is not in operation during reloses during an auto recl;ose sequence and only during manual closing operations.

1.8.3 Settings

The settings menu for the SOTF function is contained in the AUX PROTECTION Menu and contains the following settings:

Switch On To Fault	Disable / **Enable**
SOTF Mode	**AC SOTF** / DC SOTF
SOTF O/C Operate Level	0.3..4 **(0.3xIn)**
AC SOTF Pickup Delay	0..60000ms **(10000)**
Min AUX DC SOTF Dead Time	0..60000ms **(10000)**
DC SOTF Active Timer	0..60000ms (**400**)

Status Inputs: **DC SOTF MANUAL CLOSE**
START AUX DC SOTF

Relay Outputs: **SOTF OPERATED**

2 AUXILARY FUNCTIONS

2.1 FAULT LOCATOR

2.1.1 Applications

The fault locator gives the operator an indication of the location of the fault. This information can be presented in three different formats which are a percentage of line length, or the distance in either miles or kilometres. This is selected in the menu function.

2.1.2 Description of Operation

The fault locator is programmed with the Positive Sequence Line Impedance. It is important that this value must be for the total length of the feeder and not the Zone 1 reach. The values must be in terms of secondary impedance. The secondary impedance per unit must also be entered. For example a 20km line may have a secondary impedance of 15 ohms. This would give a unit value of 0.75 ohms per kilometre using these values the fault locator would accurately measure the fault position.

The fault locator if enabled will measure for any general trip condition. While the fault is being calculated the relay fascia function keys are disabled for a few seconds.

2.1.3 Relay Settings

Fault Locator	Disable / **Enable**
Pos Seq Line Impedance	0.1 .. 250 **(10)**
Sec'y Z+ per unit distance	0.001..5 **(0.5**)
Display Distance as	**Percent** / Miles / Kilometres

Status Inputs: N/A
Relay Outputs: N/A

2.2 HIGH SET OVERCURRENT

2.2.1 Description of Operation

This is simply a DTL overcurrent element which works in parallel with the distance protection. Operation of this overcurrent element will result in a main distance trip.

2.2.2 Relay Settings

High Set	Disable / **Enable**
HS Level	0.1-35 x In **(4x)**
HS Time Delay	0..60000ms **(0)**

Status Inputs: N/A
Relay Outputs: **HIGH SET**

7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

Pre release

2010/02	Document reformat due to rebrand

Software Revision History

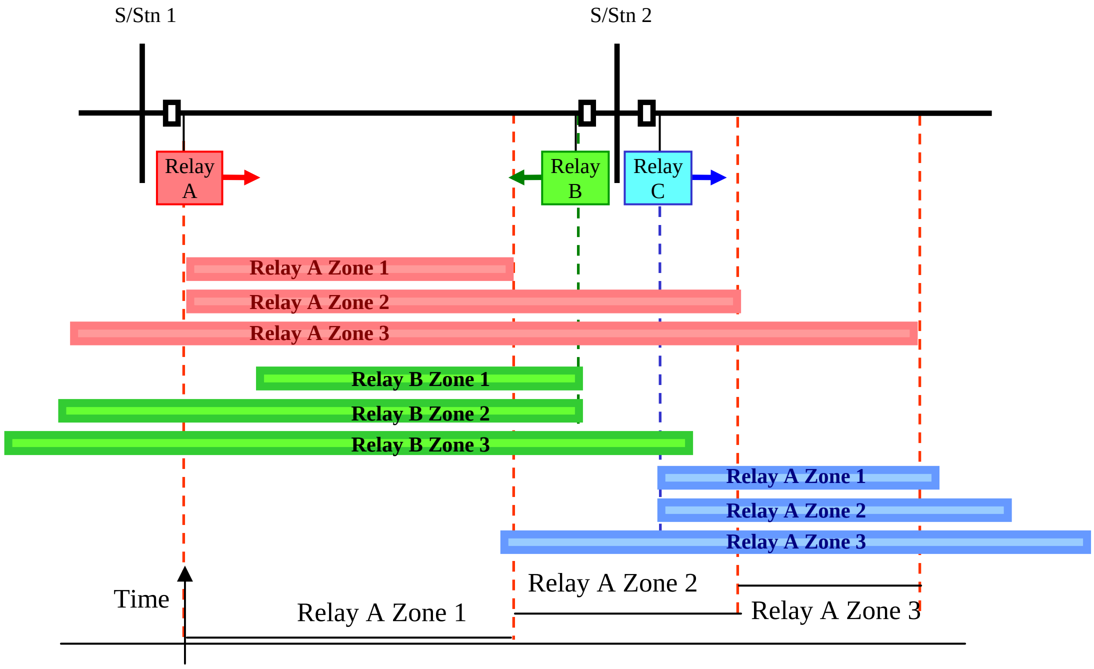
Contents

1. Basic Protection Schemes

1.1 Time Stepped Distance

1.1.1 Scheme Operation

A TIME-STEPPED DISTANCE scheme is normally applied when there is no signalling available between relays. Generally, the Zone 1 elements are set to operate for faults up to 80% of the line length. The Zone 2 elements operate up to 120% of the line length after a time delay. The Zone 3 elements are set with a longer reach than the Zone 2 elements, and often have a degree of reverse reach (i.e. an offset characteristic) to provide a further level of back up protection. The Zone 3 time delay is set to be longer than the Zone 2 time delay.



The disadvantage of such a scheme is that faults in the last 20% of the line are cleared after the Zone 2 time delay. This may be acceptable for lower voltage distribution systems, but for important circuits or higher voltage systems additional schemes are available to improve the tripping of the relay.

1.1.1.1 Settings

Distance Scheme: TIME-STEPPED

Status Inputs: N/A

Relay Outputs: N/A

1.2 Schemes Incorporating a Signalling Channel

Where a signalling channel is available between ends, the coverage of the relays can be improved. When these Protection Schemes are used, the Zone 1, 2 and 3 are arranged to trip as in the time stepped distance scheme. In addition to this, the relay is also capable of carrying out what is known as a “Carrier Aided Trip”, where the time delay on one of the Zones is removed when the conditions at the remote end, as indicated by the signalling channel meet certain criteria.

The distance protection signalling schemes use the relay outputs *Signal Send 1* and status input *Signal Received 1* for the signalling channel. It is possible to configure these channels with delay using the settings SS pickup, SS Dropoff and SR Dropoff.

1.2.1 Permissive Underreach

1.2.1.1 Scheme Operation

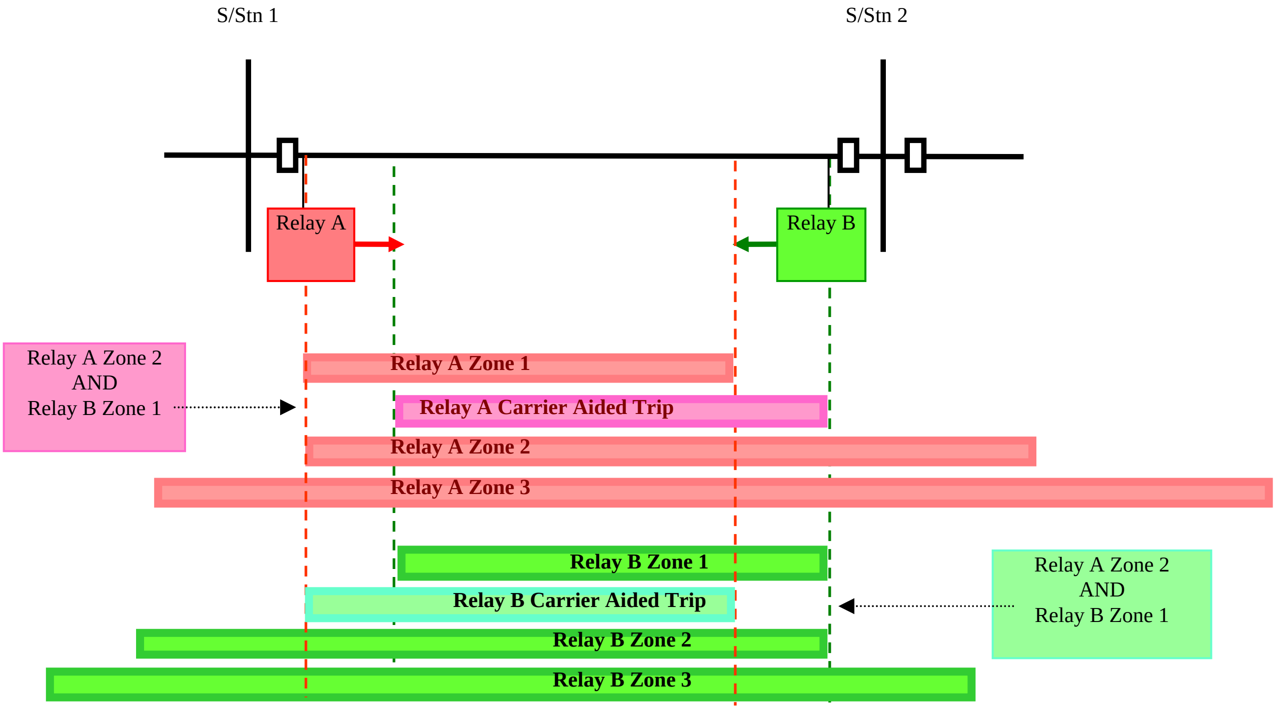
Typically (as for the time stepped scheme) the Zone 1 is set to 80% of the line length, Zone 2 to 120% of the line length and Zone 3 as delayed back up protection to cover at least the longest adjacent line.

The fault must be in the zone between the two relays (i.e. on the line section) if;

Zone 1 element operates, or

Remote end Zone 1 operates AND local Zone 2 element operates.

This is shown in the diagram below:



The relay is arranged to send a signal when its Zone 1 picks up.

The relay will trip instantaneously for a Zone 1 fault. If a signal is received from the remote end, the time delay will be removed from the Zone 2 element, allowing it to trip instantaneously. The name of the scheme comes from the fact that a Permissive signal is being sent by the Underreaching Zone 1.

Where the signalling equipment has an output which indicates that the signalling channel is out of service, this can be connected to a Status Input called *Carrier Recv Guard*. On energisation of this status input the relay will revert to a time stepped distance scheme.

In this scheme, only a single signalling channel is required for two-way signalling, since if the zone 1 elements at both operate, the permissive signal will not be required (since both ends will trip instantaneously in Zone 1).

The scheme also incorporates an *Unstabilise Relay* status input which can be used for intertripping. Energisation of this status input will initiate a signal send

1.2.1.2 Settings

Distance Scheme	**PUR**
SS Pickup	0..60000 **(0ms)**
SS Dropoff	0..60000 **(1ms)**
SR Dropoff	0..60000 **(1ms)**

Status Inputs: UNSTABILISE RELAY, CARRIER RECV GUARD

Relay Outputs: AIDED TRIP

1.2.2 Permissive Overreach Zone 1 – POR1.

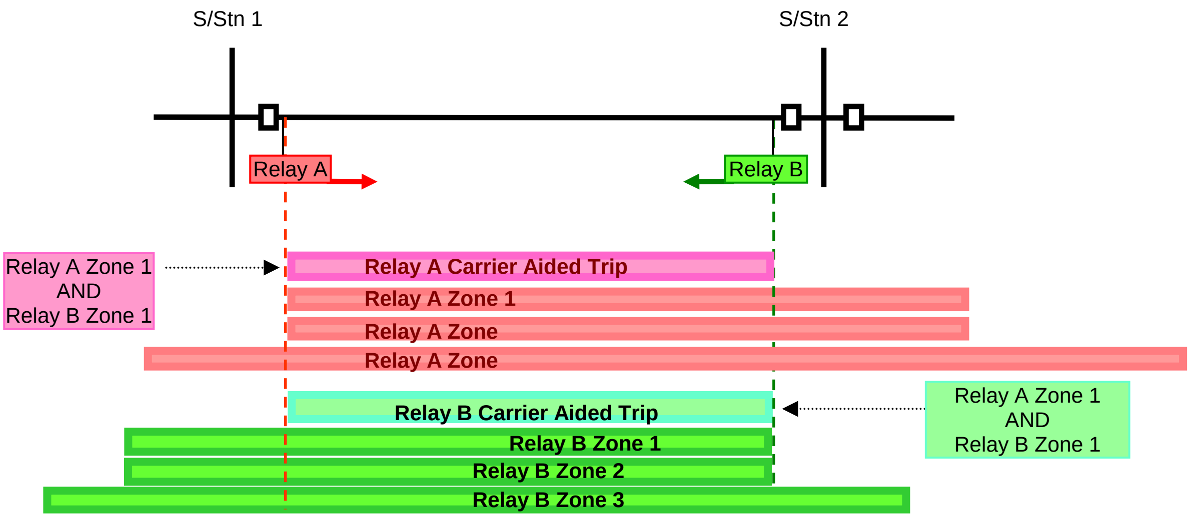
1.2.2.1 Scheme Operation

This scheme differs from the other relay schemes, in that it requires that the Zone 1 element to be set with a time delay. Typically the Zone 1 is set to 120% of the line length, Zone 2 to 120% of the line length and Zone 3 as delayed back up protection to cover at least the longest adjacent line. The Zone 1 time delay is usually set the same as the Zone 2 time delay.

The Zone 1 elements are arranged to overreach and the relay is arranged to send a Permissive signal send when any Overreaching Zone 1 element operates. When a signal is received from the remote end the relay will remove the Zone 1 time delay allowing the relays at both ends of the line to trip after a small time delay for an in-zone fault. Relay operation can be seen the diagram below;

Where the signalling equipment has an output which indicates that the signalling channel is out of service, this can be connected to a Status Input called *Carrier Recv Guard*. On energisation of this status input the relay will revert to a time stepped distance scheme.

Since this scheme does not provide any instantaneous protection zone it is rarely used. POR-2 provides a similar but more comprehensive scheme and is the preferred scheme. This scheme is only included in the relay for compatibility with older relays. CB Echo, Current Reversal Guard and Weak Infeed are equally applicable to POR-1 and POR-2, for a description of these features see the POR-2 section of this document.



1.2.2.2 Settings

Distance Scheme	**POR1**
SS Pickup	0..60000 **(0ms)**
SS Dropoff	0..60000 **(1ms)**
SR Dropoff	0..60000 **(1ms)**

Status Inputs:CARRIER RECV GUARD

Relay Outputs: AIDED TRIP

1.2.3 Permissive Overreach Zone 2 – POR2.

1.2.3.1 Scheme Operation

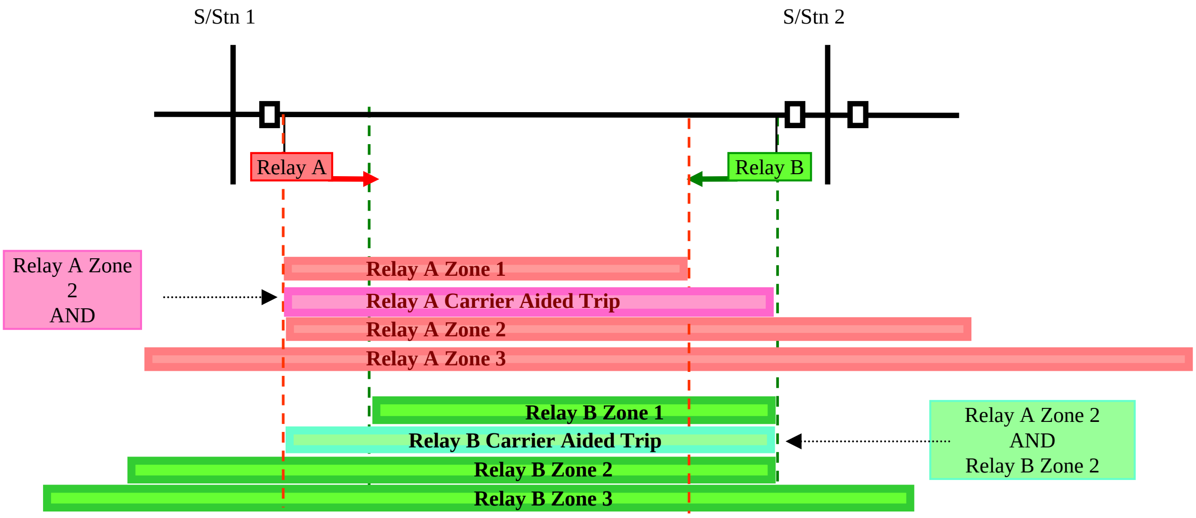
Typically (as for the time stepped and PUR schemes) the Zone 1 is set to 80% of the line length, Zone 2 to 120% of the line length and Zone 3 as delayed back up protection to cover at least the longest adjacent line. Zone 1 has no time delay, Zone 2 has a time delay, and the Zone 3 has a larger time delay.

The fault must be in the region between the two relays (i.e. on the line section) if;

Zone 1 element operates, or

Remote end Zone 2 operates AND local Zone 2 element operates.

This is shown in the diagram below:



The relay is arranged to send a signal when its Zone 2 picks up.

The relay will trip instantaneously for a Zone 1 fault. If a signal is received from the remote end, the time delay will be removed from the Zone 2 element, allowing it to trip instantaneously. The name of the scheme comes from the fact that a Permissive signal is being sent by the Overreaching Zone 2

This scheme may be used if the Zone 1 reach does not give sufficient resistive coverage, and may be useful on short lines. Note that when using POR 2, two signalling channels must be available (one in each direction) since the Zone 2 elements which initiate the signal send will both operate for a fault on the line section.

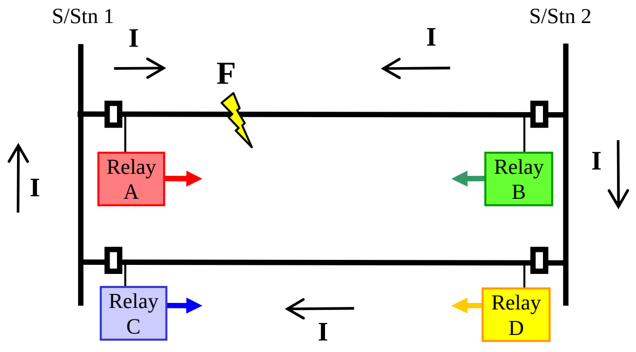
Where the signalling equipment has an output which indicates that the signalling channel is out of service, this can be connected to a Status Input called *Carrier Recv Guard*. On energisation of this status input the relay will revert to a time stepped distance scheme.

1.2.3.2 Circuit Breaker Echo.

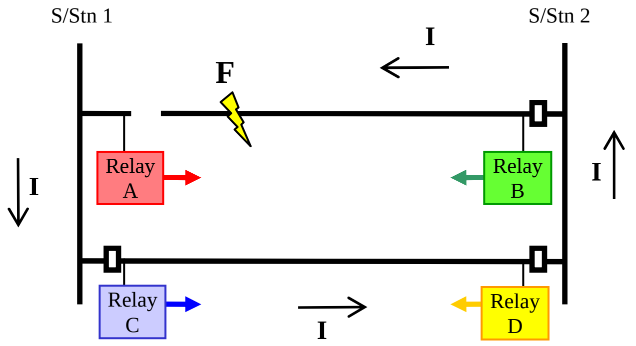
With the circuit breaker at one end of the line open, there can be no permissive signal from the remote end relay. If a fault occurs near the open circuit breaker (i.e. outside the zone 1 of the remote end relay) this would normally be cleared after the Zone 2 time delay. However, where an overreaching zone is used to provide the permissive signal, the CB Echo feature can accelerate the tripping.
If a permissive signal is received from the remote end AND the local Circuit breaker is open, the relay will send (or “echo”) a signal back to the remote end.
Thus operation of one of the relay Zone 2 elements will initiate a signal send of duration set as *POR CB Echo Pulse Width*. On receipt of a signal from the remote end, if the local circuit breaker is open, the relay will echo the signal back to the remote end relay. This will remove the time delay from the Zone 2 element, allowing tripping after a short time delay.
It should be noted that when the remote end trips, the CB open condition will drive this relay into a CB Echo condition also due to the Signal Receive being present. This is the reason that the Echo is sent as a short duration pulse only. Otherwise the relays will hold each other in a permanent echo condition.

1.2.3.3 Current Reversal Guard.

Additional logic is required in cases where the reach of Zone 2 elements is set to 150% or more of the line length and a fault has a current source at both ends of the protected line. Where parallel feeders are used, there is a danger when a circuit breaker is opened a race condition can arise between the drop-off of the signal send line and the pick-up of the local distance elements. Consider a fault at point F on the parallel line system shown below:



Point F is within the Zone 2 forward reach of relay D, so relay D will send a permissive signal to the remote end, relay C. Relay A will detect the fault in Zone 1, and trip instantaneously.
The instantaneous Zone 2 element of Relay A will operate, and send a signal to Relay B. Relay B will see the fault in Zone 2, and when it receives the signal from end A will perform a “Carrier Aided Trip” after a short time delay. Thus, Relay A will trip before Relay B, and when it does, direction of current in the healthy feeder (CD) will reverse.



The Relay D Zone 2 element, which previously operated to send a signal to Relay C will reset when breaker A opens. But the signal receive may remain high at end C due to the propagation delay in the signalling channel. The Zone 2 element of relay C will then pick-up for the fault at F when CB A opens. There is then a race condition at relay C between the drop off of the signal receive from Relay D and the pick-up of Relay C Zone 2 element. IF the signal receive element is still present in conjunction with the Zone 2 element, then Relay C will also carry out a “Carrier Aided Trip”, for a fault outside it’s intended zone of protection.
Thus, if the local Circuit Breaker is closed, and a relay has received a permissive signal, but the fault is in the reverse direction, there’s a danger of a current reversal trip when current reverses. Thus, a time delay, *POR Current Rev Reset* is introduced for which the permissive signal from relay C will be ignored by the carrier aided scheme following the resetting of a reverse fault detection.

1.2.3.4 Weak End Infeed.

If one end of the line has little or no source of fault current, the relay may not see enough fault current to cause a trip or accelerate the tripping at the remote end. Weak Infeed logic is used to detect this condition. Weak Infeed can be Enabled and Disabled to switch on the Alarm and the scheme signalling and an independent enable/disable setting is used to allow the issue of a local trip for a Weak Infeed detection. If the relay has not detected a fault in either the forward or reverse direction, and a permissive signal is received from the remote end, AND there is a residual voltage greater than the WI Voltage Level AND the local CB is closed, the relay will alarm a “Weak Infeed” condition and send a permissive signal to the remote end allowing the remote end to carry out a carrier aided trip.

1.2.3.5 Settings

Distance Scheme	**POR2**
POR Weak Infeed	**DISABLED**
POR Weak Infeed Trip	**DISABLED**
WI Voltage Level	5-85v **(54v)**
POR CB Echo Pulse Width	0-60000ms **(250ms)**
POR Current Rev Reset	0-60000ms **(200ms)**

WI Sig Recv PU Delay	0..60000 **(0ms)**
SS Pickup	0..60000 **(0ms)**
SS Dropoff	0..60000 **(1ms)**
SR Dropoff	0..60000 **(1ms)**

Status Inputs:
SIGNAL RECEIVE 1
CARRIER RECV GUARD
Relay Outputs:
AIDED TRIP
SIGNAL SEND 1
SIGNAL RECEIVE 1
POR WEAK INFEED

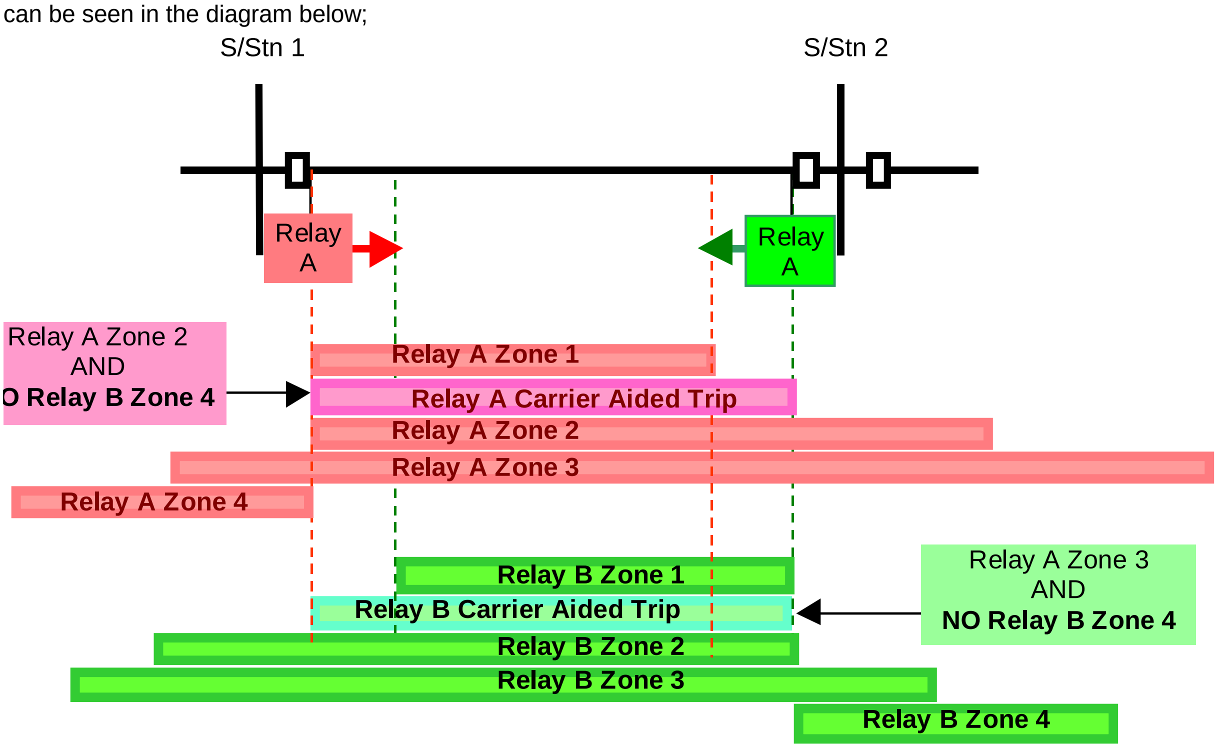
1.2.4 Blocked Overreach

1.2.4.1 Scheme Operation

This requires a reverse-looking element to allow the sending of a blocking signal.

The fault must be in the region between the two relays (i.e. on the line section) if;

The overreaching Zone 2 element operates and a reverse looking zone at the remote end has **not** operated. This can be seen in the diagram below;



When the Zone 2 instantaneous element picks up, the relay waits for a “blocking signal” to be received. If no blocking signal is received during a set time delay (known as the Permissive Trip Time) the relay will carry out a “Carrier Aided Trip”. If, during this time delay, a blocking signal is received, the Zone 2 time delay will remain in place, and the relay will carry out a Zone 2 trip after the Zone 2 Time delay.

If the fault is in the last section of the line (i.e. outside the Zone 1 reach) the Zone 2 element will operate, but the remote end relay Zone 4 element not see the fault. Thus, no blocking signal will be sent, and the relay will carry out a “Carrier Aided Trip” after the *Permissive Trip Time*.

Obviously when applying this scheme the reverse reach of the Zone 4 element must be further than the overreach of the remote end Zone 2 element.

Where the signalling equipment has an output which indicates that the signalling channel is out of service, this can be connected to a Status Input called *Carrier Recv Guard*. On energisation of this status input the relay will revert to a time stepped distance scheme.

The scheme also incorporates an *Unstabilise Relay* status input which can be used for intertripping. Energisation of this status input will initiate a signal send.

1.2.4.2 Settings

Distance Scheme	BOR
Permissive Trip Time	0..60000 **(1ms)**
SS Pickup	0..60000 **(0ms)**
SS Dropoff	0..60000 **(1ms)**
SR Dropoff	0..60000 **(1ms)**

Status Inputs: BLOCK MODE INHIBIT, CARRIER RECV GUARD, UNSTABILISE RELAY

Relay Outputs: N/A

7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

Contents

1 Menu Settings

System Configuration Menu

Setting	Range	Default
Active Group	1, 2 … 8	1
CVT in use	YES, NO	NO
Autoreclose Option	(NONE… External)	NONE
CB Aux Contacts	Type A … Type B	TYPE A
CT Ratio	0, 100, … 5000: 1,2,5	2000:1
VT Ratio	1000, 1100, … 10000, 11000, … 600000: 90, 95, … 130	132000:110
Alternate Setting Group	1, 2 … 8	1
View/Edit Group	1, 2 … 8	1
Default Screens Timer	Off..60	60
Date		1/ 1/1980
Time		00:00:00
Backlight timer	Off..60	5
Change Password	AAAA … ZZZZ	NONE
Relay Identifier	Up to 16 characters	OHMEGA-408-50

Distance Protection Menu

Setting	Range	Default
Distance Scheme	Time Stepped, PUR, POR1, POR2, BOR	Time Stepped
CT Secondary	1, 2, 5	1A
Line Angle	0, 5, … 90 Deg	75 Deg
EF Comp Z0/Z1 ratio	0, 0.01, … 10.00	2.50
EF Comp Z0 angle	0, 5, … 355 Deg	75 Deg
POR Weak Infeed	Enabled, Disabled	Enabled
POR Weak Infeed Trip	Enabled, Disabled	Enabled
WI Voltage Level	5, 5.5, …85 v	54.0 v
Quad auto Load Comp	Disable … Enable	Disable
Reactive Drop Angle	-20 … 20	-3 Deg
Z1 Phase Fault	Enabled, Disabled	Enabled
Z1 PF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z1 PF Time Delay	0, 10, … 10000ms	0ms
Z1 Earth Fault	Enabled, Disabled	Enabled
Z1 EF Type	Fwd Mho … Fwd Quad	Fwd Mho
Z1 EF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z1 EF Resistance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	4.00 Ohm
Z1 EF Time Delay	0, 10, … 10000ms	0ms
Z2 Phase Fault	Enabled, Disabled	Enabled
Z2 PF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	16.00 Ohm
Z2 PF Time Delay	0, 10, … 10000ms	1000ms
Z2 Earth Fault	Enabled, Disabled	Enabled
Z2 EF Type	Fwd Mho … Fwd Quad	Fwd Mho
Z2 EF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	16.00 Ohm
Z2 EF Resistance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z2 EF Time Delay	0, 10, … 10000ms	1000ms
Z3 Phase Fault	Enabled, Disabled	Enabled
Z3 PF Type	Fwd Mho, Rev Mho, Offset Mho, Offset Shaped	Offset Mho

Z3 PF Impedance (Fwd)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	24.00 Ohm
Z3 PF Impedance (Rev)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z3 PF Shape Factor 1	0, 0.01, … 1.00	1.00
Z3 PF Shape Factor 2	0, 0.01, … 1.00	1.00
Z3 PF Time Delay	0, 10, … 10000ms	2000ms
Z3 Earth Fault	Enabled, Disabled	Enabled
Z3 EF Type	Fwd Mho, Rev Mho, Offset Mho, Fwd Quad, Rev Quad, Offset Quad	Offset Mho
Z3 EF Impedance (Fwd)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	24.00 Ohm
Z3 EF Resistance (Fwd)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	12.00Ohm
Z3 EF Impedance (Rev)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z3 EF Resistance (Rev)	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	4.00 Ohm
Z3 EF Time Delay	0, 10, … 10000ms	2000ms
Direct Zone 4 Trip	ENABLE, DISABLE	DISABLE
Z4 Phase Fault	Enabled, Disabled	Enabled
Z4 PF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z4 PF Time Delay	0, 10, … 10000ms	0ms
Z4 Earth Fault	Enabled, Disabled	Enabled
Z4 EF Type	Rev Mho, Rev Quad	Rev Mho
Z4 EF Impedance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	8.00 Ohm
Z4 EF Resistance	0.5, 0.51, … 10.0, 10.1, 10.2, … 100, 101, … 250 Ω	4.00 Ohm
Z4 EF Time Delay	0, 10, … 10000ms	0ms

Power Swing Menu

Setting	Range	Default
Power Swing Detector	ENABLE, DISABLE	ENABLE
PSD Zone blocking	Zone 1 | Zone 2 | Zone 3 | Zone 4	Zone2-4
PSD Shape	CIRCULAR, RECTANGULAR	CIRCULAR
PSD Blinders	ENABLE, DISABLE	DISABLE
PSD Inner Fwd Impedance	0.1, 0.2, … 250.0Ω	24.0 Ohm
PSD Inner Rev Impedance	0.1, 0.2, … 250.0Ω	8.0 Ohm
PSD Inner Fwd Blinder	0.1, 0.2, … 250.0Ω	16.0 Ohm
PSD Inner Rev Blinder	0.1, 0.2, … 250.0Ω	16.0 Ohm
PSD Outer Multiplier	1.05, 1.06, … 2.00	1.50x
PSD Transit Time	0, 5, … 1000ms	50ms

Auxiliary Protection Menu

Setting	Range	Default
High Set	(Disabled..Enabled)	Enabled
HS Level	(0.1..35)	4 x In
HS Time Delay	(0..1000)	0ms
Thermal Overload Prot'n	(Disabled..Enabled)	ENABLED
Thermal Overload Tripping	(Disabled..Enabled)	ENABLED
TOL Operating Mode	SINGLE POLE … THREE POLE	Three Pole
TOL Overload Setting	(0.5 … 2)	1.05 x In

TOL Time Constant	(1 … 1000)	10 min
TOL Hot/Cold Ratio	(Disabled..Enabled)	DISABLED
TOL Hot/Cold Ratio Setting	(5 … 100)	50 %
TOL Capacity Alarm	(Disabled..Enabled)	DISABLED
TOL Capacity Level	(50 … 100)	50 %
TOL load Increase Alarm	(Disabled..Enabled)	DISABLED
TOL load Inc. Alarm Level	(50 … 100)	50 %
TOL Overload Alarm	(Disabled..Enabled)	DISABLED
SOTF	(Disabled..Enabled)	Enabled
SOTF Mode	(AC SOTF..DC SOTF)	AC SOTF
SOTF O/C Operate Level	(0.3..4)	0.3 x In
VT Supervision	(Disabled..Enabled)	Enabled
VTS Latched Operation	(Disabled..Enabled)	Enabled
VTS Mode	(Alarm Only..Alarm & Inhibit)	Alarm & Inhibit
VTS Phase Fault Inhibit	(Disabled..Enabled)	Enabled
VTS Input Source	(Res I/V..NPS I/V)	Res I/V
VTS Ires Level	(0.05..2)	0.3 x In
VTS Vop Level	(1..100)	20v

Reylogic Config Menu

Setting	Range	Default
SR Dropoff	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	1ms
POR Current Rev Reset	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	200ms
POR CB Echo Pulse	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	250ms
WI Sig Recv PU Delay	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	0ms
SS Dropoff	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	1ms
Permissive Trip Time	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	1ms
AC SOTF Pickup Delay	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	10000ms
VTS Alarm PU Delay	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	100ms
VTS Latch PU Delay	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	5000ms
TCS 1 Alarm Pick Up	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	400ms
TCS 2 Alarm Pick Up	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	400ms
TCS 3 Alarm Pick Up	0, 1, … 1000, 1010, … 10000, 10100, … 60000ms	400ms

Status Config Menu

Setting	Range	Default
Reset LED Flags & O/Ps	NONE, 1 … 27	NONE
Input 1	NONE, 1 … 27	NONE
Input 2	NONE, 1 … 27	NONE
Input 3	NONE, 1 … 27	NONE
Input 4	NONE, 1 … 27	NONE
Input 5	NONE, 1 … 27	NONE
Input 6	NONE, 1 … 27	NONE
Input 7	NONE, 1 … 27	NONE
Input 8	NONE, 1 … 27	NONE
3 pole Trip Select	NONE, 1 … 27	NONE
CB A Aux	NONE, 1 … 27	NONE
CB B Aux	NONE, 1 … 27	NONE
CB C Aux	NONE, 1 … 27	NONE
Carrier Recv. Guard	NONE, 1 … 27	NONE
Signal Receive 1	NONE, 1 … 27	NONE
Unstabilise Relay	NONE, 1 … 27	NONE
Block Mode Inhibit	NONE, 1 … 27	NONE
Manual Close	NONE, 1 … 27	NONE
VT Ccts Isolated	NONE, 1 … 27	NONE
Trip Cct 1 Fail	NONE, 1 … 27	NONE
Trip Cct 2 Fail	NONE, 1 … 27	NONE
Trip Cct 3 Fail	NONE, 1 … 27	NONE
Trigger Storage	NONE, 1 … 27	NONE
Block O/P Relays	NONE, 1 … 27	NONE
Switch Settings Grp	NONE, 1 … 27	NONE
Inhibit Group Switch	NONE, 1 … 27	NONE
Inverted Inputs	NONE, 1 … 27	NONE

Output Config Menu

Setting	Range	Default
Protection Healthy	NONE, 1 … 29	1
Output 1	NONE, 1 … 29	NONE
Output 2	NONE, 1 … 29	NONE
Output 3	NONE, 1 … 29	NONE
Output 4	NONE, 1 … 29	NONE
Output 5	NONE, 1 … 29	NONE
Output 6	NONE, 1 … 29	NONE
Output 7	NONE, 1 … 29	NONE
Output 8	NONE, 1 … 29	NONE
CB A Closed	NONE, 1 … 29	NONE
CB A Open	NONE, 1 … 29	NONE
CB B Closed	NONE, 1 … 29	NONE
CB B Open	NONE, 1 … 29	NONE
CB C Closed	NONE, 1 … 29	NONE
CB C Open	NONE, 1 … 29	NONE
Signal Received 1	NONE, 1 … 29	NONE
POR Weak Infeed	NONE, 1 … 29	NONE
Signal Send 1	NONE, 1 … 29	NONE
Aided Trip	NONE, 1 … 29	NONE
Zone 1	NONE, 1 … 29	NONE
Zone 2	NONE, 1 … 29	NONE
Zone 3	NONE, 1 … 29	NONE
Zone 4	NONE, 1 … 29	NONE
High Set	NONE, 1 … 29	NONE
Thermal O/L Alarm	NONE, 1 … 29	NONE
Thermal O/L Trip	NONE, 1 … 29	NONE
SOTF Operated	NONE, 1 … 29	NONE
VTS Alarm	NONE, 1 … 29	NONE
DAR Lockout	NONE, 1 … 29	NONE
Pole A Trip	NONE, 1 … 29	5
Pole B Trip	NONE, 1 … 29	6
Pole C Trip	NONE, 1 … 29	7
3 Pole Trip	NONE, 1 … 29	8
Trip Cct 1 Failed	NONE, 1 … 29	NONE
Trip Cct 2 Failed	NONE, 1 … 29	NONE
Trip Cct 3 Failed	NONE, 1 … 29	NONE
Phase A Fault	NONE, 1 … 29	NONE
Phase B Fault	NONE, 1 … 29	NONE
Phase C Fault	NONE, 1 … 29	NONE
Earth Fault	NONE, 1 … 29	NONE
Power Swing Alarm	NONE, 1 … 29	NONE
Carrier Recv Guard	NONE, 1 … 29	NONE
Start Phase A	NONE, 1 … 29	NONE
Start Phase B	NONE, 1 … 29	NONE
Start Phase C	NONE, 1 … 29	NONE
Zone 1 Start	NONE, 1 … 29	NONE
Zone 2 Start	NONE, 1 … 29	NONE
Zone 3 Start	NONE, 1 … 29	NONE
Zone 4 Start	NONE, 1 … 29	NONE
Hand Reset Outputs	NONE, 1 … 29	NONE
Fast Reset Outputs	NONE, 1 … 29	14
Inhibit Outputs	NONE, 1 … 29	NONE

Output Relay Dwell Time Menu

Setting	Range	Default
Min Op Time 1	1,10 … 2000ms	100ms
Min Op Time 2	1,10 … 2000ms	100ms
Min Op Time 3	1,10 … 2000ms	100ms
Min Op Time 4	1,10 … 2000ms	100ms
Min Op Time 5	1,10 … 2000ms	100ms
Min Op Time 6	1,10 … 2000ms	100ms

Min Op Time 7	1,10 … 2000ms	100ms
Min Op Time 8	1,10 … 2000ms	100ms
Min Op Time 9	1,10 … 2000ms	100ms
Min Op Time 10	1,10 … 2000ms	100ms
Min Op Time 12	1,10 … 2000ms	100ms
Min Op Time 13	1,10 … 2000ms	100ms
Min Op Time 14	1,10 … 2000ms	100ms
Min Op Time 15	1,10 … 2000ms	100ms
Min Op Time 16	1,10 … 2000ms	100ms
Min Op Time 17	1,10 … 2000ms	100ms
Min Op Time 18	1,10 … 2000ms	100ms
Min Op Time 19	1,10 … 2000ms	100ms
Min Op Time 20	1,10 … 2000ms	100ms
Min Op Time 21	1,10 … 2000ms	100ms
Min Op Time 22	1,10 … 2000ms	100ms
Min Op Time23	1,10 … 2000ms	100ms
Min Op Time 24	1,10 … 2000ms	100ms
Min Op Time 25	1,10 … 2000ms	100ms
Min Op Time 26	1,10 … 2000ms	100ms
Min Op Time 27	1,10 … 2000ms	100ms
Min Op Time 28	1,10 … 2000ms	100ms
Min Op Time 29	1,10 … 2000ms	100ms

Led Config Menu

Setting	**Range**	**Default**
Output 1	NONE, 1 … 29	NONE
Output 2	NONE, 1 … 29	NONE
Output 3	NONE, 1 … 29	NONE
Output 4	NONE, 1 … 29	NONE
Output 5	NONE, 1 … 29	NONE
Output 6	NONE, 1 … 29	NONE
Output 7	NONE, 1 … 29	NONE
Output 8	NONE, 1 … 29	NONE
CB A Closed	NONE, 1 … 29	NONE
CB A Open	NONE, 1 … 29	NONE
CB B Closed	NONE, 1 … 29	NONE
CB B Open	NONE, 1 … 29	NONE
CB C Closed	NONE, 1 … 29	NONE
CB C Open	NONE, 1 … 29	NONE
Signal Received 1	NONE, 1 … 29	9
POR Weak Infeed	NONE, 1 … 29	11
Signal Send 1	NONE, 1 … 29	NONE
Aided Trip	NONE, 1 … 29	10
Zone 1	NONE, 1 … 29	1
Zone 2	NONE, 1 … 29	2
Zone 3	NONE, 1 … 29	3
Zone 4	NONE, 1 … 29	4
High Set	NONE, 1 … 29	19
Thermal O/L Alarm	NONE, 1 … 29	20
Thermal O/L Trip	NONE, 1 … 29	21
SOTF Operated	NONE, 1 … 29	17
VTS Alarm	NONE, 1 … 29	18
DAR Lockout	NONE, 1 … 29	NONE
Pole A Trip	NONE, 1 … 29	NONE
Pole B Trip	NONE, 1 … 29	NONE
Pole C Trip	NONE, 1 … 29	NONE
3 Pole Trip	NONE, 1 … 29	NONE
Trip Cct 1 Failed	NONE, 1 … 29	NONE
Trip Cct 2 Failed	NONE, 1 … 29	NONE
Trip Cct 3 Failed	NONE, 1 … 29	NONE
Phase A Fault	NONE, 1 … 29	5
Phase B Fault	NONE, 1 … 29	6
Phase C Fault	NONE, 1 … 29	7

Earth Fault	NONE, 1 … 29	8
Power Swing Alarm	NONE, 1 … 29	24
Carrier Recv Guard	NONE, 1 … 29	NONE
Start Phase A	NONE, 1 … 29	NONE
Start Phase B	NONE, 1 … 29	NONE
Start Phase C	NONE, 1 … 29	NONE
Zone 1 Start	NONE, 1 … 29	NONE
Zone 2 Start	NONE, 1 … 29	NONE
Zone 3 Start	NONE, 1 … 29	NONE
Zone 4 Start	NONE, 1 … 29	NONE
Self-reset LEDs	NONE, 1 … 29	18,24

Data Storage Menu

Setting	Range	Default
Pre-trigger Storage	10 … 90%	20%
Record Duration	10x1s,5x2s,2x5s &1x10s	10 x 1 sec

Communications Menu

Setting	Range	Default
Station Address	0, 1, … 254	0
IEC870 on port	COM1, COM2	COM1
COM1 Baud Rate	75, 110, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	57600
COM1 Parity	Even, Odd, None	EVEN
COM1 Line Idle	Light On, Light Off	LIGHT OFF
COM1 Data Echo	Off, On	OFF
COM2 Baud Rate	75, 110, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	19200
COM2 Parity	Even, Odd, None	NONE
COM2 Line Idle	Light On, Light Off	LIGHT OFF
COM2 Data Echo	Off, On	OFF
COM2 Direction	Auto-Detect, Rear Port, Front Port	FRONT PORT

Fault Locator Menu

Setting	Range	Default
Fault Locator	Enabled, Disabled	Enabled
Pos Seq Line Impedance	0.1, 0.11, …,10, 10.1, …, 100, 101, …, 250 Ω	10.00 Ohm
Sec'y Z+ per unit distance	0.001, 0.002, …, 5 Ω	0.500 Ohm
Display distance as	Percent, Kilometres, Miles	Percent

2 Settings Walkthrough

The relay displays are organised into three lists:-

A list of settings
A list of meters (instruments)
A list of fault records

This walkthrough describes the settings and is intended to be read in front of a powered-up relay.
The starting point is the relay identifier screen. This is the screen the relay displays when it is first powered-up and can be reached from any display by pressing **CANCEL** a few times.

From this position press the down arrow key once, the relay will display **"SETTINGS MODE".**
From this display the down arrow key can be pressed again to enter the setting list, or the right arrow key ⇨ can be pressed to choose a different list ("**INSTRUMENTS MODE" or "FAULT DATA MODE**").
Press the down arrow key ⇩. The relay enters the settings list and displays "**SYSTEM CONFIG MENU**".

2.1 SYSTEM CONFIG MENU

This menu contains general settings which allows the relay to be configured. Press ⇨ to open the menu and display the settings.

Active Group (1 … 8) 1
This is the settings group which is currently being used by the relay. This is not necessarily the same group as those currently displayed.

CVT in use (NO..YES) NO
If CVT's are used then this setting should be set to YES. This will give extra security to the protection during the case of severe CVT transients. Due to this extra security, operation of the relay will be approximately 5ms slower if CVTs are being used.

Autoreclose Option **(**None, Internal) None
Specifies whether the interface to an external autorecloser is required.

CB Aux Contacts (Type A, Type B) Type A
This settings specifies the Circuit Breaker auxiliary inputs as either type A or B. The contacts are required as inputs to the autoreclose and some other logic functions to define CB state. Type A contacts copy the CB, i.e. contacts closed when CB is closed. Type B are opposite to CB action, i.e. contacts closed when CB is open.

CT Ratio (0:1..5000:5) 2000¦1
This setting defines the turns ratio of the protection CT. This will allow the meter display to show the correct primary current. This setting does not affect any protection functions.

VT Ratio (1000:90..600000:130) 132000¦110
This setting defines the ratio of the protection VT. This will allow the meter display to show the correct primary voltage. This setting does not affect any protection functions.

Alternate Setting Group (1..8) 1
It is possible to cause the relay to switch from one setting group to another on application of a signal to the Status Input *Use Alt Setting Grp*. When this status input is energised, the relay will switch from whichever group is currently active to the alternate group defined in this setting. The relay will revert to the previous active setting group when the *Use Alt Setting Grp* Status Input is de-energised.

View/Edit Group (1 … 8) 1
This is the settings group which is currently being displayed by the relay. This is the group which would be changed if any setting is edited. This is not necessarily the same group as those currently in use.

Default Screens Timer (Off, 1-60 mins) 60
This is the time delay after which the relay will return to the default screen, if no keys are pressed.

Backlight timer (OFF..60) 5 min
Defines the length of time for which the backlight for the LCD screen will remain illuminated after the last keypress.

Change Password (Password) NONE

The relay is provided with a password feature. If set it will prevent any un-authorised changes to any of the relay settings. The password is a four character word once set it can be disabled by entering the new password "NONE". Once a password has been set, the relay will display a 10 digit code in the Change Password setting. If the password has been lost then an authorised person should contact a Siemens representative, quoting this 10-digit code. This can be used to obtain the current password.
The password must be entered in order to alter any of the relay settings. Once the password has been entered, the relay will remain "logged-in" for 1 hour. After this time, the relay password must be entered again before settings can be changed.

Relay Identifier (16 Character String) OHMEGA-408-50
The relay is supplied with a default identifier usually the relay type. This can be changed to any 16-digit identifier to give any meaningful identification to the relay. e.g. feeder name or circuit number.

2.2 DISTANCE PROTECTION MENU

The settings for the impedance elements are located in this menu.

Active Scheme (Time Stepped, PUR, POR1, POR2 BOR)Time Stepped
There are a number of different protection schemes available in the relay depending upon the model. These can be chosen at this setting. Only one scheme can be active at a time. The schemes are described in Section 3 of this manual.

CT Secondary (1..5) 1 A
The relay can operate from 1, 2 or 5 Amp CT secondary circuits. The value MUST be programmed for the correct CT. This will affect the impedance measurements if not programmed correctly.

Line Angle (0..90) 75 deg
This is the angle of the positive sequence impedance of the composite transmission line.

EF Comp Z0/Z1 ratio (0..10) 2.5
This is the ratio between the magnitudes of the zero sequence and positive sequence impedances of the system. The ratio of Z0/Z1 is used in an internal calculation for earth-fault compensation. This is common for all Zones.

EF Comp Z0 angle (0..355) 75 deg
This is the angle of the zero sequence impedance of the system.

POR Weak Infeed (Disabled..Enabled) Disabled
Operation of the Weak Infeed logic within the Permissive overreach scheme can be enabled or disabled from this setting. This allows the Weak Infeed detection to echo a received Scheme Signal to allow the remote end to trip and enables the POR Weak Infeed Alarm.

POR Weak Infeed Trip (Disabled..Enabled) Disabled
This setting is used to allow a main trip output operation to result from a Weak Infeed detection. The Weak Infeed function must first be enabled using the setting above.

WI Voltage Level (5 .. 85volts) 54v
This is the voltage level at which the POR Weak Infeed detector registers a voltage depression which is characteristic of a weak infeed situation.

Quad auto Load Comp Disabled, Enabled Enabled
Compensation applied to the reactance line of the quad characteristic to allow for load current during a fault.

Reactive Drop Angle -20..20 -3deg
Defines the angle of the reactance comparator to the vertical, for the quad characteristic

Z1 Phase Fault (Disabled..Enabled) Enabled
Operation of the Zone 1 phase-fault elements A-B, B-C & C-A, can be enabled or disabled from this setting.

Z1 PF Impedance (0.1..250) 8 ohms
Defines the Zone 1 phase-fault impedance reach in terms of the secondary positive sequence impedance.

Z1 PF Time Delay (0..10000) 0 ms
An independent time delay from 0 – 10s can be applied to the Zone 1 phase-fault protection elements.

Z1 Earth Fault (Disabled..Enabled) Enabled
Operation of the Zone 1 earth-fault elements A-E, B-E & C-E, can be enabled or disabled from this setting.

Z2 Earth Fault Type (Fwd Mho, Fwd Quad) Fwd Mho

Defines the Forward Zone 1 characteristic as either Mho or Quadrilateral.

Z1 EF Impedance (0.1..250) 8 ohms
Defines the Zone 1 earth-fault impedance reach (in terms of secondary positive sequence impedance) for the mho characteristic.

Z1 EF Resistance (0.1..250) 4 ohms
When Quad characteristics are selected, this defines the reach along the resistive axis. Note that residual compensation is *not applied* to this part of the characteristic.

Z1 EF Time Delay (0..10000) 0 ms
An independent time delay from 0 – 10s can be applied to the Zone 1 earth-fault protection elements.

Z2 Phase Fault (Disabled..Enabled) Enabled
Operation of the Zone 2 phase-fault elements A-B, B-C & C-A, can be enabled or disabled from this setting.

Z2 PF Impedance (0.1..250) 16 ohms
Defines the Zone 2 phase-fault impedance reach in terms of the secondary positive sequence impedance.

Z2 PF Time Delay (0..10000) 1000 ms
An independent time delay from 0 – 10s can be applied to the Zone 2 phase-fault protection elements.

Z2 Earth Fault (Disabled..Enabled) Enabled
Operation of the Zone 2 earth-fault elements A-E, B-E & C-E, can be enabled or disabled from this setting.

Z2 Earth Fault Type (Fwd Mho, Fwd Quad) Fwd Mho
Defines the Forward Zone 2 characteristic as either Mho or Quadrilateral.

Z2 EF Impedance (0.1..250) 16 ohms
Defines the Zone 2 earth-fault impedance reach (in terms of secondary positive sequence impedance) for the mho characteristic.

Z2 EF Resistance (0.1..250) 8 ohms
When Quad characteristics are selected, this defines the reach along the resistive axis. Note that residual compensation is *not applied* to this part of the characteristic.

Z2 EF Time Delay (0..10000) 1000 ms
An independent time delay from 0 – 10s can be applied to the Zone 2 earth-fault protection elements.

Z3 Phase Fault (Disabled..Enabled) Enabled
Operation of the Zone 3 phase-fault elements A-B, B-C & C-A, can be enabled or disabled from this setting.

Z3 PF Type (Fwd Mho, Rev Mho, Offset Mho, Offset Shaped)Offset Mho
There are three types of Zone 3 characteristic for phase-faults: Forward (Fwd) Mho, Reverse (Rev) Mho or Offset Mho. If either forward or reverse is selected then these elements become a standard directional element and require a polarising voltage. If an offset characteristic is selected, then operation can occur without polarising voltage.

Z3 PF Impedance (Fwd) (0.1..250) 24 ohms
The Zone 3 phase-fault forward impedance reach is defined by this setting, in terms of secondary positive sequence impedance. If the element is selected as a reverse element then this setting is ignored.

Z3 PF Impedance (Rev) (0.1..250) 8 ohms
The Zone 3 phase-fault reverse impedance reach is defined by this setting, in terms of secondary positive sequence impedance. If the element is selected as a forward element then this setting is ignored.

Z3 PF Shape Factor 1 (0..1) 1
Z3 PF Shape Factor 2 (0..1) 1
Sets the relay shape factors where Zone 3 Shaped characteristics are being applied. If Shaped Zone 3 characteristics are not used, this setting will have no effect.

Z3 PF Time Delay (0..10000) 2000 ms
An independent time delay from 0 – 10s can be applied to the Zone 3 phase-fault protection elements.

Z3 Earth Fault (Disabled..Enabled) Enabled
Operation of the Zone 3 earth-fault elements A-E, B-E & C-E can be enabled or disabled from this setting.

Z3 EF Type (Fwd Mho, Rev Mho, Offset Mho, Fwd Quad, Rev Quad, Offset Quad) Offset Mho

There are six types of Zone 3 characteristic for earth-faults. If either forward or reverse is selected then these elements become a standard directional element and require a polarising voltage. If an offset characteristic is selected, then operation can occur without polarising voltage.

Z3 EF Impedance (Fwd) (0.1..250) 24 ohms
The Zone 3 earth-fault forward reach impedance values are defined using this setting, in terms of secondary positive sequence impedance. If the element is set as a reverse-looking element, this setting is ignored.

Z3 EF Resistance (Fwd) (0.1..250) 12 ohms
With Quad characteristics selected, this defines the reach along the resistive axis in the forward direction. Note that residual compensation is not applied to this part of the characteristic.

Z3 EF Impedance (Rev) (0.1..250) 8 ohms
The Zone 3 earth-fault reverse reach impedance values are defined using this setting, in terms of secondary positive sequence impedance. If the element is set as a forward-looking element, this setting is ignored.

Z3 EF Resistance (Rev) (0.1..250) 4 ohms
With Quad characteristics selected, this defines the reach along the resistive axis in the reverse direction. Note that residual compensation is not applied to this part of the characteristic.

Z3 EF Time Delay (0..10000) 2000 ms
An independent time delay from 0 – 10s can be applied to the Zone 3 earth-fault protection elements.

Direct Zone 4 Trip (DISABLE..ENABLE) DISABLE
This enables Zone 4 to issue a general trip when the Zone 4 operates. The Zone 4 is normally used for the blocking schemes only (i.e. it is a non-tripping zone), but it can be used to trip under certain circumstances.

Z4 Phase Fault (Disabled..Enabled) Enabled
The reverse Zone 4 phase-fault elements A-B, B-C & C-A, can be enabled or disabled from this setting.

Z4 PF Impedance (0.1..250) 8 ohms
Defines the Zone 4 phase-fault impedance reach (in terms of secondary positive sequence impedance) for the mho characteristic.

Z4 PF Time Delay (0..10000) 0 ms
An independent time delay from 0 – 10s can be applied to the Zone 4 phase-fault protection elements.

Z4 Earth Fault (Disabled..Enabled) Enabled
Operation of the Zone 4 earth-fault elements A-E, B-E & C-E, can be disabled from this setting.

Z4 Earth Fault Type (Rev Mho, Rev Quad) Rev Mho
Defines the Reverse Zone 4 characteristic as either Mho or Quadrilateral.

Z4 EF Impedance (0.1..250) 8 ohms
Defines the Zone 4 earth-fault impedance reach (in terms of secondary positive sequence impedance) for the mho characteristic.

Z4 EF Resistance (0.1..250) 4 ohms
When Quad characteristics are selected, this defines the reach along the resistive axis. Note that residual compensation is *not applied* to this part of the characteristic.

Z4 EF Time Delay (0..10000) 0 ms
An independent time delay from 0 – 10s can be applied to the Zone 4 earth-fault protection elements.

2.3 POWER SWING MENU

Settings for the power swing element are defined in this section.

Power Swing Detector (DISABLE..ENABLE) ENABLE
This setting allows the Power Swing detector to be enabled or disabled.

PSD Zone blocking (4 Bit Binary) -111
This defines which Zones of protection tripping would be blocked for in the event of a Power Swing.

PSD Shape (CIRCULAR..RECTANGULAR) CIRCULAR
Allows setting of the Power Swing Zone characteristics as either circular or rectangular.

PSD Blinders (DISABLE..ENABLE) DISABLE
This allows blinders to be applied to the Power Swing Zone to prevent load encroachment. These are applied parallel to the line angle when enabled.

PSD Inner Fwd Impedance (0.1..250) 24 ohms
Sets the inner impedance reach in the forward direction (on the line angle) for the PSD characteristic. This is usually set equal to, or greater than, the Zone 3 reach.

PSD Inner Rev Impedance (0.1..250) 8 ohms
Sets the inner impedance reach in the reverse direction (on the line angle) for the PSD characteristic. This is usually set equal to, or greater than, the Zone 3 reverse reach.

PSD Inner Fwd Blinder (0.1..250) 16 ohms
This is the impedance (perpendicular to the line angle) between the line impedance and the blinder applied to the PSD Zone, to the right of the line characteristic. The blinder is applied parallel to the line angle.

PSD Inner Rev Blinder (0.1..250) 16 ohms
This is the impedance (perpendicular to the line angle) between the line impedance and the blinder applied to the PSD Zone, to the left of the characteristic. The blinder is applied parallel to the line angle.

PSD Outer Multiplier (1.05..2) 1.5 x
The outer reach of the Power Swing detector is set as a multiple of the inner reach, normally 1.5 times the inner reach.

PSD Transit Time (0..1000) 50 ms
This is the length of time for which the impedance characteristic must be between the inner and outer Zones of the Power Swing Detector for a Power Swing to be detected. The default setting of 50ms should be suitable for most applications.

AUX PROTECTION MENU
Any additional protection elements are programmed in this section.

High Set (DISABLE..ENABLE) ENABLE
Overcurrent high set elements can be enabled or disabled using this setting.

HS Level (0.1..35) 4 xIn
The overcurrent setting is applied here. It is set in multiples of the nominal current, I_n which is set in the DISTANCE PROTECTION MENU under the *CT Secondary* setting.

HS Time Delay (0..1000) 0 ms
A definite time delay from 0 – 1s can be added to the instantaneous operating time of the high set elements.

Thermal Overload Protection (DISABLED..ENABLED) ENABLED
This allows the Thermal Overload Protection to be completely switched off.

Thermal Overload Tripping (DISABLED..ENABLED) ENABLED
This setting will determine whether the Thermal Overload Element will cause the main trip output to operate.

TOL Operating Mode **(Single Pole, Three pole) 3 pole**
In Single pole mode the relay will evaluate the thermal state of the three poles individually, and operate if any the thermal states are above the set levels.
In Three Pole mode the relay will find the average of the three phase currents and use these to produce a single thermal state for the system.

TOL Overload Setting (0.5..2) 1.05 xIn
Stated as a multiple of nominal current, this is used as the main parameter to establish the Thermal Overload Characteristic.

TOL Time Constant (1…1000) 10 minutes
This time constant is used to establish the Thermal Overload Characteristic.

TOL Hot/Cold Ratio (DISABLED..ENABLED) DISABLED
Will enable or disable the Hot/Cold Ratio setting.

TOL Hot/Cold Ratio Setting (5 – 100) 50%
This will reduce the effect of the prior current on the operating time of the protection. This setting is equivalent to (1-H/C). For most overhead line and cable applications, this should be set to 100%

TOL Capacity Alarm (DISABLED..ENABLED) ENABLED
Will enable or disable the TOL Capacity alarm, which will operate the Thermal O/L Alarm output if the Thermal state reaches a certain percentage of the Thermal Capacity.

TOL Capacity Level (50-100) **50%**
The percentage of the Thermal Capacity at which the Thermal O/L Alarm will operate if the TOL Capacity Alarm is enabled.

TOL load Increase Alarm (DISABLED..ENABLED) ENABLED
Will enable or disable the TOL Load Increase Alarm, which will operate the Thermal O/L Alarm output if the Load suddenly increases by a set percentage.

TOL load Inc. Alarm Level (50-100) **50%**
The percentage increase in load at which the Thermal O/L Alarm will operate if the TOL Load Increase Alarm is enabled.

TOL Overload Alarm (**Disabled** / Enabled) Disabled
Allows the Alarm output to se switched off/on.

SOTF (DISABLED..ENABLED) ENABLED
This setting determines whether the Switch On To Fault protection is enabled or not.

SOTF Mode (AC SOTF..DC SOTF) AC SOTF
The Switch On To Fault feature has two modes of operation. It can be energised from an AC function or a DC function. The DC SOTF function is energised by the operation of a status input from the CB manual close handle (i.e. a D.C. signal). The AC SOTF function monitors the line current and voltage (i.e. the AC signals) and thus cannot be used if the VT is on the busbar side of the relay.

SOTF O/C Operate Level (0.3..4) 0.3 xIn
This current setting is used as a minimum value to cause operation of the SOTF function after 25ms of fault current on all three phases.

VT Supervision (DISABLED..ENABLED) ENABLED
This checks for the security of the VT circuit. It can be enabled or disabled.

VTS Latched Operation (DISABLED..ENABLED) ENABLED
Defines whether the VTS will latch after being raised for a preset time or reset if the operating current increases at any time when it is raised.

VTS Mode (ALARM ONLY..ALARM & INHIBIT) ALARM & INHIBIT
If the VTS operates it can be selected to give an alarm only or it can inhibit the operation of the impedance elements.

VTS Phase Fault Inhibit (DISABLED..ENABLED) ENABLED
During a fault condition the VTS is reset when the zero sequence current exceeds the setting. For a phase-fault there is no zero sequence current therefore the relay may be inhibited during a phase-fault.
With this setting disabled, the relay will trip for a two-phase VT failure.
With this setting enabled, the relay will remain stable for a two-phase VT failure but will not trip if a phase-fault occurs during such a failure.

VTS Input Source **(RES I/V…NPS I/V)** **Res I/V**
VTS operation can be set based on Residual voltage and current or Negative phase sequence quantities.

VTS Ires Level (0.05..2) 0.3 xIn
VTS Vop Level (1..100) 20 V
The VTS feature operates by measuring the summated voltages of the healthy system, and comparing this with the measured residual current. The VTS will operate if the relay detects residual voltage without detecting a corresponding residual current. These settings define the levels of residual current and voltage used. The default residual voltage setting of 20 volts is suitable for most applications, but this can be changed to make the function more or less sensitive. The current setting is made in terms of the nominal current, and the default setting is 30%. The default settings used here are suitable for most applications.

2.4 REYLOGIC CONFIG

Elements of functions that have had the logic configured in REYLOGIC are found in this menu.

SR Dropoff (0..60000) 1 ms
The Distance signal received can be extended using this timer to provide a variable pulse length.

POR Current Rev Reset (0..60000) 1 ms
This is the time for which tripping is inhibited following a current reversal when a Permissive Overreach is in use.

POR CB Echo Pulse (0..60000) 1 ms
This is the duration for which the signal send is activated when a Signal Receive input is energised when the circuit breaker is open when the POR scheme is in use.

WI Sig Recv PU Delay (0..60000) 0 ms
This is used to delay the acknowledgement of a Signal Receive by the Weak Infeed logic. This may be required to co-ordinate the W.I. blocking due to local fault detection with a particularly fast re mote fault detection combined with a fast signalling system.

SS Dropoff (0..60000) 1 ms
The Distance send signal can be delayed using this timer to provide a variable pulse length.

Permissive Trip Time (0..60000) 1 ms
This is used for the distance blocked overreach scheme (BOR). This is the time for which the relay will wait for a blocking signal from the remote end before a carrier-aided trip is carried out.

AC SOTF Pickup Delay (0..60000) 10000 ms
The logic requires that the circuit breakers must have been closed for a minimum time before the SOTF logic is initiated. This minimum time is set here.

VTS Alarm PU Delay (0..60000) 100 ms
Specifies the time for which a VTS condition must be present on the system before a VTS alarm is raised. This is set to avoid nuisance alarms.

VTS Latch PU Delay (0..60000) 5000 ms
This is the minimum time that the VT fail conditions must remain on the system before the VT alarm is latched such that reset does not occur if the operating current is removed. It is usually set to 5000ms to avoid erroneous tripping due to load imbalance following a fuse failure..

TCS 1 Alarm Pick Up **(0..60000)** **400** **ms**
TCS 2 Alarm Pick Up **(0..60000)** **400** **ms**
TCS 3 Alarm Pick Up **(0..60000)** **400** **ms**
Delay on Pick-up of the Trip Circuit Supervision Status Inputs, to avoid nuisance alarms.

2.5 STATUS CONFIG

The number of status inputs can vary with the relay model type. Each of the status inputs can be mapped to any one or more of the relay functions. The following list shows the purpose of the function.

Reset LED Flags (39 Character String) NONE
Energising this Status Input will reset all LED flags, in the same way as pressing the TEST/RESET button on the relay.

Input 1 ... 8 (39 Character String) NONE
In order to utilise the status inputs and output relay matrix a number of connections have been created. These are named as Input 1..8. Energising the Status Input assigned here will cause the *Input X Operated* output to operate.

3 Pole trip Select **(39 Character String)** **NONE**
Forces all trip outputs to be 3 pole trips.

CB A Aux (39 Character String) NONE
CB B Aux (39 Character String) NONE
CB C Aux (39 Character String) NONE
Allows CB auxiliary contacts to be connected to the relay to indicate CB status.

Carrier Recv Guard (39 Character String) NONE
Where it is available, a signal may be taken from the signalling equipment, which will energised this status input when the signalling channel is faulty. This will cause the selected scheme to act as a time stepped distance scheme, until the SI is de-energised.

Signal Receive 1 (39 Character String) NONE
Signalling channel used for Distance Protection.

Unstabilise Relay (39 Character String) NONE
When used this will cause the relay to issue a permissive signal or remove a blocking signal, depending on the selected scheme.

Block Mode Inhibit (39 Character String) NONE
Will inhibit operation of the *Blocked Overreach* scheme (where selected)

Manual Close (39 Character String) NONE
This status input must be used if the *Switch On To Fault mode* is set to *DC SOTF*. A contact is required from the circuit breaker closing handle. It is disabled by default. For 400ms after this element is first energised, the relay will remove the time delay from Zone 3. See Section 2 of this manual for a full description of the *Switch On To Fault* feature.

VT Circuits Isolated (39 Character String) NONE
Used where MCBs are used to isolate VTs. IF all VT phases are lost, this SI should be energised to indicate a 3-phase VT failure.

Trip Cct Fail 1 (39 Character String) NONE
Trip Cct Fail 2 (39 Character String) NONE
Trip Cct Fail 3 (39 Character String) NONE
Connected to the three single-phase trip circuits. Where 3-pole tripping is used these can be assigned to the same input, if required. Operation of these will directly operate the output assigned to *Trip Circuit Fail*.

Trigger Storage (39 Character String) NONE
Energising this SI will trigger waveform storage.

Block Output Relays (39 Character String) NONE
Operation of all outputs which are designated in the output relay menu as inhibited, using the 'Inhibit Outputs' setting, will be blocked whilst this input is energised.

Switch Settings Grp (39 Character String) NONE
When this SI is energised, the relay will switch groups, from the currently active group to the *Alternate Setting Group* defined in the System Config Menu. The relay will remain in the alternate setting group until the SI is de-energised, when the relay will revert to the previous setting group.

Inhibit Group Switch (39 Character String) NONE
Energising this status input will prevent the relay from changing groups when the Switch Settings group Input is energised.

Inverted Inputs (39 Character String) NONE
Any inputs which are selected here will be inverted, i.e. de-energisation of the input will be considered as a logical '1' input to their applicable logic diagram.

2.6 OUTPUT CONFIG

Depending upon the configuration of the relay there are a large number of signals which can be mapped to output contacts.

Protection Healthy (39 Character String) 1···
This output monitors the condition of the relay and dc power supply to the relay. This is usually mapped to one of the changeover outputs, and connected to the normally closed contact (by default relay 1). When this function is selected it will permanently operate the selected relay. By using a normally closed contact if there is any failure then this contact will close giving a fail-safe alarm condition.

Output 1-8 (39 Character String) NONE
Outputs driven by energisation of the unallocated inputs 1-8.

CB A Closed
CB A Open
CB B Closed
CB B Open
CB C Closed
CB C Open (39 Character String) NONE
Used to indicate CB position based on inputs from CB auxiliary contacts.

Signal Received 1 (39 Character String) NONE
Operates on receipt of a signal from the remote end distance relay.

POR Weak Infeed (39 Character String) NONE
Operates to indicate that a Weak Infeed trip has occurred

Signal Send 1 (39 Character String) NONE
Operates according to the selected scheme to send either a permissive signal or a blocking signal to the remote end.

Aided Trip (39 Character String) NONE
Operates when the relay operation was aided by the active scheme, i.e. indicates whether it was a simple time stepped distance trip or not.

Zone 1 (39 Character String) NONE
Zone 2 (39 Character String) NONE
Zone 3 (39 Character String) NONE
Zone 4 (39 Character String) NONE
Indicates the Zones involved in the fault. Note these outputs are not starters – they will have the same time-delayed operation as the zones themselves.

High Set (39 Character String) NONE
Indicates operation of the Highset Overcurrent element.

Thermal O/L Alarm (39 Character String) NONE
Indicates that a Thermal Overload has been detected above the Alarm Setting.

Thermal O/L Trip (39 Character String) NONE
Indicates that a Thermal Overload has been detected above the Trip Setting.

SOTF Operated (39 Character String) NONE
Indicates that a Switch-onto-fault Operation has occurred.

VTS Alarm (39 Character String) NONE
Operates when one or more phases of the Voltage Transformer fails.

DAR Lockout (39 Character String) NONE
Operates when a trip occurs which should not initiate Autoreclose, i.e. a Zone 2 or Zone 3 fault. May be used to prevent operation of an external Autorecloser.

Pole A Trip (39 Character String) NONE
Pole B Trip (39 Character String) NONE
Pole C Trip (39 Character String) NONE
3 Pole Trip (39 Character String) NONE
These are used as the initiation for the tripping of the local circuit breaker(s). Depending on the settings of the relay, they may be operated by any of the distance elements, Highset Overcurrent, Thermal Overload etc. If the relay is used in conjunction with an external autorecloser the 3 phases may be tripped independently.

Trip Cct 1 Failed (39 Character String) NONE
Trip Cct 2 Failed (39 Character String) NONE
Trip Cct 3 Failed (39 Character String) NONE
When a Trip circuit fails, this indicates which phases are involved.

Phase A Fault (39 Character String) NONE
Phase B Fault (39 Character String) NONE
Phase C Fault (39 Character String) NONE
Indicates the phase(s) involved in the fault condition

Earth Fault (39 Character String) NONE
Operates when the fault involves an earth path.

Power Swing Alarm (39 Character String) NONE
Operates when the System impedance characteristic has entered the Power Swing Detection Zone and remained there for longer than the *PSD Transit time*.

Carrier Recv Guard (39 Character String) NONE
Operates when the carrier guard SI has operated because of a faulty signalling channel.

Start Phase A (39 Character String) NONE
Start Phase B (39 Character String) NONE

Start Phase C (39 Character String) NONE
These indicate that a phase segregated starter has operated.

Zone 1 Start (39 Character String) NONE
Zone 2 Start (39 Character String) NONE
Zone 3 Start (39 Character String) NONE
Zone 4 Start (39 Character String) NONE
Indicates the Zones involved in the fault. This will indicate the non-time delayed operation of the zones, ie. the zone starters.

Hand Reset Outputs (39 Character String) NONE
Indicates which Outputs are latched.

Fast Reset Outputs (39 Character String) NONE
Output relays selected here will be reset more frequently than standard relays.

Inhibit Outputs (39 Character String) NONE
Outputs relays listed here will be disabled when the Inhibit Inputs status input is energised.

2.7 OUTPUT RELAY DWELL TIME MENU

This menu is used to set a minimum operating time for each output relay in turn. i.e. if the stimulus causing the relay is of short duration the relay out put relay operation will be extended beyond the drop-off of the stimulus.

2.8 LED CONFIGURATION MENU

With the exception of the “Protection Healthy” item, this menu has the same relay outputs as the output Configuration menu and these can be used to energise any of the LED flags.

Self reset leds
This setting is used to list any led which is to extinguish when the driving stimulation is removed. Any led omitted from this list will therefore latch once operated and will not reset until manually reset.

2.9 DATA STORAGE MENU

Pre-trigger Storage **(10, 20, … 90%)**
Sets the percentage of the total record duration which is stored before the trigger picks up.

Record Duration **(10x1sec, 5x2sec, 2x5sec, 1x10sec)**
This setting selects the number and duration of waveform records, from 10 record, each of 1 second duration up to only 1 record of 10 seconds duration.

2.10 COMMUNICATIONS MENU

Station Address (0, 1, … 254) **0**
Defines the relay address number. When set to zero, the relay will not communicate.

IEC870 on port (*COM1*, COM2)
Defines the port which uses IEC 870 Communication protocol. The front port and the top rear fibre Optic ports are denoted COM2. When using a PC to communicate locally with the relay, this should be set to COM2.
Note that this should not be confused with the comms port on the PC.

COM1 Baud Rate **(**75, 110, 300, 600, 1200, 2400, 4800, 9600, *19200*, 38400, 57600, 115200)
Defines the Baud rate used by the COM 1 of the relay to communicate with an external device. The relay and the external device must both be using the same baud rate in order for communications to be established.

COM1 Parity (Even, Odd, *None*)
Defines the type of Parity used by the COM 1 of the relay when communicating with an external device. The relay and the external device must both be using the parity in order for communications to be established.

COM1 Line Idle (Light On, **Light Off**)
For the Fibre Optic port. Defines whether the fibre optic light will be ON or OFF when the line is idle.

COM1 Data Echo (**Off**, On)

This setting must be switched on, to enable the relay to pass data around a ring system. If a number of relays are connected together, the data echo feature must be switched on to allow data transfer. When communicating with a single relay it may be easier to switch this setting to OFF.

COM2 Baud Rate (75, 110, 300, 600, 1200, 2400, 4800, 9600, **19200**, 38400, 57600, 115200)
Defines the Baud rate used by the COM 1 of the relay to communicate with an external device. The relay and the external device must both be using the same baud rate in order for communications to be established.

COM2 Parity (Even, Odd, **None**)
Defines the type of Parity used by the COM 2 of the relay when communicating with an external device. The relay and the external device must both be using the parity in order for communications to be established.

COM2 Line Idle (Light On, **Light Off**)
For the Fibre Optic port. Defines whether the fibre optic light will be ON or OFF when the line is idle.

COM2 Data Echo **(Off**, On)
This setting must be switched on, to enable the relay to pass data around a ring system. If a number of relays are connected together, the data echo feature must be switched on to allow data transfer. When communicating with a single relay it may be easier to switch this setting to OFF.

COM2 Direction (Auto-Detect, Rear Port, Front Port)
The relay has two external connections to COM port 2 – via the rear fibre optic connection or via the front RS232 connection. This defines which port is used. When set as auto-detect it will switch between ports depending on the connected devices.

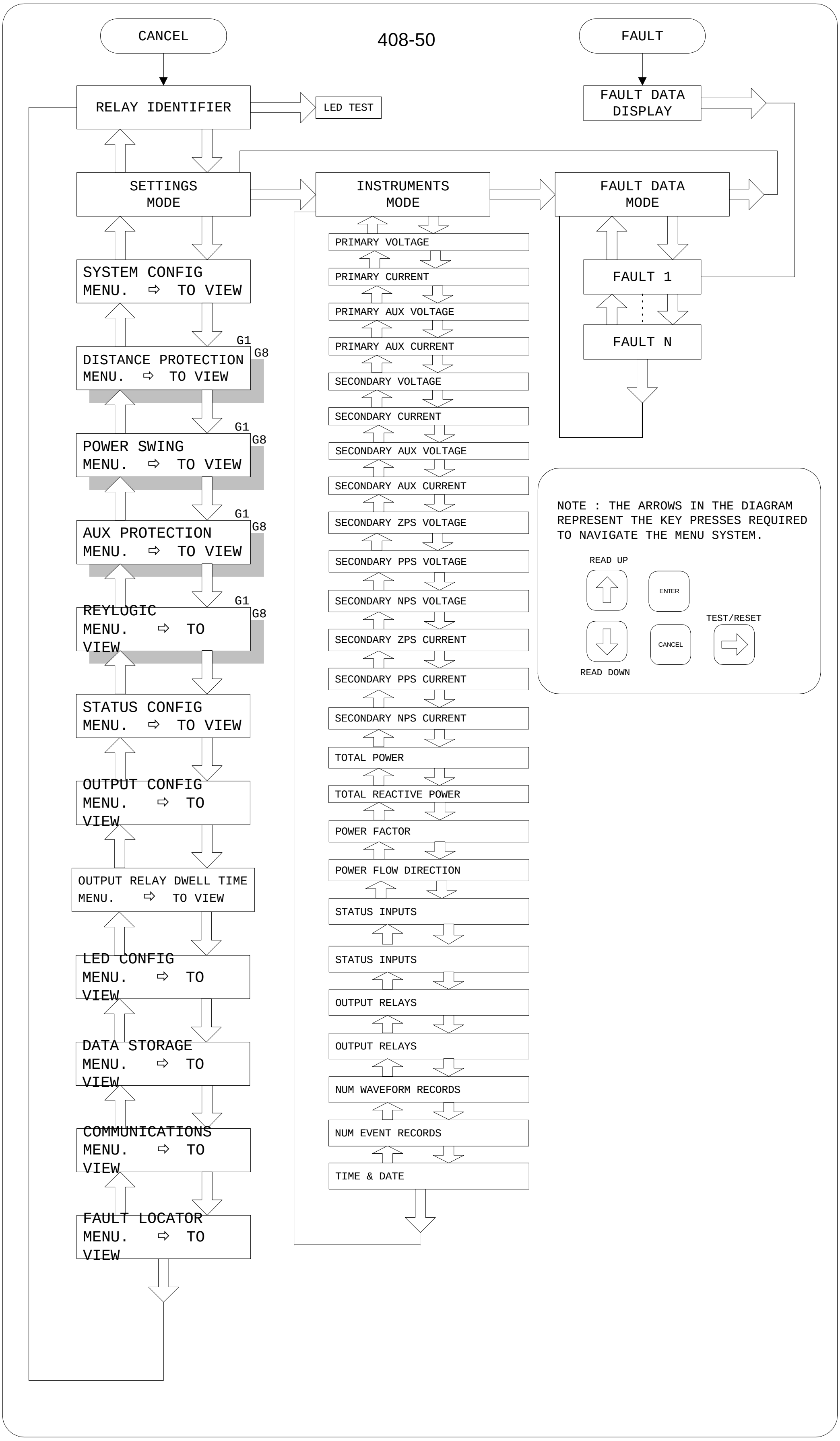
2.11 FAULT LOCATOR MENU

Pos Seq Line Impedance (0.1 – 250 Ω) 10 Ω
This is the positive sequence impedance of 100% of the line.

Sec'y Z+ per unit distance (0.1 – 250Ω) 0.500 Ω
Defines the secondary positive sequence impedance per mile or kilometre.

Display distance as (*Percent*, Kilometres, Miles)
Defines whether the distance is displayed as a distance or as a percentage of the Pos Seq Line Impedance setting.

Fault Locator *Enabled*/ Disabled
Allows the fault locator to be enabled or disabled.



Menu Structure

7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

Contents

1 Introduction

The following document defines the technical and performance specification of the standard features in this series of relays. Optional features are described in the last part of the document.

Performance Data to:
IEC60255-6, IEC60255-6A and IEC60255-16.

2 Technical Specification

2.1 Rated Current

Three possible current ratings can be obtained by programming the correct rating.
1, 2 or 5 Amps

2.2 Rated voltage

The relay requires a four wire voltage system, phase A, B, C & N
Rated voltage 63.5 Volts ac Phase - N

2.3 Rated Frequency

Two operating frequencies are available
Frequency - 50 or 60Hz

2.4 Characteristic Angle

The characteristic angle can be adjusted to suit any composition of line or cable circuit. This angle is used for all zones.
Angle - 0° - 90° in 5° steps

2.5 Zone impedance settings

Distance relays usually quote the boundary of performance in terms of SIR (System Impedance Ratio) plotted against the accuracy of the relay. This is a powerful method of describing the relays performance.

Adjustment of the positive sequence zone impedance is made by the menu selection. Each zone has the same setting range

Rating	Zone Range
1A	0.1-250 Ohm
2A	0.1-125 Ohm
5A	0.1-50 Ohm

Any zone is selectable within the setting range specified. Step sizes within the ranges are as follows:
0.1-10ohms - 0.01ohm step,
10-100ohms - 0.1ohm step,
100-250ohms - 1ohm step.
The protection provides the option of using the 5A (or 2A) tap on a 1A CT in order to attain a lower range.

2.6 Residual Compensation

The residual compensation applies to all zones.

Z_O/Z_1 0-10 in steps of 0.01
Z_O angle – 0 to 355° in steps of 5°

2.7 Zone 4 Settings

The zone 4 element is a reverse of zone one and has independent impedance settings with the same range as zone 1. The angle is a mirror image of the forward fault angle.

2.8 Voltage Memory

Under fault conditions the relay adds a replica of the positive sequence voltage to the polarising voltage of each comparator.
Voltage memory is applied for a maximum of 200ms, after which time the zone 1 and, where fitted, zone 4 comparators will be either inhibited from operating or have their operation latched until the fault is cleared.

2.9 Timers

2.9.1 Distance Function Zone Timers

Zone Timers (Z1T through Z4T)
0 to 10 s in steps of 10ms

2.9.2 Additional Timers

Timing functions for scheme operation and other protection functions are available. These are model specific and the relay setting section must be consulted for the individual timing range and step setting.

2.10 Measuring Elements

2.11 Zone 1 and Zone 2 elements

Both zone 1 and zone 2 have six measuring elements each. Three are for phase fault and three are for earth fault. Each element is independent giving the relay full scheme capabilities. The characteristic shapes available are circular polarised MHO for phase and earth fault and an option of quadrilateral characteristic for earth fault.

2.12 Zone 3 elements

Zone three has three phase fault phase fault elements and three earth fault elements The characteristic shapes available for both phase and earth fault are:-
Circular polarised MHO forward
Circular polarised MHO reverse
Circular offset MHO

Phase fault characteristics have the additional feature to allow for load encroachment and can be shaped.

An option of quadrilateral characteristic for earth fault is also available.

2.13 Zone 4 elements

This provides a reverse polarised MHO characteristic or E/F quadrilateral zone and is normally used in schemes which require reverse fault coverage or blocking schemes.

3 Additional Features

3.1 High Set Overcurrent

A High Set transient free overcurrent element is available this can be selectable to Instantaneous or Definite Time Lag (DTL). It has the following range of settings:-
0.1 – 6.0I_n in steps of 0.1
6.25 – 35I_n in steps of 0.25
0 – 1.0 s in steps of 0.001 s

3.2 Voltage Transformer Supervision (VTS)

Modes of operation:-
Alarm only
Alarm & inhibit
Inhibit can be selected to either block operation of phase & earth fault elements or to only block operation of earth fault elements during loss of voltage conditions.

VTS Ires level 0.05 – 2.0 I_n in steps of 0.1I_n
VTS Vres level 1 – 100V in steps of 1V

Output configuration:-

Instantaneous operation/reset
Minimum delayed alarm 100ms
Delayed alarm/reset 0.1 – 60s

3.3 Switch On To Fault

Two arrangements provide instantaneous tripping when switching on to a bolted three-phase fault.

a) D.C. Line check
This arrangement is energised from the circuit breaker closing circuit and allows instantaneous zone 3 coverage for a period of 400ms after energising the line.

b) A.C. Line check
This arrangement is not dependant on the circuit breaker closing circuit and allows instantaneous zone 3 coverage for a period of 200 ms after the line is energised. After the line is de-energised the line check resets after the programmed time delay. Line de-energisation is detected by three-phase pole-dead logic, while the line check measurement uses this in conjunction with phase current detectors.

3.4 Power Swing

The power swing element has a circular or rectangular offset element that consists of two concentric characteristics. The inner zone impedance is set between the ranges of 0.1 – 250 Ohms and the outer zone has a setting, which is a multiplier of the inner zone. This is set between 1.05 and 2x in steps of 0.01x.
The blocking detector uses a transition time between the inner and outer boundaries this is adjustable between 0 – 1000 ms in 5 ms steps.
The power swing blocking function will be released during an unsymmetrical fault.
The blocking can be arranged to block any zone.

3.5 Fault Locator

The fault locator is triggered by the fault recorder in the event of a general trip. It uses information from the waveform record associated with the fault to determine both the fault type and the line impedance between the relay and the fault location, ignoring any fault resistance. This information is then displayed as part of the relay fault record. By default, the location is displayed as a percentage of the positive sequence line impedance. This can be set in the range 0.1 – 250 ohms in magnitude, and uses the relay line angle as set for the distance protection.
The fault location can be displayed instead as a distance in miles or kilometres by selecting the required display units, and by setting an appropriate value for the secondary positive sequence impedance per unit length. This can be set in the range 0.001 to 5.000 ohms.

4 Indication

Indication is provided by 32 red LEDs; these are fully configurable to the user. Adjacent to each column of LEDs is a removable strip on which the LED function can be printed, allowing comprehensive fault indication. It is possible to print the indicator strip in languages other than English. The LCD provides further fault indication and can be used for programming the relay. See section 1 for a detailed explanation for the programming of the relay.

5 Output contacts

As with the indication the output contacts are fully programmable the basic I/O module has 5 output contacts three of which are change over. Additional modules can be added to provide more contacts. These are added in-groups of eight.

6 Status inputs

As with the indication and output contacts the status inputs are fully programmable the basic I/O module has 3 status inputs these can be set to high speed for signalling. Additional modules can be added to provide more inputs. These are added in-groups of eight.

7 Optional Features

7.1.1 Directional Earth Fault Setting Range

Polarising Quantity
1V polarising voltage

Characteristics:
DTL, IEC-NI, IEC-VI, IEC-EI,IEC-LTI, ANSI-MI, ANSI-VI, ANSI-EI.

DEF OverCurrent Setting
0.05 x I_n to 4 x I_n in steps of 0.05

DEF IDMTL Characteristic setting
0.05 x In - 4 x In in 0.05 steps.

DEF Characteristic Angle Setting
0° to 85° lagging in steps of 5°

DEF DTL Timer (DT1)
0 to 5 secs in steps of 10ms

DEF IDMTL Time Multiplier:
0.025-1.6 in steps of 0.025

RESET Characteristics:
DTL, Instantaneous, ANSI Decaying.

8 Performance Specification

Throughout the performance specification accuracy statements are made at reference conditions. These reference conditions are as follows:

Reference Conditions

General	IEC60255 Parts 6, 6A & 16
Auxiliary Supply	Nominal
Frequency	50 or 60Hz
Characteristic Line Angle	75°
Ambient Temperature	20°C

Zone 1 impedance 6.0 Ohms
Zone 2 impedance 6.0 Ohms
Zone 3 impedance 6.0 Ohms
Zone 4 impedance 6.0 Ohms

Neutral impedance Z_O/Z_1 ratio 2.5
Z_O angle = 75°

8.1 Accuracy General

Transient Overreach of Distance Protection for X/R = 35	±-5%
Disengaging Time	30ms

Note: Output contacts have a minimum dwell time of 100ms, after which the disengaging time is as above.

8.2 Accuracy Influencing Factors

Temperature

Ambient range	-10°C to +55°C
Variation over range	≤ 5%

Frequency

Range	47Hz to 52Hz 57Hz to 62Hz
Setting variation	≤ 5%
Operating time variation	≤ 5%

Harmonic Content

Harmonic content of waveforms	Frequencies to 550Hz
Operating time variation	≤ 5%

Auxiliary DC Supply – IEC 60255-11

Allowable superimposed ac component	≤ 12% of DC voltage
Allowable breaks/dips in supply (collapse to zero from nominal voltage)	≤ 20ms

8.3 Distance Function Reach

Reach Accuracy, ± 5% or 0.1 Ω which ever is greater up to an SIR of 30
Reach Accuracy, ± 10% or 0.1 Ω which ever is greater, from an SIR of 30 to an SIR of 60

Typical characteristics for all fault types are shown in Figure 4

Characteristic Angle Setting ≤ ±3°

Zone Timers (Z1T through Z4T)
≤ ±1% or ±10ms (whichever is greater)

8.4 Departure from Reference Angle

The nominal setting of the relay at angles other than the reference angle depends upon the characteristic shape. In general terms the impedance setting (Z) at any angle (Φ) can be expressed in terms of the nominal setting (ZN) at the reference angle (ΦN) as follows,

$$Z = Z_N f(\Phi)$$

Where $f(\Phi)$ is the equation defining the characteristic. Using this method the variation in characteristic shape can be simply specified in terms of class accuracy and the deviation from the reference angle. At nominal voltage the variations are listed below.

Circular characteristic

Φ_N – Nominal characteristic angle

Z_N – Nominal impedance setting

$Z_N^{\,1}$ – Measured impedance at nominal angle Φ_N

$$\text{For } \Phi = \Phi_N \pm 10°$$

$$Z = Z_N^{\,1} * \cos(\Phi_N - \Phi) \pm 0.05 Z_N$$

At other angles within the limits 90° ≥ Φ ≥ 0°

$$Z = Z_N^{\,1} * \cos(\Phi_N - \Phi) \pm 0.1 Z_N$$

The departure from reference angle is for a three phase balanced condition.

The above variations can also be applied to offset characteristics by transferring the origin.

8.5 Transient overreach

The class index plus an error not exceeding the class index.

8.6 Departure from reference setting

The class index plus an error not exceeding the class index.

8.7 Departure from reference frequency

Over the range of 47 – 52 Hz (50Hz nominal) or 57 – 62 Hz (60Hz nominal), the variations in accuracy are the class index plus an error not exceeding the class index.

8.8 Departure from reference temperature

The variations in accuracy over the operating temperature range is the class index plus an error not exceeding the class index.

8.9 High Set Overcurrent Function

Operating Current
≤ ±5% of setting

Reset current
>95% of operating current

Overcurrent Time (OCT)
≤ ±1% or ±10ms (whichever is greater)

8.10 Forward and Reverse Directional Earth Fault Functions

Operating Current
≤ ±5% of setting

Reset Current
>95% of operating current

Definite Time Lag
≤ ±1%

DEF DTL Timers (DEFF, DEFR)
≤ ±1% or ±5ms (whichever is greater)

8.11 Power Swing (PS) Impedance Variation Setting Range

Characteristic or Impedance Variation
≤ ±5% error

8.12 Timing

Figures 1, 2 and 3 shown typical timing curves.

8.13 Fault locator

Accuracy is dependant upon circuit configuration and power flow conditions.

8.14 THERMAL WITHSTAND

Continuous and Limited Period Overload

AC Current Inputs

12A	Continuous
15A	for 10 minutes
30A	for 2 minutes

AC Voltage Input – 3.5Vn	Continuous

Short Term Overload

340A	for 1 sec
240A	for 2 sec
625A	for 1 cycle (Peak)

AC Voltage Inputs

3.5Vn	Continuous

8.15 BURDENS

Current Circuits

	AC Burden (VA per phase)
1A tap	0.025
2A tap	0.1
5A tap	0.625

Voltage Circuits
0.01VA per phase

NB. Burdens and impedances are measured at nominal rating.

D.C. Burden

	DC Burden (watts)
Quiescent (Typical)	15
Max	27

9 OUTPUT CONTACT PERFORMANCE

Contact rating to IEC 60255-0-2.

Carry continuously 5A ac or dc

Make and Carry
(limit L/R ≤ 40ms and V ≤ 300 volts)

for 0.5 sec	20A ac or dc
for 0.2 sec	30A ac or dc

Break
(limit ≤ 5A or ≤ 300 volts)

ac resistive	1250VA
ac inductive	250VA @ PF ≤ 0.4
dc resistive	75W
dc inductive	30W @ L/R ≤ 40 ms 50W @ L/R ≤ 10 ms

Minimum number of operations	1000 at maximum load
Minimum recommended load	0.5W, limits 10mA or 5V

10 AUXILIARY ENERGIZING QUANTITY

DC Power Supply

	Nominal	Operating Range
VAUX	30/34V	24V to 37.5V dc
VAUX	50/110/125V	37.5V to 137.5V dc
VAUX	220/250/260V	175V to 286V dc

DC Status Inputs

Nominal Voltage	Operating Range
30/34	18V to 37.5V

48/54	37.5V to 60V
110/125	87.5V to 137.5V
220/250	175 to 286V

Status Input Performance (30V and 48V)

Minimum DC current for operation	10mA
Reset/Operate Voltage Ratio	≥ 90%

Status Input Performance (110V and 220V)

Minimum DC current for operation	1mA
Reset/Operate Voltage Ratio	≥ 90%

NB Status operating voltage need not be the same as the main energising voltage. 48/54 volt rated status inputs can be supplied with external dropper resistors, for use with 110V or 220V dc supplies, as follows:-

Status Input External Resistances

Nominal Voltage	Resistor Value; Wattage
110/125V	2k7 ± 5% ; 2.5W
220/250V	8k2 ± 5% ; 6.0W

Two types of status inputs are provided, viz:-

a) High speed status inputs.

Typical response time	<5ms
Typical drop off time	<5ms
Typical response time when programmed to energise an output relay contact	<10ms

b) Scheme status inputs. These status inputs will not respond to either 250V RMS 50/60 Hz applied for 1 second or to the discharge of a 10µF capacitor charged to maximum DC auxiliary supply voltage.

Typical response time	<25ms
Typical Drop off time	<25ms
Typical response time when programmed to energise an output relay contact	<30ms

11 ENVIRONMENTAL WITHSTAND

Temperature - IEC 6068-2-1/2

Operating range	-10°C to +55°C
Storage range	-25°C to +70°C

Humidity - IEC 6068-2-3

Operational test	56 days at 40°C and 95% RH

Transient Overvoltage –IEC 60255-5

Between all terminals and earth or between any two independent circuits without damage or flashover	5kV 1.2/50µs 0.5J

Insulation - IEC 60255-5

Between all terminals and earth	2.0kV rms for 1 min
Between independent circuits	2.0kV rms for 1 min
Across normally open contacts	1.0kV rms for 1 min

High Frequency Disturbance -
IEC 60255-22-1 Class III

	Variation
2.5kV Common (Longitudinal) Mode	≤ 3%
1.0kV Series (Transverse) Mode	≤ 3%

Electrostatic Discharge -
IEC 60255-22-2 Class III

	Variation
8kV contact discharge	≤ 5%

Radio Frequency Interference -
IEC 60255-22-3 Class III

	Variation
20MHz to 1000MHz, 10V/m	≤ 5%

Fast Transient – IEC 60255-22-4 Class IV

	Variation
4kV 5/50ns 2.5kHz repetitive	≤ 3%

Vibration (Sinusoidal) –IEC 60255-21-1 Class 1

		Variation
Vibration response	0.5gn	≤ 5%
Vibration endurance	1.0gn	≤ 5%

Shock and Bump–IEC 60255-21-2 Class 1

		Variation
Shock response	5 gn 11ms	≤ 5%
Shock withstand	15 gn 11ms	≤ 5%
Bump test	10 gn 16ms	≤ 5%

Seismic – IEC 60255-21-3 Class 1

		Variation
Seismic Response	1gn	≤ 5%

Mechanical Classification

Durability	In excess of 10^6 operations

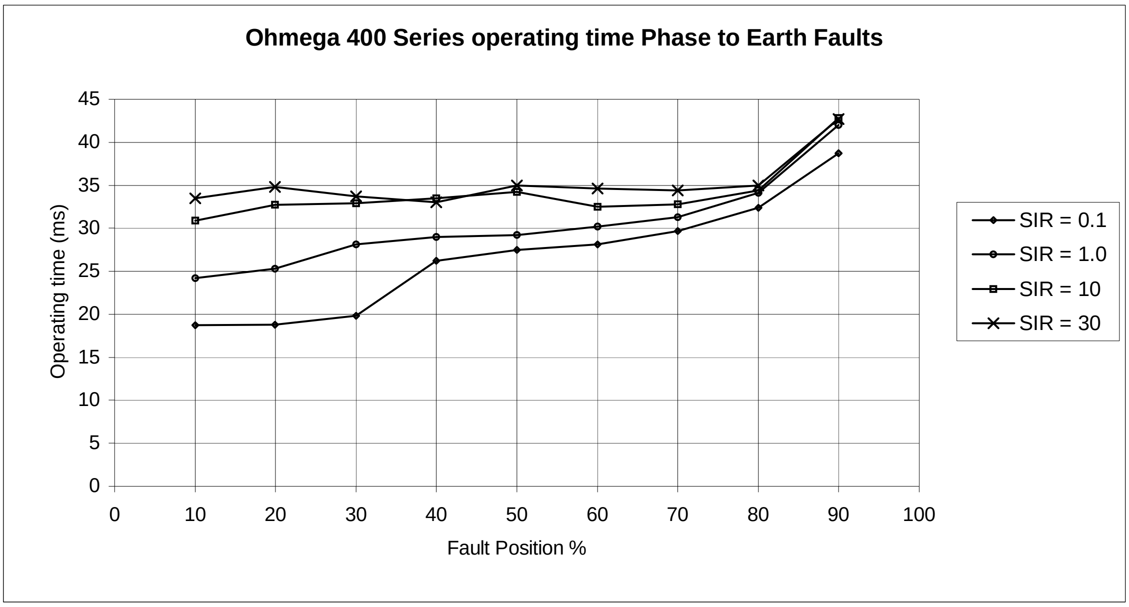


Figure 1

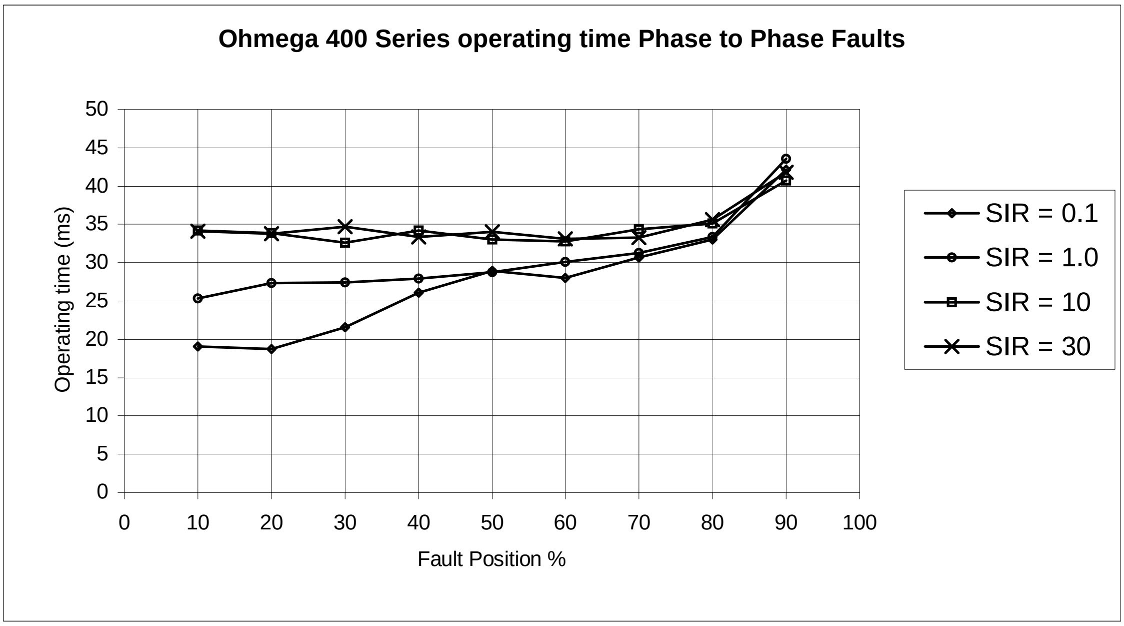


Figure 2

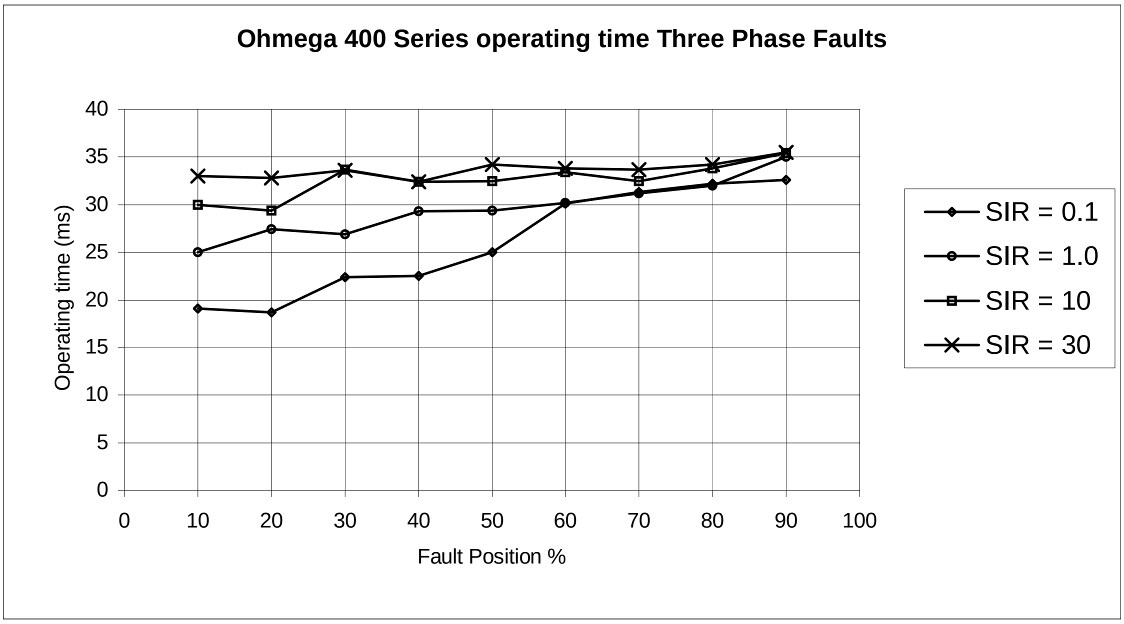


Figure 3

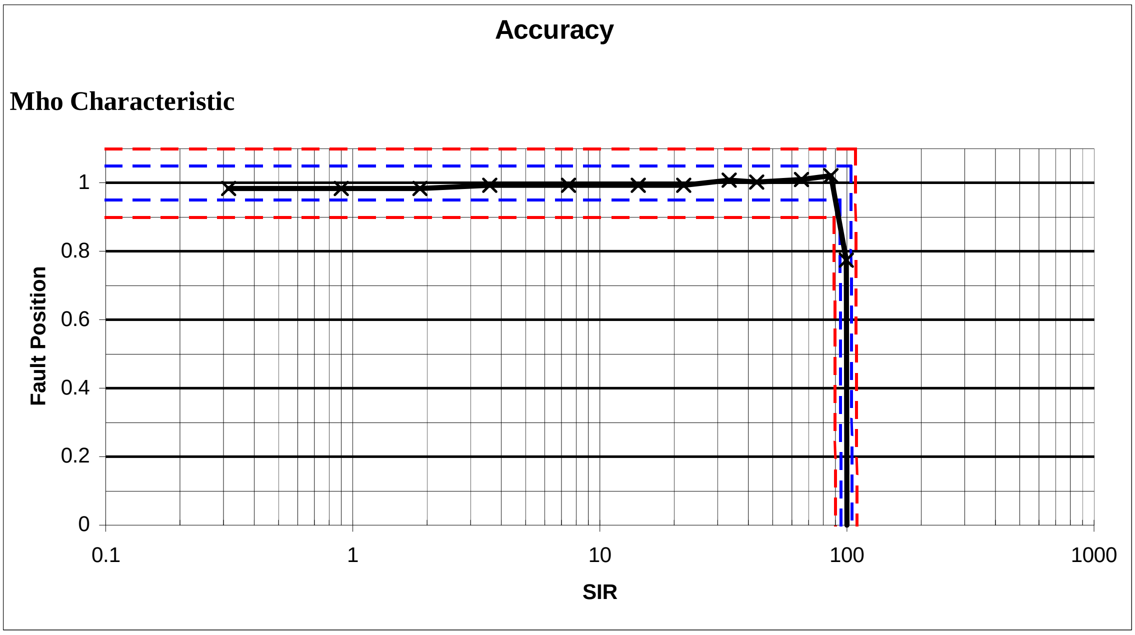


Figure 4

7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

Contents

1 INTRODUCTION

The Communication Interface module in the relay incorporates the following ports:

1 An IRIG-B input for time synchronisation

2 A pair of fibre optic ST connectors for transmit and receive communications (port 1).

3 A pair of fibre optic ST connectors as for (2) but intended for transmit and receive communications to a substation SCADA or integrated control system and using IEC 60870-5-103 protocol. (Port 2B). The same port can be accessed instead through an RS232 connector mounted on the relay fascia. (Port 2A). This provides facilities for access to the relay from a lap-top or PC used for commissioning or interrogating relays on site.

See the Installation section of this manual, for further information.

The following text gives details of connecting the IEC 60870-5-103 Complaint Informative Communication Interface to a control system or interrogating computer. To access the interface, appropriate software such as Reydisp Evolution is needed within the control system or the interrogating computer.

2 CONNECTION SPECIFICATION AND RELAY SETTINGS

This section defines the connection medium as defined by IEC 870-5-103. Appendix A shows some typical communication connections.

2.1 Recommended cable

200μm Plastic Coated Silica (PCS) or 62.5/125μm glass. All cables should be terminated with ST connectors.

2.2 Connection Method

Communication networks can be connected in star or optical ring format. The Optical Ring architecture requires data to be passed from one relay to the next, therefore when using this method all relays in the ring must have **Data Echo = ON** selected in the Communications Interface menu of the settings list. Otherwise this setting is to be **Data Echo = OFF**. Appendix A illustrates a number of network arrangements.

2.3 Transmission Method

Half Duplex serial asynchronous transmission. In IEC 60870-5-103 the line idle state is defined as **Light On**. This can alternatively be selected as **Light Off** in the Communications Interface menu of the settings list if required for use with alternate hardware (See Section 2.5).

2.4 Transmission Rate

Rates of **115200, 57600, 38400, 19200**, **9600**, **4800**, **2400**, **1200**, **600**, **300**, **150**, **110** and **75** bits per second (BPS) are provided. Only **19200** and **9600** BPS are defined in IEC 60870-5-103, the additional rates are provided for local or modem communications.

2.5 Line Idle Setting

The line idle setting must be set to be either **ON** or **OFF** to be compatible with the device connected to the relay. IEC 60870-5-103 defines a line idle state of **Light On**. Unless the device connected to it has a compatible fibre optic port Sigma 4, a converter to connect it to a standard RS232C electrical interface is needed.

Alternately, it may be connected via a **Sigma 3 Dual RS232 Port** or **Sigma 1 Passive Fibre Optic Hub.**

The Sigma 3 Dual RS232 port provides a Fibre-Optic interface to a relay and 2 RS232 Ports. The RS232 system port is typically connected to a control system. Both this and the Fibre Optic port would usually be hidden from view inside a panel. The second RS232 port is local port. When it is in use the system port is automatically disabled. The Dual port device has an internal link to define whether the fibre optic port will operate as **Light On** or **Off**. Default is **Off**.

The Sigma 1 Passive Fibre Optic Hub provides fibre optic interfaces for up to 29 relays. It has a fibre optic port to the control system and multi relay connect. Each of the 30 fibre optic ports can be configured for **Light On** or **Off** operation. Default for all is **Off**.

2.6 Parity Setting

IEC 60870-5-103 defines the method of transmission as using **Even** Parity, however, in some instances an alternative may be required, this option allows the setting of parity to **None**.

2.7 Address Setting

The remaining setting on the communications menu is the Address setting. The address of the relay must be set to a value between 1 and 254 inclusive before communication can take place. Setting the address to zero disables communications to the relay, although if it is in an optical ring it will still obey the Data Echo setting. All relays in an optical ring must have a unique address. Address 255 is reserved as a global broadcast address.

2.8 Modems

The communications interface has been designed to allow data transfer via modems. However, IEC 60870-5-103 defines the data transfer protocol as an 11 bit format of 1 start, 1 stop, 8 data and Even Parity which is a mode most commercial modems do not support. High performance modems, for example, Sonix (now 3Com) Volante and Multi Tech Systems MT series will support this mode, but are expensive. For this reason a parity setting (see section 2.6) to allow use of easily available and relatively inexpensive commercial modems has been provided. The downside to this is that the data security will be reduced slightly, and the system will not be compatible with true IEC60870 control systems.

2.8.1 Connecting a modem to the relay(s)

RS232C defines devices as being either Data Terminal Equipment (DTE) e.g. Computers, or Data Communications Equipment (DCE) e.g. Modems, where one is designed to be connected to the other. In this case two DCE devices (the Modem and the Fibre-Optic Converter converter) together via a Null Terminal connector which switches various control lines. The Fibre-Optic converter is then connected to the relay network Tx to Relay Rx and Rx to Relay Tx.

2.8.2 Setting the Remote Modem

The exact settings of the modem are dependent on the type of modem preset. Although most support the basic Hayes ‘AT’ command format, different manufacturers use different commands for the same functions. In addition, some modems use DIP switches to set parameters, others are entirely software configured.

Before applying the following settings it is necessary to return the modem to its factory default settings, to ensure it is in a known state.

There are several factors which must be set to allow remote dialling to the relays. The first is that the modem at the remote end must be configured as Auto Answer. This will allow it to initiate communications with the relays. Next the user should set the data configuration at the local port, i.e. baud rate and parity, so that communication will be at the same rate and format as that set on the relay; and the error correction is disabled.

Auto-Answer usually requires 2 parameters to be set. The auto answer setting should be switched on and the number of rings after which it will answer. The Data Terminal Ready (DTR) settings should be forced on. This tells the modem that the device connected to it is ready to receive data.

The parameters of the modem’s RS232C port need to be set to match those set on the relay, set baud rate and parity to be the same as the settings on the relay, and number of data bits to be 8 and stop bits 1. Note, although it may be possible to communicate with the modem at say 19200 BPS it may only be able to transmit over the telephone lines at 14400. Therefore a baud rate setting that the modem can transmit should be chosen. In this case, there is no14400 BPS on the relay choose the next lowest i.e. 9600 BPS.

Since the modems need to be transparent, simply passing on the data sent from the controller to the device and vice versa, the error correction and buffering must be turned off.

In addition if possible force the Data Carrier Detect (DCD) setting to ON as this control line will be used by the Fibre-Optic converter.

Finally these settings should be stored in the modem’s memory for power on defaults.

2.8.3 Connecting to the remote modem

Once the remote modem is configured correctly, should it be possible to dial into it using standard configuration from a local PC. As the settings on the remote modem are fixed, the local modem should negotiate with it on connecting and choose suitable matching settings. If it does not, set the local modem to mimic the settings of the remote modem described above.

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1 INTRODUCTION

This family of Digital Distance Relays give full scheme protection with independent measurements for every zone and fault loop. Impedance starting elements are not required. Optional features provide a full range of protection functions supplements by control, metering, data storage, fault locator, auto-reclose and fibre optic data communication capabilities.

The relays can be applied to either overhead line or cable feeders and, depending on the availability and type of teleprotection channels available, can be configured to provide unit protection in a number of different models.

2 CURRENT TRANSFORMER REQUIREMENTS

The current transformers used with the relay should be class TPS to IEC 46-6 (ie BS3938 class x). The CT's should have a knee point voltage Vk as follows:-

$$V_k = K.\frac{I_p}{N}\left(1 + \frac{X_p}{R_p}\right)(0.03 + R_{ct} + R_l)$$

$$V_k = K.\frac{I_e}{N}\left(1 + \frac{X_e}{R_e}\right)(0.06 + R_{ct} + R_l)$$

Where:

I_p = Primary phase fault current calculated for X_p/R_p ratio at the end of zone 1.

Ie = Primary earth fault current calculated for $\underline{X_e}$ ratio at the end of zone 1

N = C.T. ratio

X_p/R_p = power system resistance to reactance ratio for the total plant including the feeder line parameters calculated for a phase fault at the end of zone 1.

X_e/R_e = similar ratio to above but calculated for an earth fault at the end of zone 1.

R_{ct} = C.T. internal resistance

R_l = lead burden, C.T. to relay terminals

K = factor chosen to ensure adequate operating speed and is <1. K is usually 0.5 for distribution systems, a higher value is chosen for primary transmission systems.

Both V_k values should be calculated and the higher value chosen for the C.T. to be used.

3 DETERMINATION OF RELAY SETTINGS

3.1 Information Required For The Setting Calculations

To match a distance protection relay to a feeder the following data must be known:-

- Positive sequence of the feeder Z_1 ohm/km
- Zero sequence impedance of the feeder Z_0 ohms/km
- Length of protected feeder
- Maximum and minimum fault current infeed at relaying point
- Current transformer ratio
- Voltage transformer ratio
- Impedance of adjacent lines which are partially or wholly included within the Zone 2, 3 or 4
- The position, rating and reactance of any power transformers connected to the system within the zone 3 forward and reverse impedance reach.
- Fault current infeeds at tee-off points or remote substations
- Fault clearance time on circuits within the Zone 2 and Zone 3 and Zone 4 impedance reaches
- Maximum load current
- Phase angle of line impedance
- Maximum residual capacitance current at the relaying points for earth faults in adjacent circuits
- Minimum residual current available to operate the earth fault detector

3.2 Distance Protection Settings

The first settings in the menu are common for all zones. The relay will use a time-stepped scheme by default. All relay schemes are detailed in Section 3 of this manual.

3.2.1 Overall Settings.

The first settings made in the distance protection menu apply to all zones of protection. The CT secondary, is set as set as 1A, 2A or 5A depending on the CT rating. The line angle is the angle of the positive sequence impedance of the feeder.

3.2.2 Residual Compensation Settings.

The Zone reach settings for each zone of protection are made in terms of the positive sequence impedance of the transmission line. To allow the earth fault comparators to correctly take account of the fault loop impedance, the ratio of voltage to current is multiplied by a factor of K_N+1, where K_N is the Residual Compensation Factor, which may be determined from the following equation; $K_N = \frac{1}{3}\left(\frac{Z_0}{Z_1} - 1\right)$

Settings made on the relay are:

EF Comp Z0/Z1 ratio. This is simply the ratio between the zero and positive sequence impedances. It ranges between 0 – 10 in 0.01 steps.

EF Comp Z0 Angle. This is simply the angle of the zero sequence impedance. It is set from 0-355° in 5° steps.

The relay automatically calculates the residual compensation from these two settings.

3.2.3 Zone 1 Impedance Setting

Normal practice is to make the Zone 1 setting equal to 80% of the positive sequence impedance of the protected feeder to allow for the inherent errors in estimating line impedance's and possible errors in voltage and current transformers.

Settings other than 80% are possible, but to ensure that the relay does not overreach into the remote busbars, care is necessary when choosing such settings. It is particularly important to ensure that the impedance of the protected feeder is accurately known and the mutual effects due to adjacent feeders are considered for all known operating conditions. On a teed-feeder the Zone 1 impedance setting should be approximately 80% of the positive sequence impedance from the relaying point to the nearer of the remote ends.

On lines with tee-off transformers connected to them, the Zone 1 setting can extend beyond the tee-off point, provided it does not reach beyond the windings of any transformer. If a transformer is earthed on the line side, it can supply zero sequence current which is equivalent to an infeed (see Fig. 1), and should be considered when choosing the Zone 1 setting.

On feeder transformers, Zone 1 impedance should be set to cover at least 1.2 times the positive sequence impedance of the feeder. It should not, however, exceed 0.8 times the sum of the feeder impedance and the transformer impedance.

Having decided upon the impedance setting required, the relay setting is determined as follows:- Zone 1 Setting = $L_1 \times C/V$

where: L_1 = required Zone 1 reach in primary positive sequence ohms.
C = protection current transformer ratio
V = protection voltage transformer ratio

The available setting ranges are:- 1 amp relay = 0.1 – 250 ohms
2 amp relay = 0.1 – 125 ohms
5 amp relay = 0.1 – 50 ohms

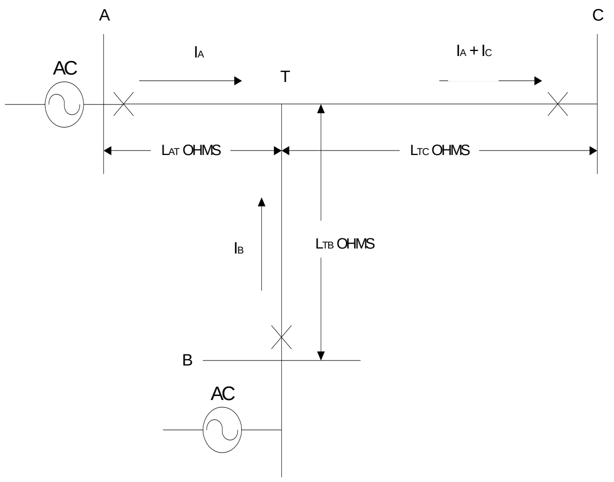
The minimum recommended settings are:- 1 amp relay = 0.1ohms
2 amp relay = 0.2ohms
5 amp relay = 0.5ohms

The Zone 1 resistance setting for earth fault quad characteristics is set to give an adequate resistive cover to allow for tower footing resistance and arc resistance. This setting is required in secondary ohms.

3.2.4 Zone 2 Impedance Setting

Zone 2 impedance setting should be at least 1.2 times the positive sequence impedance of the protected feeder. For teed feeders the setting should be at least 1.2 times the impedance to the most remote end, the effect of infeeds at the tee points being allowed for as shown in the setting for maximum infeeds, but care should be taken to ensure that the relay does not encroach onto the second zone of distance protection of adjacent feeders for minimum fault infeed conditions.

On lines with tee-off transformers connected to them, the tee-off transformers can supply zero sequence current if they are earthed on the line side. This is equivalent to an infeed as indicated in and must be taken into account when choosing the Zone 2 setting. Normally the Zone 2 reach will be set so that it does not extend beyond a power transformer, but should a particular application require an extended reach of this nature, then care should be taken to grade the protection accordingly.



The Zone 2 reach is obtained by adjusting the impedance setting.

$$Zone2\ Setting at\ A \geq 1.2\left[L_{AT} + L_{TC}\left(\frac{I_A + I_B}{I_A}\right)\right]$$

The Zone 2 Resistance setting for earth fault quad characteristics is set to give an adequate resistive cover to allow for tower footing resistance and arc resistance. This setting is required in secondary ohms and is often set to the same value as Zone 1 Resistance.

The Zone 2 and Zone 3 timers are normally set to give a grading margin between the zones and ensure that fault clearance times are achieved.

3.2.5 Zone 3 Impedance Setting

The Zone 3 impedance setting will depend upon the system adjacent to the protected feeder and the amount of back-up protection required. To give back-up protection on the protected feeder, the Z3 should be at least equal to and not less than the Z2 setting.

The Zone 2 and Zone 3 timers are normally set to give a grading margin between the zones and ensure that fault clearance times are achieved.

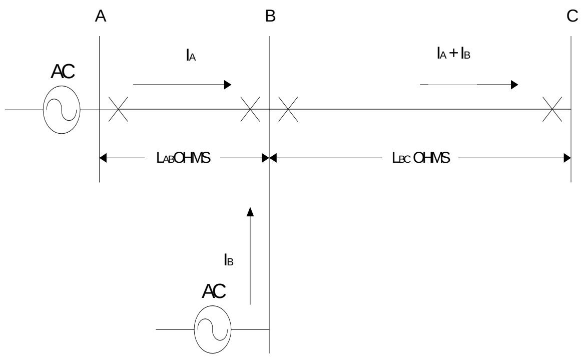
On lines with tee-off transformers, the transformers can supply zero sequence current if they are earthed on the line side. This is equivalent to an infeed as indicated in and should be considered when choosing the Zone 3 setting. Care should be taken to grade the Zone 3 setting with the rest of the system.

As with Zone 2, the Zone 3 forward reach will normally be set so that it does not extend beyond a power transformer, however if a particular application requires an extension of reach beyond a transformer then the protection should be graded accordingly.

The characteristic of the zone 3 allows for a reverse reach setting which is adjustable and this is programmed as a secondary impedance. This reach is used to provide time delayed backup protection for the busbars behind the relay and the short zone immediately prior to the line CT.

The Zone 3 forward reach is obtained by adjusting the impedance setting.

$$Zone\ 3\ Forward\ Setting\ at\ A \geq 1.2\left[L_{AB} + L_{BC}\left(\frac{I_A + I_B}{I_A}\right)\right]$$



3.2.6 Zone 4 Impedance Setting

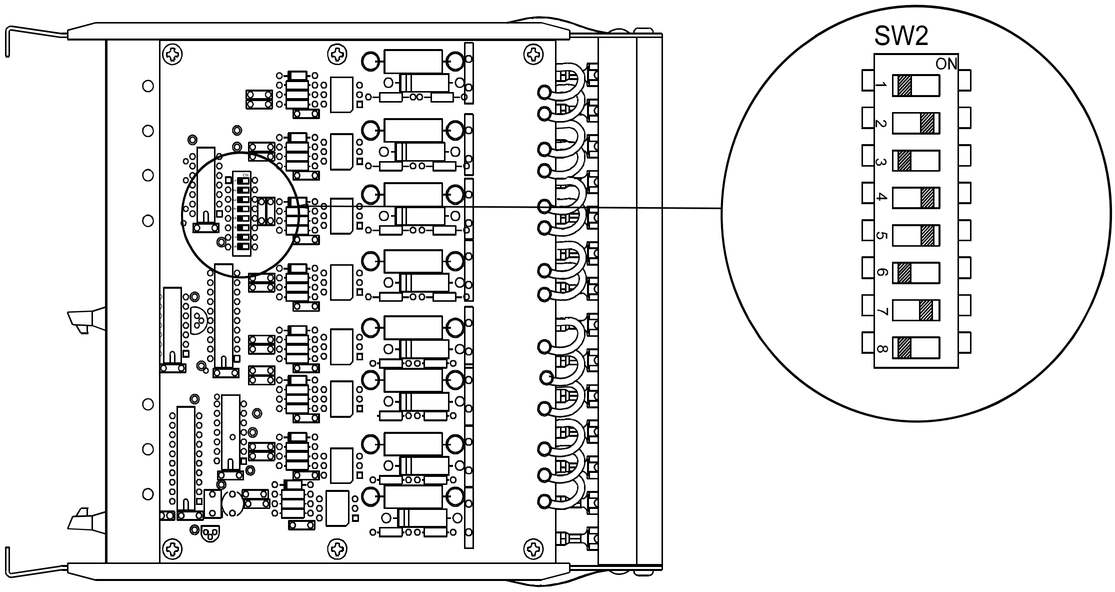
The Zone 4 setting has an independent impedance range the line angle is the mirror image of the forward angle and is not independently adjustable. The Zone 4 impedance element can be used to directly trip the relay or it can be used with the scheme logic to provide reverse looking fault detection for protection blocking schemes.

The Zone 4 resistance setting for earth fault quad characteristics is set to give an adequate resistive cover to allow for tower footing resistance and arc resistance. This setting is required in secondary ohms.

APPENDIX A Status Inputs

As stated in the “Performance Specification” (section 5 of this manual), status inputs used for protection signalling are high speed devices with operating times of under 5ms. As supplied, all status inputs are of this type.

If a status input is being employed to control a circuit breaker (i.e. trip or close) and the external wiring route takes it outside the panel on which the relay is mounted into the electrically onerous area of a substation and the initiation circuit is not double pole switched, it is recommended that an ESI 48-4-1 compliant version is used. Should the user require any status input to meet the requirements of ESI 48-4-1 for ac rejection and capacitive discharge ie to have high stability in the presence of spurious signals, the relevant status input module should be withdrawn from the relay case and the desired inputs changed in accordance with figure 3.



Note: Switch SW2 controls 8 status inputs. As supplied, all switches are in the left hand position and all status inputs are high speed devices.
For high stability use, the relevant switch should be moved to the right hand position as shown for switches 2, 4, 5 & 7.

Figure 3. Status input control.

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1 UNPACKING, STORAGE AND HANDLING

On receipt, remove the relay from the container in which it was received and inspect it for obvious damage. It is recommended that the relay modules are not removed from the case. To prevent the possible ingress of dirt, the sealed polythene bag should not be opened until the relay is to be used.

If damage has been sustained a claim should immediately be made against the carrier, also inform the local Siemens office.

When not required for immediate use, the relay should be returned to its original carton and stored in a clean, dry place.

The relay contains static sensitive devices, these devices are susceptible to damage due to static discharge and for this reason it is essential that the correct handling procedure is followed.

The relay’s electronic circuits are protected from damage by static discharge when the relay is housed in its case. When individual modules are withdrawn from the case, static handling procedures should be observed.

- Before removing the module from its case the operator must first ensure that he is at the same potential as the relay by touching the case.
- The module must not be handled by any of the module terminals on the rear of the chassis.
- Modules must be packed for transport in an anti-static container.
- Ensure that anyone else handling the modules is at the same potential.

As there are no user serviceable parts in any module, there should be no requirement to remove any component parts.

If any component parts have been removed or tampered with, then the guarantee will be invalidated. Siemens reserve the right to charge for any subsequent repairs.

2 RECOMMENDED MOUNTING POSITION

The relay uses a liquid display (LCD) which is used in programming and or operation. The LCD has a viewing angle of ± 45º and is back lit. However, the best viewing position is at eye level, and this is particularly important when using the built-in instrumentation features.

The relay should be mounted to allow the operator the best access to the relay functions.

3 RELAY DIMENSIONS

The relay is supplied in an Epsilon case 16. Diagrams are provided elsewhere in this manual.

4 FIXINGS

4.1 Crimps

AMP PIDG or Plasti Grip Funnel entry ring tongue

Size	AMP Ref
0.25-1.6mm^2	342103
1.0-2.6mm^2	151758

4.2 Panel Fixing Screws

2-Kits – 2995G10046 each comprising:

- Screw M4 X10
  2106F14010 – 4 off

- Lock Washes
  2104F70040 – 4 off

- Nut M4
  2103F11040 – 4 off

4.3 Communications

ST fibre optic connections – 4 per relay (Refer to section 4 – Communications Interface).

5 ANCILLARY EQUIPMENT

The relay can be interrogated locally or remotely by making connection to the fibre optic terminals on the rear of the relay or the RS232 port on the relay fascia. For local interrogation a portable PC is required. The PC must be capable of running Microsoft Windows Ver 3.1 or greater, and it must have a standard RS232 port. A standard data cable is required to connect from the PC to the 25 pin female D type connector on the front of the relay. For remote communications more specialised equipment is required. See the section on Communications for further information, and also see Report No. 690/0/01 on Relay Communications.

6 PRECAUTIONS

When running fibre optic cable, the bending radius must not be less than the minimum radius specified by the cable manufacturer.

If the fibre optic cables are anchored using cable ties, these ties must be hand tightened – under no circumstances should cable tie tension tools or cable tie pliers be used.

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1 COMMISSIONING

A separate commissioning guide is available for each model of the relay which details the testing of each function.

1.1 Required Test Equipment

1000V Insulation resistance test set.

Digitally controlled automatic test equipment suitable for distance relay testing (3 phase o/ps)

Primary injection equipment 5KVA with variable 500A output

Phase sequence meter

A d.c. supply with nominal voltage within the working range of the relays d.c. auxiliary supply rating.

A d.c. supply with nominal voltage within the working range of the relays d.c. input rating.

Additional equipment for testing the communications channel:
Portable PC with fibre optic modem, or RS232 connections.

2 INSPECTION

Ensure that all connections are tight and in accordance with the relay wiring diagram and the scheme diagram. Check the relay is correctly programmed and fully inserted into the case. Refer to the Description of Operation for programming the relay.

3 APPLYING SETTINGS

The relay settings for the particular application should be applied before any secondary testing occurs. If they are not available then the relay has default settings which can be used for pre-commissioning tests. Note the input and output relays must be programmed correctly before any scheme tests are carried out. See the Relay Settings section of this manual for the default settings.

The relay feature eight alternative settings groups. In applications where more than one settings group is to be used then it may be necessary to test the relay in more than one configuration.

When using settings groups it is important to remember that the relay need not necessarily be operating according to the settings which are currently being displayed. There is an "active settings group" on which the relay operates and an "edit/view settings group" which is visible on the display and which can be altered. This allows the settings in one group to be altered while the protection continues to operate on a different unaffected group. This "active settings group" and the "edit settings group" are selected in the "System Configuration Menu".

Elsewhere in the settings menu system, those settings which can be altered for different groups are indicated by the symbols G1, G2 etc in the top left of the display. Other settings are common to all groups.

4 PRECAUTIONS

Before testing commences the equipment should be isolated from the current and voltage transformers and the CT's short circuited in line with the local site procedures. The tripping and alarm circuits should also be isolated where practical. Ensure that the correct d.c. supply voltage and polarity is applied. See the relevant scheme diagrams for the relay connections.

5 TESTS

5.1 Insulation

Connect together all of the C.T. terminals and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together all of the V.T terminals and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the DC auxiliary supply circuit and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the DC status input circuits and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Connect together the terminals of the output relay circuits and measure the insulation resistance between these terminals and all of the other relay terminals connected together and to earth.

Satisfactory values for the various readings depend upon the amount of wiring concerned. Where considerable multi-core wiring is involved a reading of 2.5 to 3.0 Megaohms can be considered satisfactory. For short lengths of wiring higher values can be expected. A value of 1.0 Megaohm or less should not be considered satisfactory and should be investigated.

Remove temporary connections.

5.2 Secondary Injection

Select the required relay configuration and settings for the application.

Configure the status input and output relays to the requirements of the schematic diagrams. Also select the scheme logic applicable to the protected circuit from the system configuration menu, as well as the relevant CT and VT ratios.

The relay is equipped with comprehensive self testing routines which automatically check correct initialisation and processing operation. The "Protection Healthy" LED is under software control and if, after application of the correct DC supply, it gives a steady light this is an indication that the relay is functioning correctly. A flashing LED, or no LED light indicates faulty equipment. As there are no user serviceable components in the withdrawable modules, faulty relays must be returned to Siemens.

Using the automatic test equipment, inject 1 amp 3 phase into the current circuits of the relay and apply 63.5 volts 3 phase to the voltage circuits. Check that the fascia display indicates the correct corresponding primary currents and voltages applicable to the relevant instrument transformer ratios selected. If the metering displays on the fascia are correct all the relay operations under load and fault conditions will be correct.

If possible each status input should be energised in turn and checked for correct operation and fascia display.

Check the operation of each output relay by selecting it in the "Test Plant Control" setting.

Correct operation of all the above checks will ensure that the relay will perform correctly. If added confidence is required, each element can be individually tested with the appropriate current and voltage from the test set, and the settings verified.

5.3 Primary Injection

Current Transformer Connections
Check that the supply links and fuses are arranged as follows:-

- Trip links removed
- Voltage transformer links removed
- Earth links inserted
- Current transformer connected for normal operation
- To test the current transformers for ratio, relative polarity and soundness of the secondary leads, connect the circuit as shown in figure 1. Inject at least 50% of the rated primary current into the red-yellow phases - record the ammeter readings in Table 1. Check that:-
- Meters A, A1, A2 and relay meter readings Ia and Ib give the same reading (corrected if necessary, for different C.T ratios).
- Meters A3, A4 and relay meter readings Ia and Ix give negligible current readings
- Repeat the above test, but with primary current injected into the yellow-blue phases. Record current recordings in Table 1. Check that:-
- Meters A, A2 and A3 and relay meter readings 1b and Ic give the same reading (corrected if necessary, for different C.T. ratios).
- Meters A1 and A4 and relay meter readings Ia and Ix give negligible current readings.

- Inject at least 50% of the rated primary current into the red phase (figure 1b). Record the ammeter readings in Table 1. Check that:-
- Meters A, A1, A4 and relay meter readings Ia and Ix give the same reading.
- Meters A2, A3 and relay meter readings Ib and Ic give negligible current readings.

Table 1 Current Transformer Connections

Current Transformer Secondary Levels									
	Ammeter Readings								
Current Injection	A	A1	A2	A3	A4	Ia	Ib	Ic	Ix
R-Y Phases									
Y-B phases									
R Phase									

Primary Current =
Test CT Ratio =
Line CT Ratio =
Relay set CT Ratio =

Table 2 Voltage Transformer Connections

Voltage Transformer Secondary Voltages									
R-N	Y-N	B-N	R-Y	Y-B	B-R	Va	Vb	Vc	Vx

Primary Voltage =
V.T Ratio =

Check that the supply links and fuses are arranged as follows:-

- Trip links removed
- Voltage transformer fuses and links inserted
- Current transformers connected for normal operation
- Earth links inserted
- Measure the phase to neutral and phase to phase voltages at the relay terminals and also the phase to phase voltages on the relay terminals and also the phase to neutral voltages on the relay display Tabulate the results in table 2.
- Check the phase sequence of the voltage transformer supply.

5.4 Load Checks

Directional Check
Check that the arrangement of supply links and fuses are arranged as follows:-

- Trip links removed
- Voltage transformer fuses and links inserted
- Current transformers connected for normal operation
- Earth links inserted

For this test a three-phase load current is required. Select the fascia display to INSTRUMENT MODE. Scroll in this mode until the power flow direction meter is displayed.

This meter indicates the direction of power flow forward or reverse, of each phase. If three dashes appear on the display, this indicates that the power flow is too small to accurately give direction. If power flows from busbars to feeder, the direction displayed is forward.

If the directions are opposite to those expected, the relay is incorrectly connected and a careful check should be made of the schematic and wiring diagrams and the necessary wiring alternatives made and the test repeated.

5.5 Tripping Tests

Having established the validity of the relay connections it is advisable to check the d.c. wiring to the trip and control circuits.

To do this repeat the zone 1 secondary injection tests above with the trip links inserted. Check that for phase-phase faults all three phases of the circuit breaker are tripped and any associated signalling and repeat relay operations occur correctly. If possible, using a P.C. or laptop computer loaded with Reydisp Evolution software, check the current and voltage waveforms and relay operations. For phase-earth faults, check that correct tripping as per scheme is obtained i.e. either single pole tripping or three pole tripping with the associated control operations.

6 PUTTING INTO SERVICE

- Remove the external test connections and heavy duty test plugs
- Check that the current and voltage transformer are wired for normal operation
- Check that all a.c. and d.c. supply links and fuses are inserted
- Check that the earth links are inserted
- Check that all the relay settings are as recommended.
- Test and reset the LED indication display
- Replace the relay cover
- Insert the trip link

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1 MAINTENANCE INSTRUCTIONS

The relay is a maintenance free device, with no user serviceable parts. During the life of the relay it should be checked for operation during the normal maintenance period for the site on which the product is installed. It is recommended the following tests are carried out:

1 Visual inspection of the metering display (every year)

2 Operation of output contacts (every 2 years)

3 Secondary injection of each element (every 5 years)

2 TROUBLE SHOOTING GUIDE

The following table describes the action of the relay under various conditions, and suggested remedial actions when problems are encountered.

If problems are being experienced and the suggested action does not work, or the problem is not detailed below, then please contact Siemens.

SYMPTOM	PROBLEM	ACTION
LCD Screen is faint or difficult to read.	Contrast too low	Press TEST/RESET & UP Button simultaneously
LCD Screen is dark or has lines across it.	Contrast too high	Press TEST/RESET & DOWN Button simultaneously
Protection Healthy LED not lit, LCD blank, Backlight off & No Flag LEDS lit.	Relay is not powered up	Check Auxiliary DC supply is available. Check connections on rear of relay.
Relay LCD displays “PSU alarm asserted, supply out of limits”	Power supply is too low.	Check the magnitude of the input DC voltage. Ensure it is within the relay’s working range of 37.5 to 137.5 V
	Internal ribbon cable connection not made.	Check ribbon connection cable to module A is correctly attached.
Protection Healthy LED blinking, Messages & cursor blocks flashing across the LCD screen	Internal ribbon connections not made correctly	Check ribbon connection cables to each module are correctly attached.
Relay displays “Number of inputs or outputs changed… Relay must cold start… Settings will be defaulted…Please press enter”	Relay has performed a cold start due to a perceived change in hardware.	If the hardware has not been changed (i.e. status input/relay output card added or removed) then there may be a problem with the hardware. Contact Siemens
Protection Healthy LED is flashing. Protection Healthy Output contact is not energised.	Watchdog Operated: Hardware or Software Fault	Contact Siemens
Protection Healthy LED is steady, and LCD screen displays ohmega symbols (Ω). Protection Healthy Output contact is not energised.		

SYMPTOM	PROBLEM	ACTION
Relay unable to communicate using ReyDisp Evolution software	Communication channel incorrectly configured. Refer to Section 6 of this manual for more details on the configuration of the Communication Channel	Ensure connection between PC and relay (either via the front RS232 port or TX2 and RX2 on the rear of the relay) has been correctly made.
		Ensure Relay address is set correctly on both the relay and within ReyDisp Evolution. If the relay address is set to “0” the relay will not communicate.
		Ensure the baud rate / parity settings on the PC are the same as those set on the relay.
		If using the front port ensure that the setting *IEC870 on Port* is set to COM2 & COM2 DIRECTION is set to either Auto-Detect or the port being used.

DEFECT REPORT FORM

Please copy this sheet and use it to report any defect which may occur

Customers Name & Address:			Contact Name:	
			Telephone No:	
			Fax No:	
Supplied by:			Date when installed	
Site:			Circuit:	
Date Found:	During Commissioning:	During Maintenance:	From a System Fault:	Other, please state:
Product Name: 7SG164			Serial Number:	
Copy any message displayed by the relay:				
Describe Defect:				
Describe any other action taken:				

Signature:	Please print name:	Date:

For Siemens use only:					
Date Received:	Contact Name:	Reference No:	Date acknowledged:	Date of Reply	Date Cleared:

Siemens Protection Devices
PO Box 8
HEBBURN
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Fax: +44 (0)191 401 5575

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1 Relay Connections

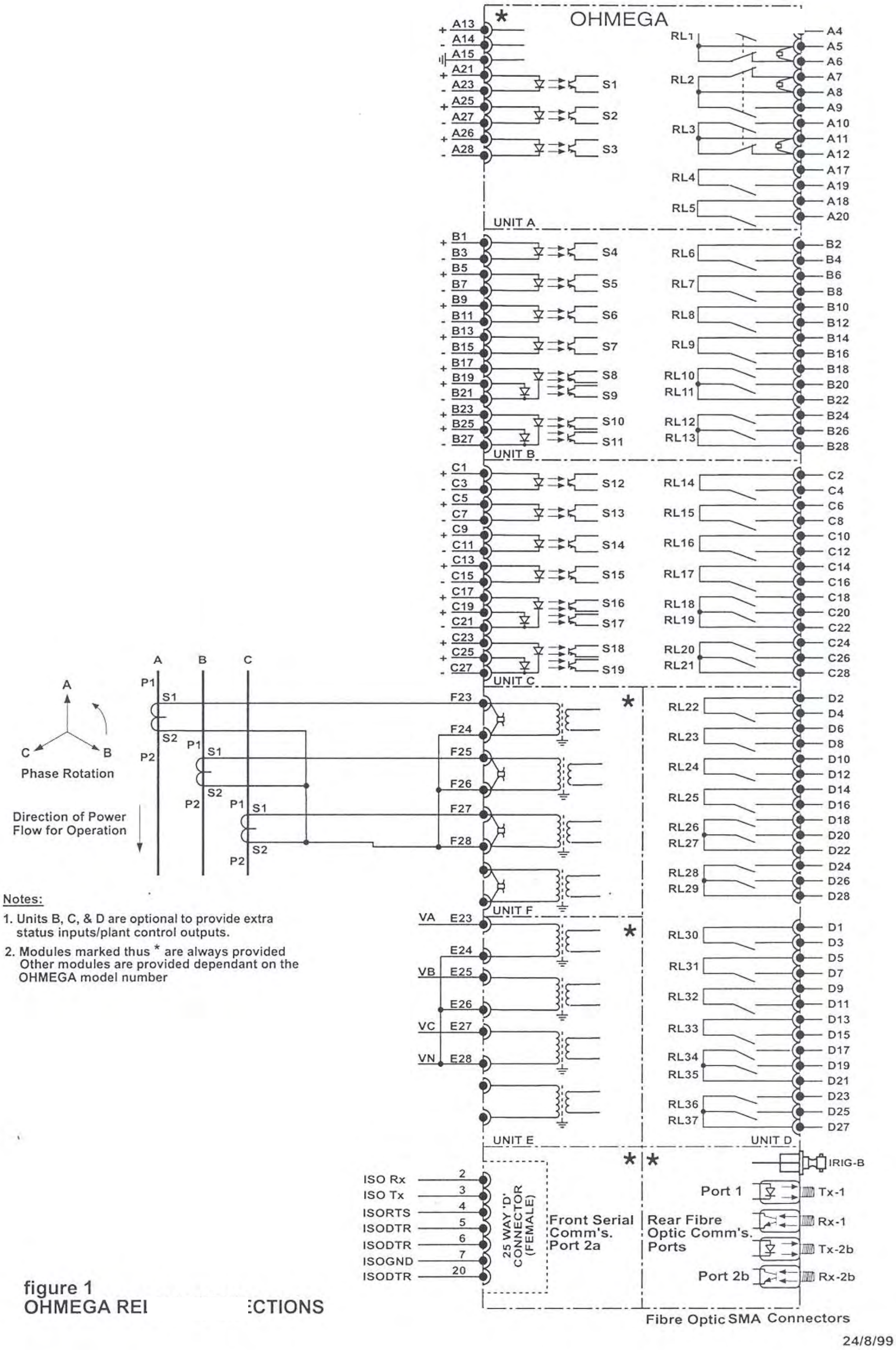
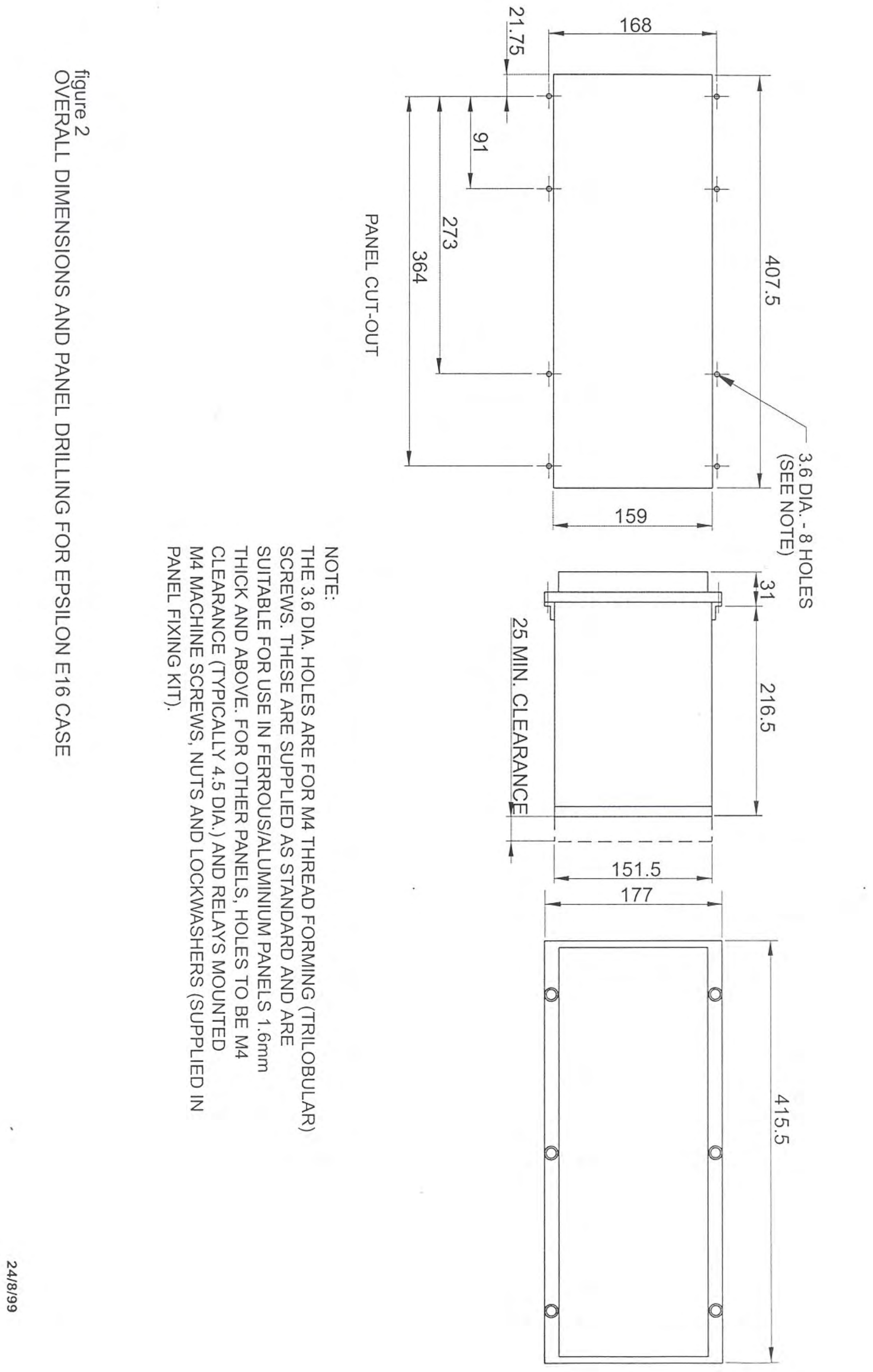


figure 1
OHMEGA REI :CTIONS

2 Overall dimensions and panel drilling for Epsilon E16



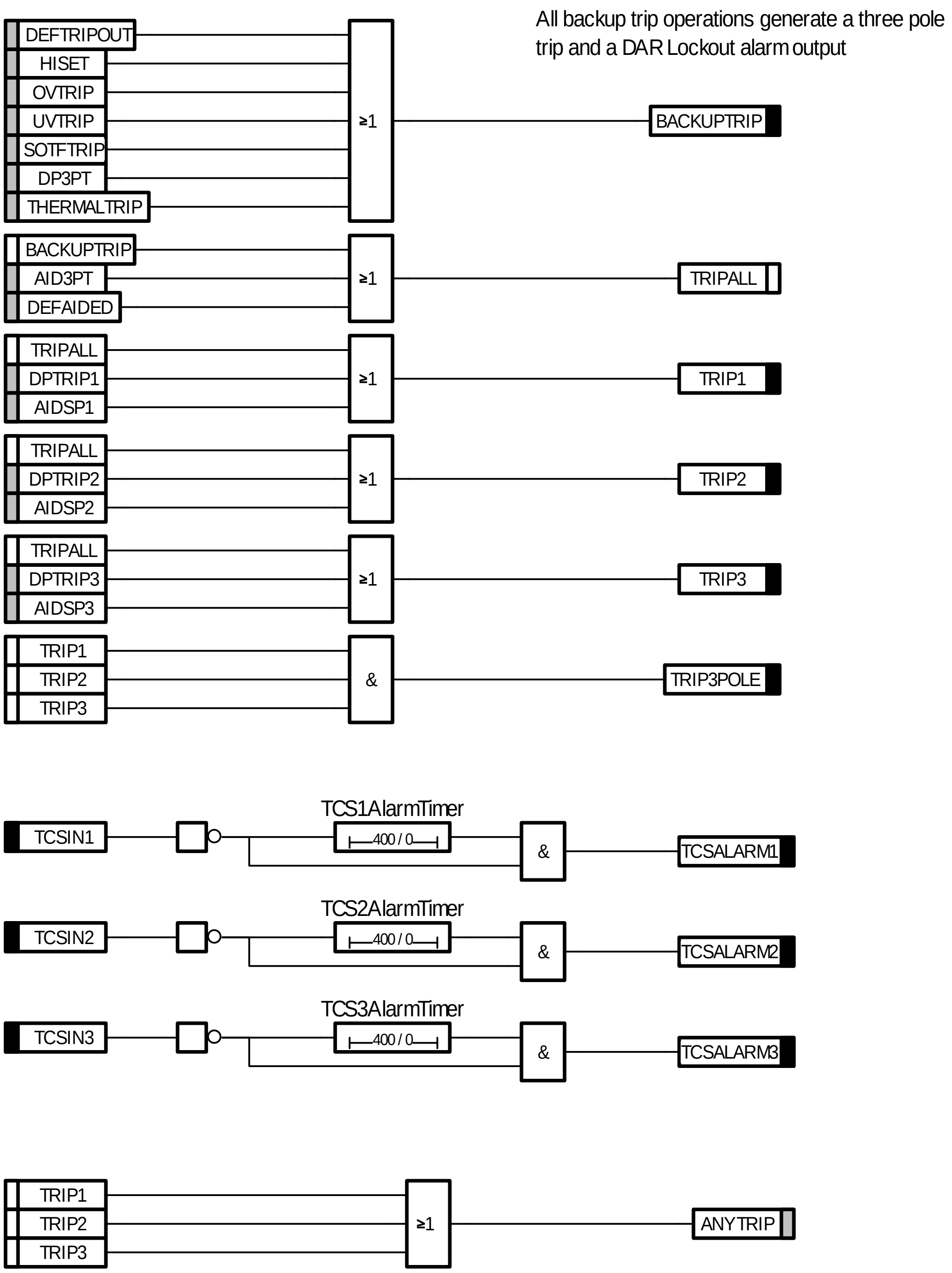
3 Reylogic Diagrams.

The following diagrams show the logic used in the relay. This is split up into three sections – firstly the logic used for the distance protection function, then the auxiliary function logic, then finally the scheme logic.

Distance Protection

Trip Outputs

This diagram is responsible for final generation of the trip signals. It not only connects the single pole outputs to the matrix, but also generates the 3 pole operation from the TRIPALL boolean. Also contains the trip circuit supervision logic and the general ANYTRIP boolean for connection to the autoreclose logic.

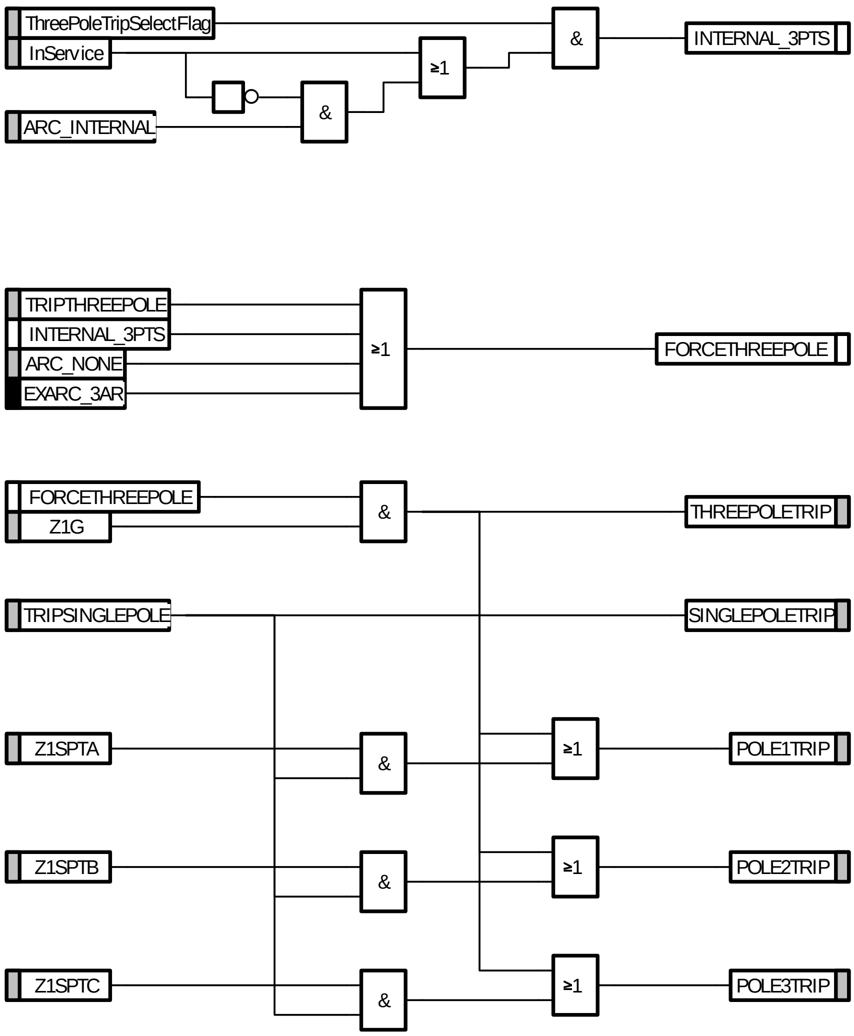


Single Pole Tripping

This diagram provides single pole tripping for distance zone 1, supported by the sequence current check module outputs. The enable/disable setting provides the FORCETHREEPOLE input.

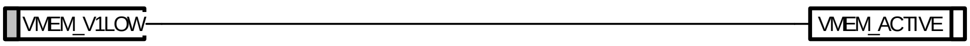
The check module provides the TRIPTHREEPOLE and TRIPSINGLEPOLE bools. If the fault is determined to be three pole, or single pole tripping is disabled, then a three pole trip is forced on operation of any zone 1 comparator. If single pole tripping is enabled and the fault looks like single phase, then single pole tripping is left to the zone 1 logic outputs to be decided.

Additional logic allows the autorecloser to force three pole tripping when it requires it. Also, an external autorecloser can be used with the relay, and we must allow for it to force three pole trips via an external control. If there is no recloser in use at all, then WE MUST FORCE ALL TRIPS TO BE THREE POLE. A setting will provide this functionality. The FORCETHREEPOLE boolean also needs to used within the scheme logic to force three pole tripping as appropriate.

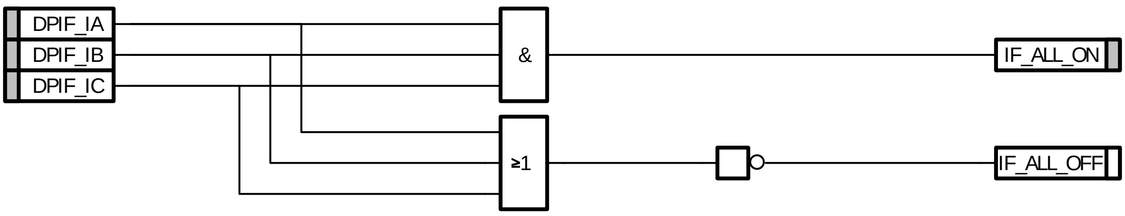


Voltage Memory

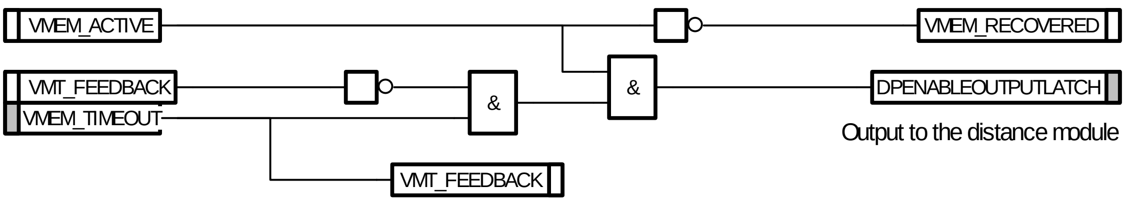
When a heavy three phase fault occurs, the fault voltage will collapse and the voltage memory will start timing out. After approx 100ms, the memory output will clamp off and the memory timeout signal will go active. This applies an inhibit to zone 1 and (where fitted) zone 4. The latch operation is required to prevent dropoff of the trip relays too early because of removal of of the comparator outputs. Reset occurs when memory recovers (voltage back) or the fault current is removed in all phases.



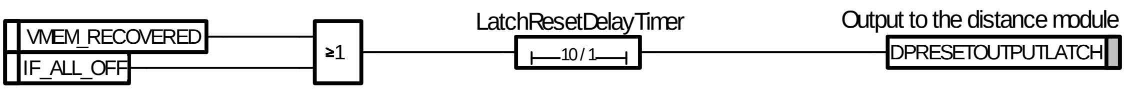
Next, we generate a reset control from the distance fault current detectors



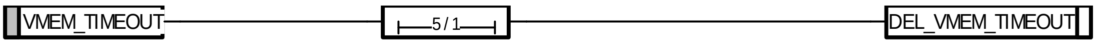
Next, we generate the latch control signals for use by the distance module output latches - first the latch enable



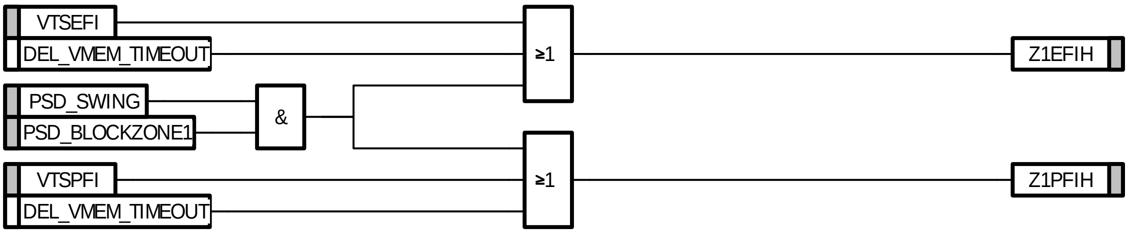
Now the latch reset signal



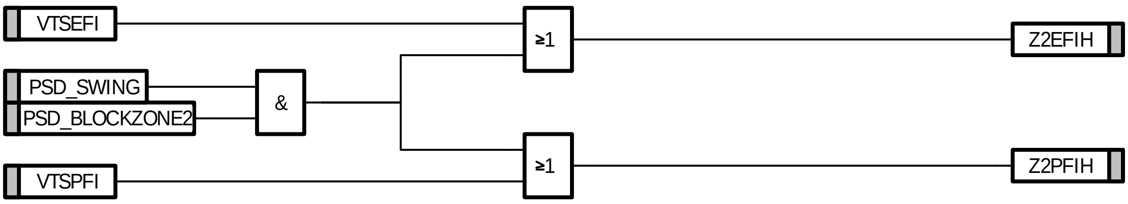
Trip Inhibit Logic



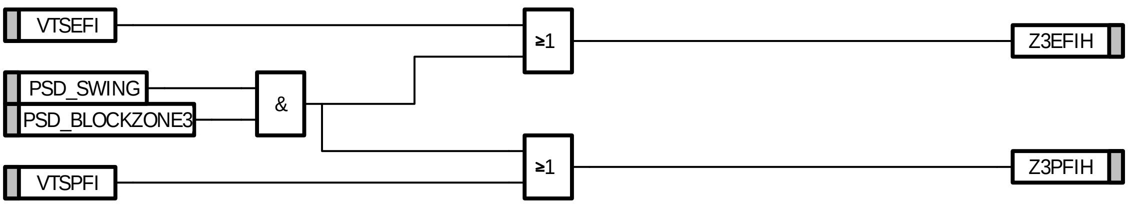
Allow Zone 1 to be inhibited by Power Swing, VTS, or Voltage Memory timing out.



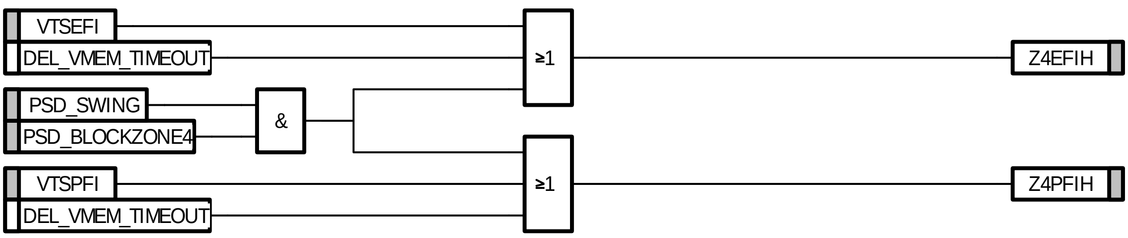
Allow Zone 2 to be inhibited by the same; Power Swing, VTS, or Vmem timed out.



Zone 3 has no memory voltage, so only inhibit from Power Swing and VTS



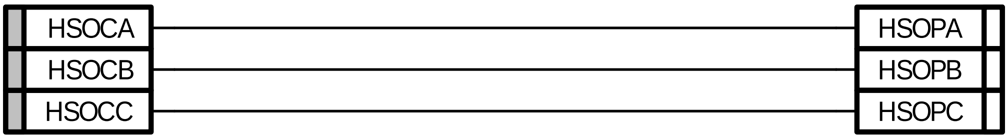
Zone 4 does have memory voltage, so inhibit from all, ie Power Swing, VTS, or Vmem timed out.



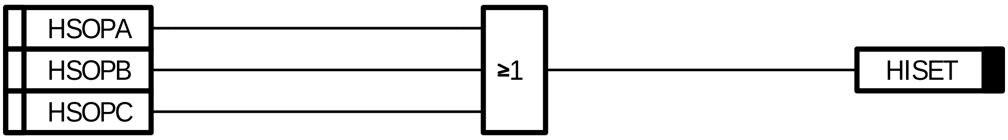
Auxilary Functions

High Set Overcurrent

Copy the protection output booleans to local bools for speed/safety

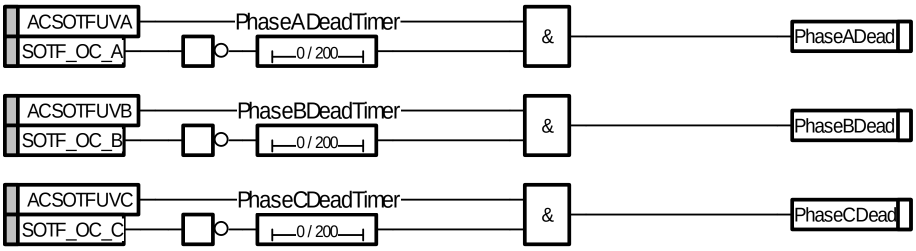


Generate an alarm output for the hiset. This is also used later as a 3 pole trip

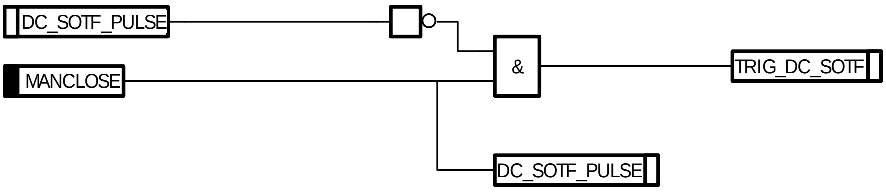


Switch-onto-Fault

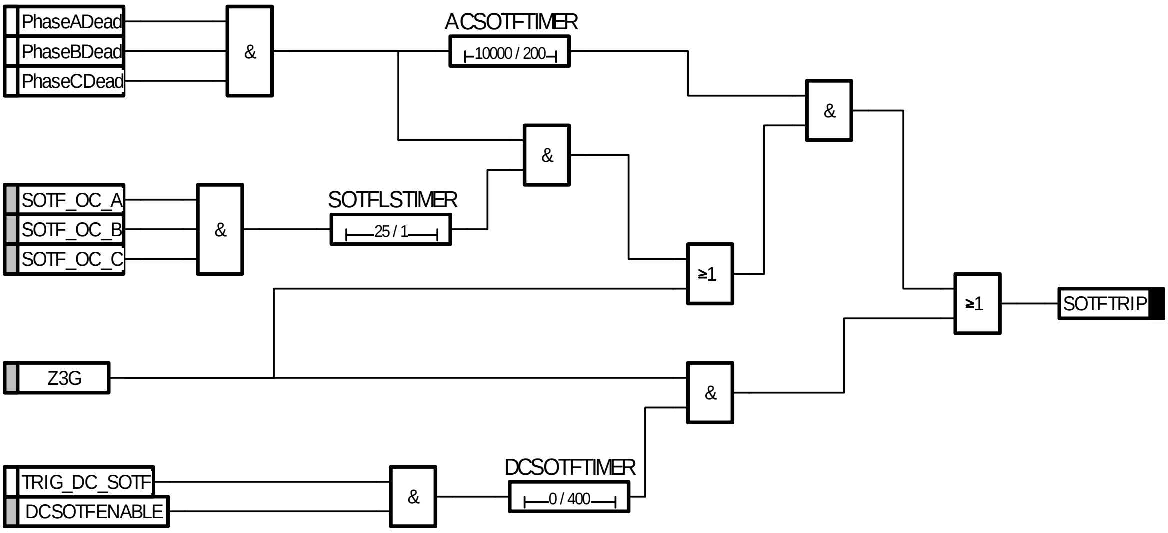
First test each pole to see if it's 'dead'



Generate a pulse from the manual close input.

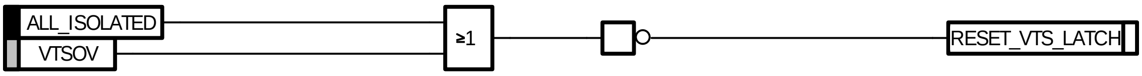


Now use this to evaluate the SOTF logic

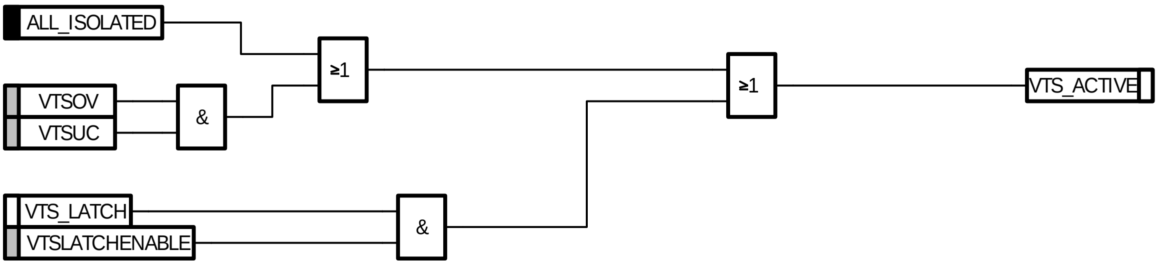


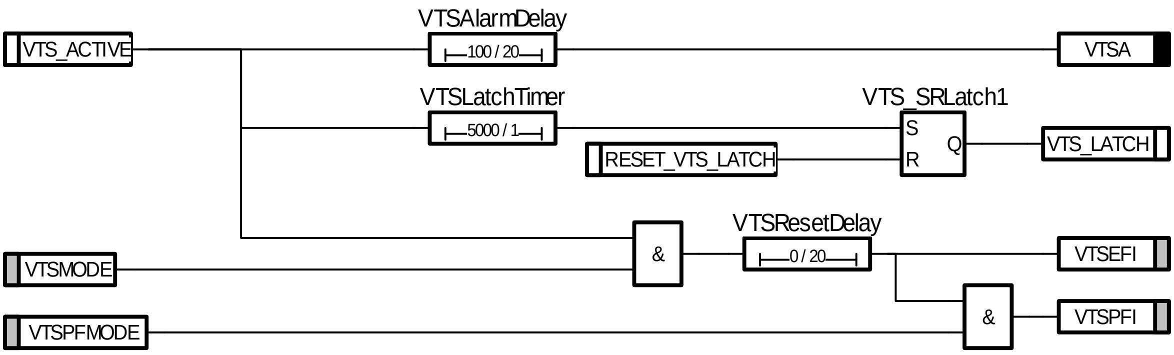
Voltage Transformer Supervision

Generate the latch reset from the voltage recovery



Now the actual VTS logic

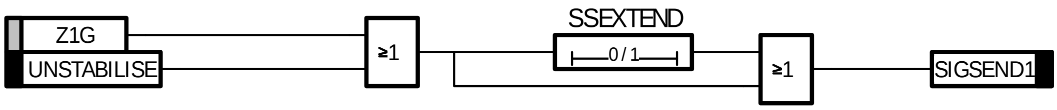




Protection Schemes

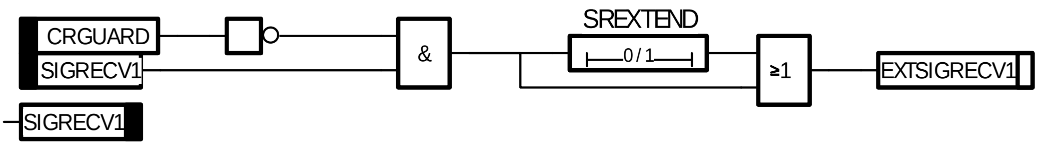
PUR

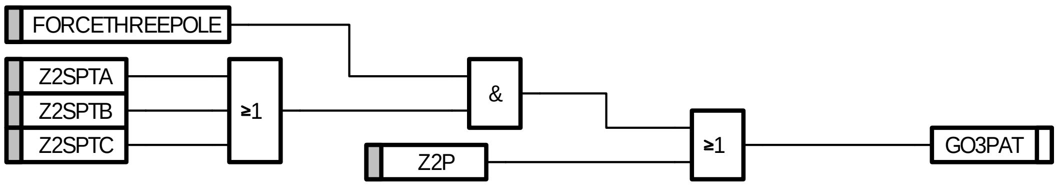
First, generate signal send from Zone 1 instantaneous, or the unstabilising input, which is either a manual operation, or comes from an external protection relay, giving us an intertrip

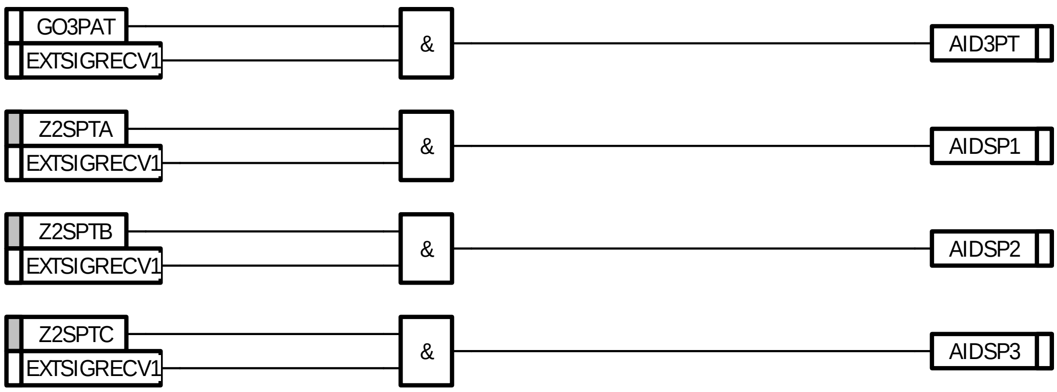


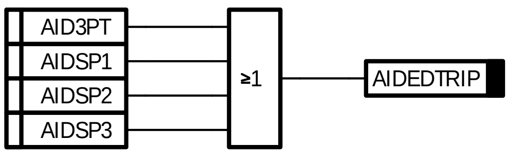
Next, we generate two forms of the aided trip signal; one from the zone 2 phase instantaneous output, and the other a phase segregated version for single pole tripping from the single pole trip logic.

We also generate an output tag for the signal received input.

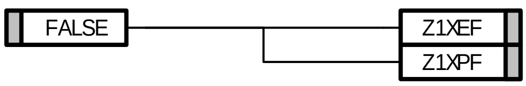






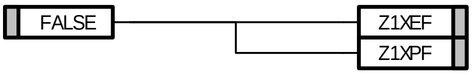


Clear the reach extension control flags - that scheme obviously not in use

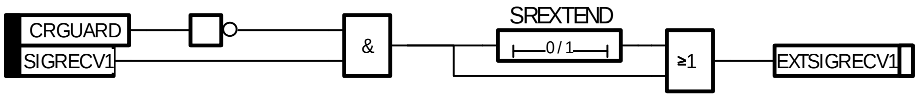


POR 1

Clear the reach extension control flags to ensure that the Zone 1 distance elements are using normal Zone 1 settings



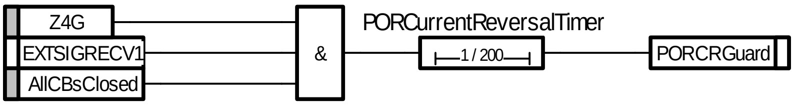
Process Signal Receive 1 first. Carrier receive guard signal from the comms equipment should be high when there is a problem with the carrier equipment. This would then block signal receive and prevent any nuisance operations due to communications channel or equipment failure.



SIGRECV1 Allow an output for alarm or test purposes

Current Reversal Logic

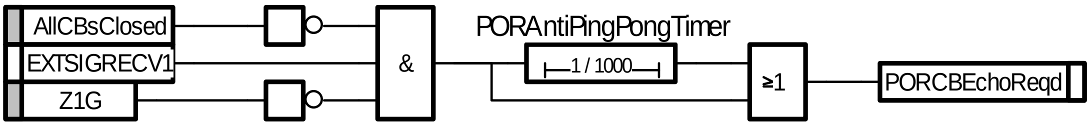
When the relay is applied to a feeder which has another in parallel, then if there is a fault on the adjacent feeder we may see it as a reverse fault. When the CB on the adjacent feeder at this end opens, then if the breaker at the other end operates more slowly, there is a chance that the fault current will reverse and we will see the fault as a forward operation for a time. If we are already receiving a signal from our partner relay at the other end of our feeder, then we are in danger of tripping due to current reversal. To overcome this we use current reversal guard. If we see a reverse fault and a signal, and all of our CBs are closed, then we block operation for a user defined period after the reverse fault has been removed or the signal has dropped off. Zone 4 does the reverse fault detection.



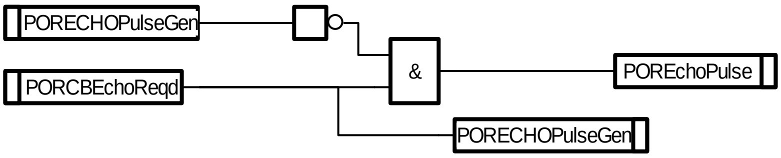
CB Echo

If any of the Circuit Breakers at this end are open, we see SigRx and there is no fault, then reflect the signal straight back to the sending end to allow it to trip.

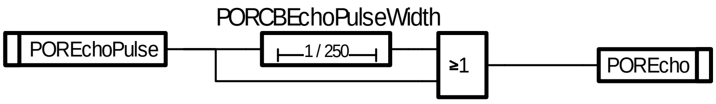
To avoid a lockup situation where the CB Echos at each end reinforce each other and prevent SigSend from dropping off we limit the duration of the CB Echo signal and keep the CB Echo Required signal asserted until the trigger condition has been absent for 1 second.



Generate a pulse for 1 reylogic execution period to start the echo pulse monostable

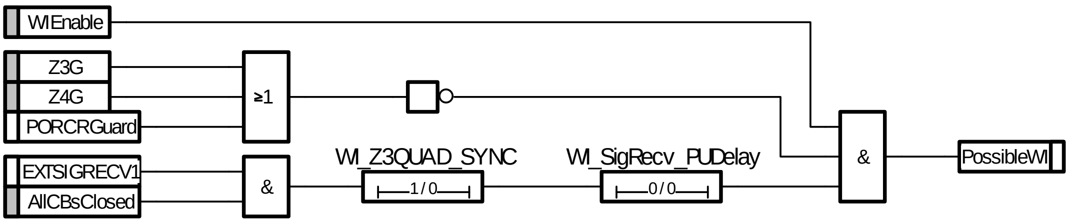


This is the echo pulse monostable. This stretches the single period pulse generated above into one of user specified width (default 250ms).

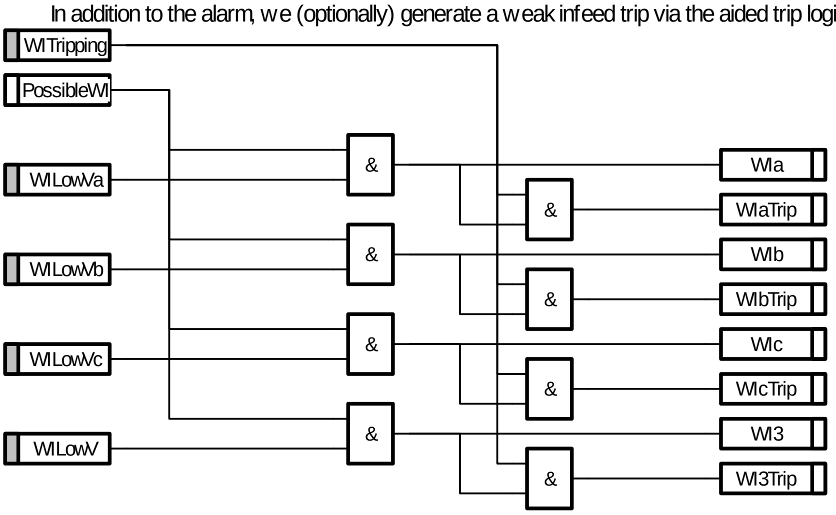


Weak Infeed Logic

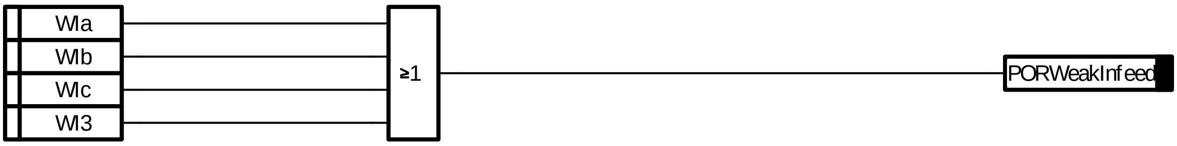
Under certain system conditions, such as on radial systems, or where the source capacity at one end of a line is reduced for some reason, then there may not be sufficient fault current flowing for the relay to determine the fault impedance. Under these circumstances we use weak infeed protection. This uses the fact that the relay at the remote (strong) end can see a fault and so sends us a signal, but we cannot see a fault. In addition, our CBs must be closed. We use these criteria to say that there may be a fault in front of us that we cannot see.



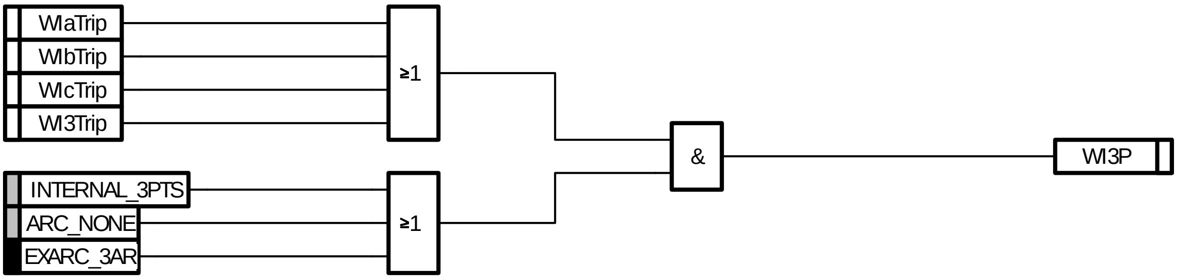
The possibility of a weak infeed condition is then confirmed by the use of phase undervoltage detectors. If there is a weak infeed condition, then we will see only the fault voltage (which will be very small), and so we can generate phase seqregated weak infeed booleans (WIx), and a general weak infeed alarm. For phase to phase conditions, there will be two voltages low, for which the UV detector gives us a general output to use for 3 pole operation.
In addition to the alarm, we (optionally) generate a weak infeed trip via the aided trip logic.



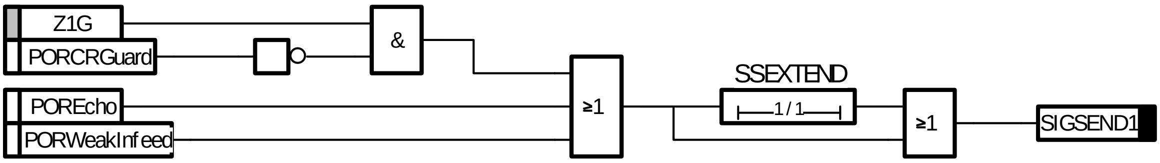
Combine the WIx booleans to give a general weak infeed alarm output.



Combine the WIxTrip booleans to give a general weak infeed Trip output.

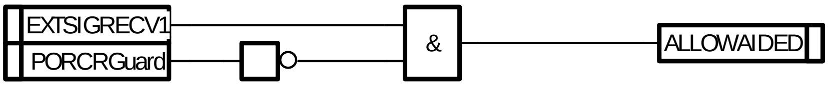


Now the signal send logic. POR1 uses Z1 for SigSend, qualified with no current reversal, and we also send a signal for CB echo and for weak infeed conditions.

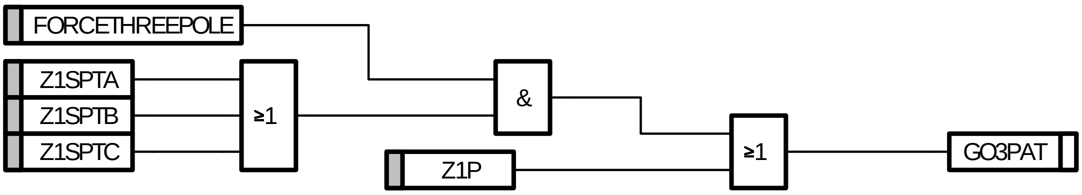


Aided Trip Logic

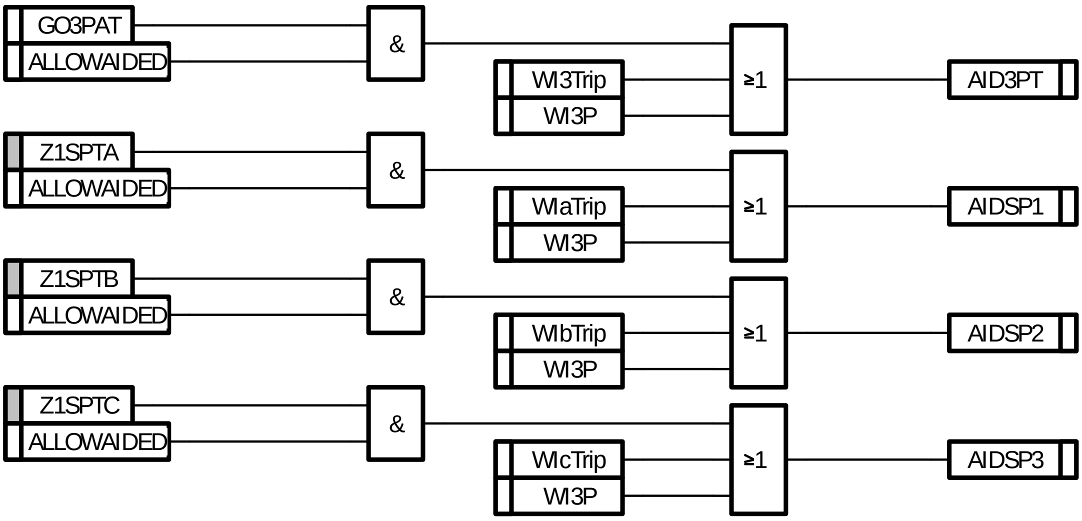
First we generate an enabling signal from SignalRx AND no Current Reversal Guard



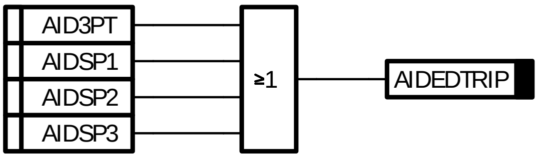
Three pole aided tripping is used for phase faults, or where 3P trips are forced.



Now we generate the aided trip signals. These may be three pole trip or single pole where allowed. These are used within the trip logic diagram.

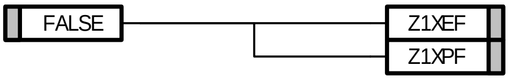


Combine the aided trip signals to give us a general aided trip for alarm and indication

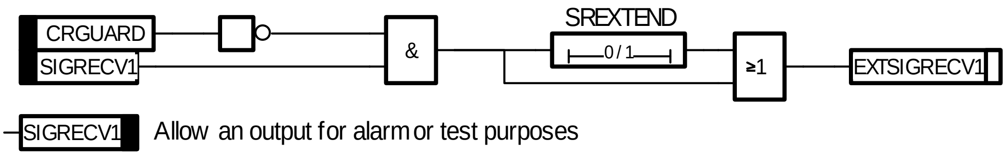


POR2

Clear the reach extension control flags to ensure that the Zone 1 distance elements are using normal Zone 1 settings



Process Signal Receive 1 first. Carrier receive guard signal from the comms equipment should be high when there is a problem with the carrier equipment. This would then block signal receive and prevent any nuisance operations due to communications channel or equipment failure.



Current Reversal Logic

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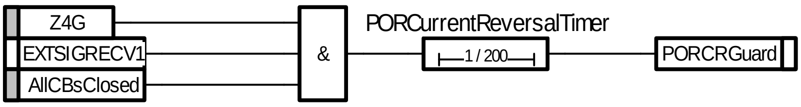

CB Echo

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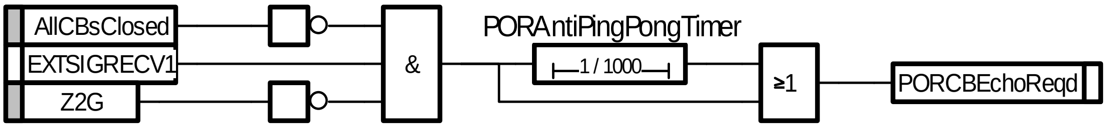
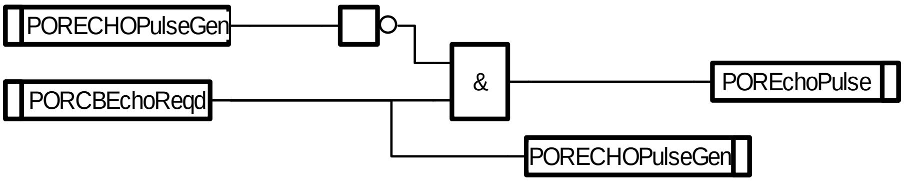
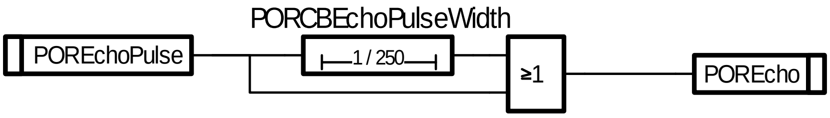
To avoid a lockup situation where the CB Echos at each end reinforce each other and prevent SigSend from dropping off we limit the duration of the CB Echo signal and keep the CB Echo Required signal asserted until the trigger condition has been absent for 1 second.



Generate a pulse for 1 reylogic execution period to start the echo pulse monostable

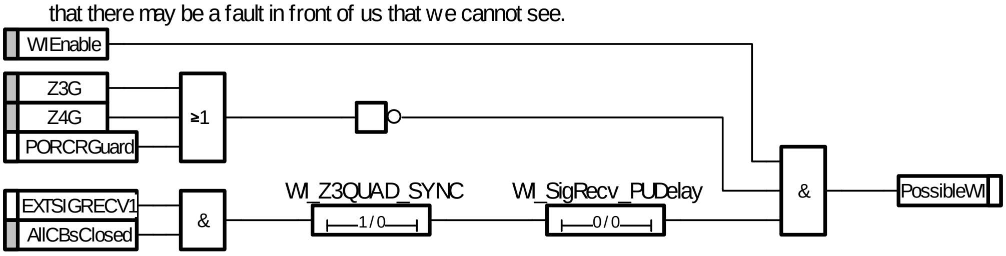


This is the echo pulse monostable. This stretches the single period pulse generated above into one of user specified width (default 250ms).

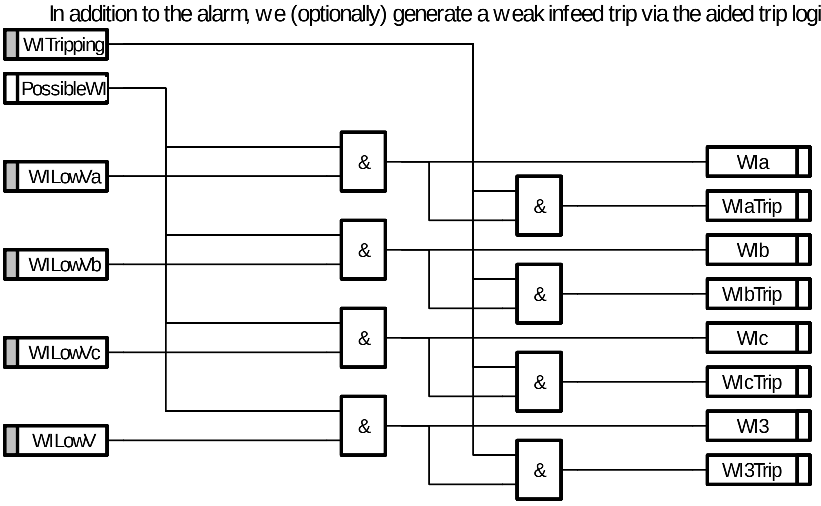


Weak Infeed Logic

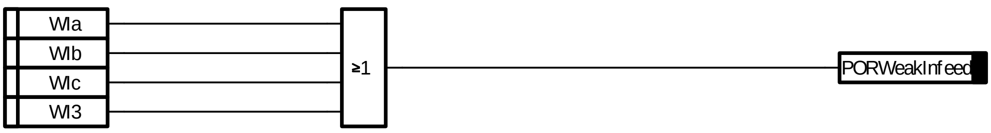
Under certain system conditions, such as on radial systems, or where the source capacity at one end of a line is reduced for some reason, then there may not be sufficient fault current flowing for the relay to determine the fault impedance. Under these circumstances we use weak infeed protection. This uses the fact that the relay at the remote (strong) end can see a fault and so sends us a signal, but we cannot see a fault. In addition, our CBs must be closed. We use these criteria to say that there may be a fault in front of us that we cannot see.



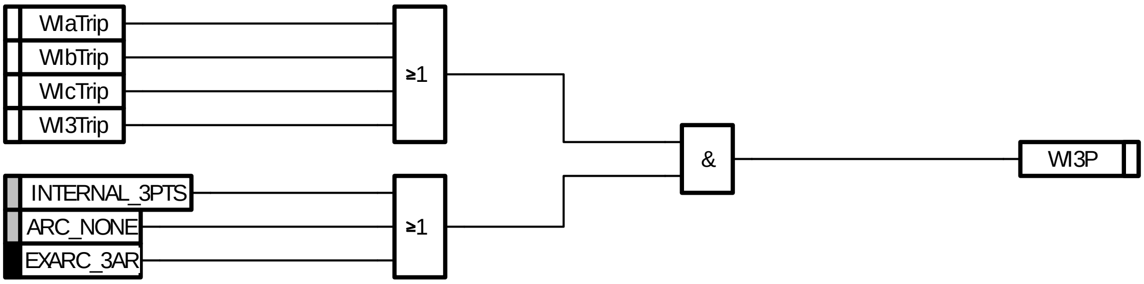
The possibility of a weak infeed condition is then confirmed by the use of phase undervoltage detectors. If there is a weak infeed condition, then we will see only the fault voltage (which will be very small), and so we can generate phase seqregated weak infeed booleans (WIx), and a general weak infeed alarm. For phase to phase conditions, there will be two voltages low, for which the UV detector gives us a general output to use for 3 pole operation. In addition to the alarm, we (optionally) generate a weak infeed trip via the aided trip logic.



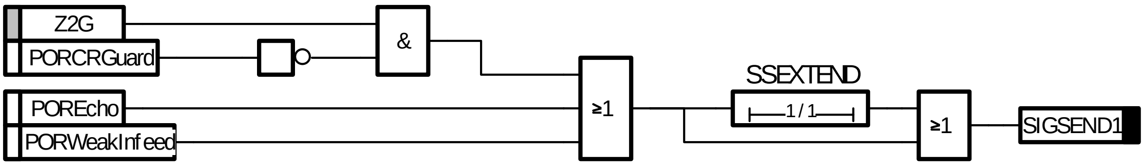
Combine the WIx booleans to give a general weak infeed alarm output.



Combine the WIxTrip booleans to give a general weak infeed Trip output.

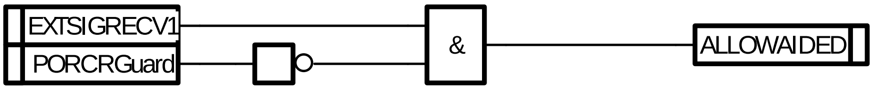


Now the signal send logic. POR2 uses Z2 for SigSend, qualified with no current reversal, and we also send a signal for CB echo and for weak infeed conditions.

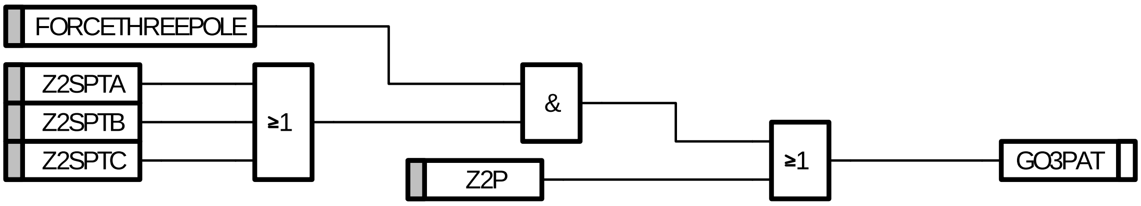


Aided Trip Logic

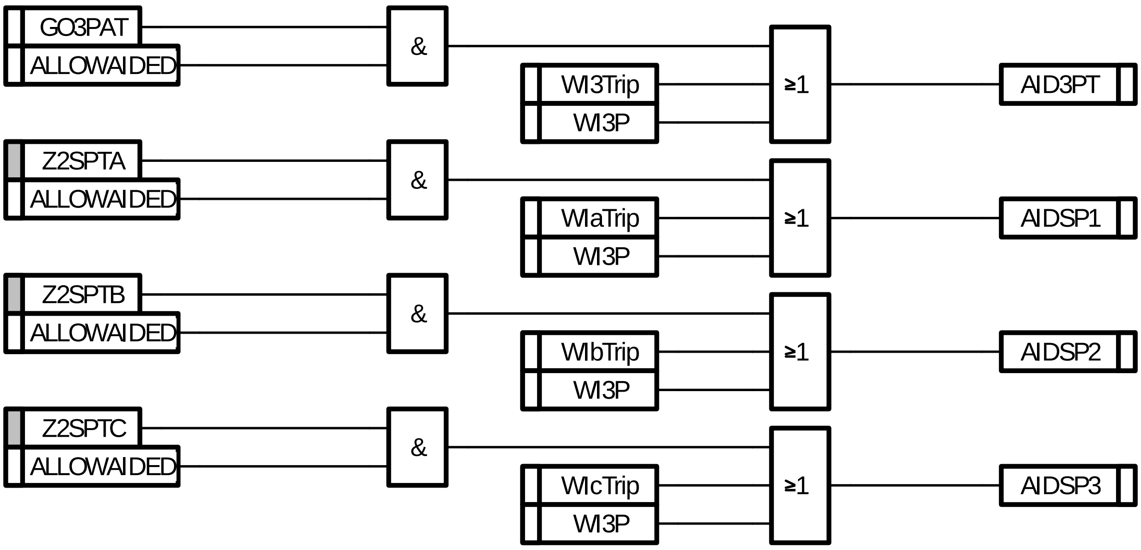
First we generate an enabling signal from SignalRx AND no Current Reversal Guard



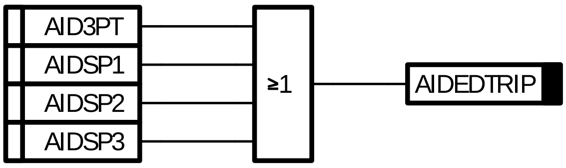
Three pole aided tripping is used for phase faults, or where 3P trips are forced.



Now we generate the aided trip signals. These may be three pole trip or single pole where allowed. These are used within the trip logic diagram.

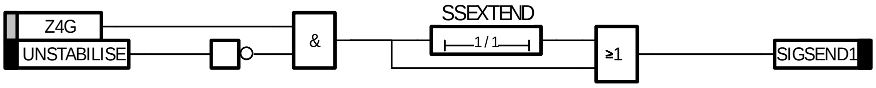


Combine the aided trip signals to give us a general aided trip for alarm and indication

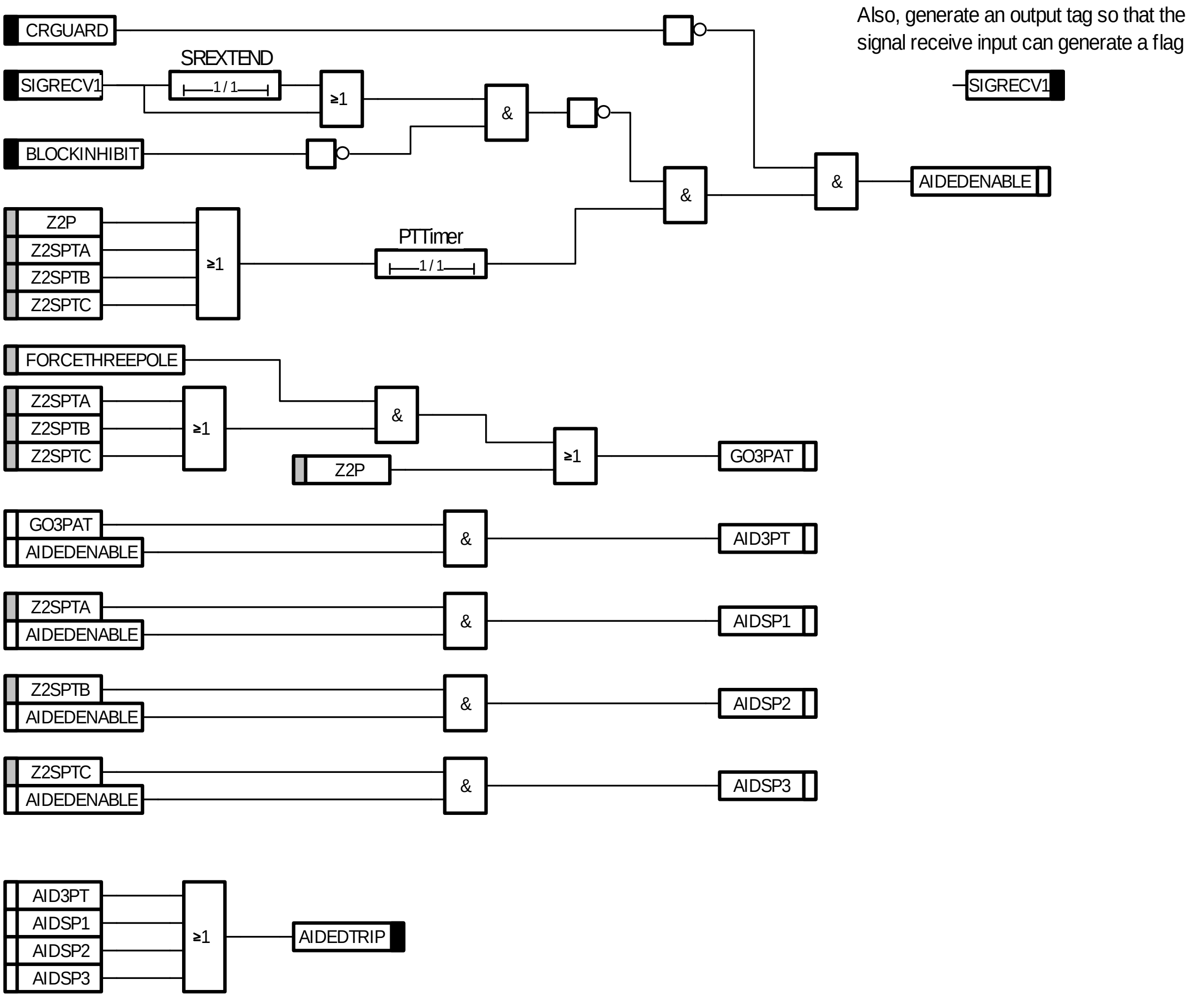


BOR

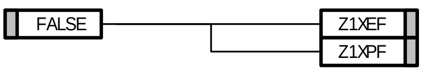
We generate a blocking signal if Zone 4 operates. Zone 4 is reverse looking, so blocks out-of-zone (reverse) faults
Also, we add the external unstabilise control (Manual/external trip) into the equation to allow it to work with the scheme.



Now we generate the aided trip signal, which is delayed to allow time for blocking, and is blocked if signal receive is active.
Also, we need an inhibit signal (re NGC) to prevent blocking under certain circumstances. And the inclusion of the Carrier Receive Guard means that if the carrier fails we can prevent inadvertant accelerated tripping due to loss fo the blocking signal



Clear the reach extension control flags - that scheme obviously not in use



7SG16 Ohmega 408

7SG164 Protection Relay

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand

Software Revision History

Contents

1 Introduction.

Thermal protection is used to safeguard against system abnormalities rather than faults (abnormally heavy loads, etc). The temperature of the protected equipment is not measured directly. Instead, the relay uses the measured current to determine the ”Thermal State” of the protected plant. The relay will take account of the heating effect when current flows and the cooling effect when current is reduced, or doesn’t flow, and operate the Thermal Overload element when the thermal capacity of the protected plant is exceeded.

The current measurement can either be carried out on the average value of the three phases, or on an individual phase basis.

A Hot/Cold ratio is also included. Where the protected plant has a design characteristic which creates “hot spots”, when current magnitudes change quickly, the maximum rating of the plant may be somewhat higher than the normal load. In such cases, a factor is added into the equation, which takes advantage of this oversizing, and increases the operating time of the protection accordingly.

A thermal overload alarm is available, which will operate for any of three conditions. Firstly, if a certain percentage of the plant’s thermal capacity has been exceeded (TOL Capacity Alarm), or, secondly, if the measured current is at a level which would lead to a thermal overload trip if the current were maintained at that level (Thermal Overload Alarm). Thirdly if there is a sudden increase in the load (TOL Load Increase Alarm).

2 Thermal Overload Characteristic.

Thermal Overload Characteristics of the relay conform to IEC255-8 (Thermal Electrical Relays) which defines a 'cold' operating characteristic of

$$t = \tau \times \log_n \left\{ \frac{I^2}{I^2 - (K.In)^2} \right\}$$

Where t = Operating Time
τ = TOL Time Constant
I = Measured Current (Average of three phase values)
K = TOL Overload Setting (given as a multiple of Nominal Current, In)

Should the average current rise above a defined level for the operating time, t, the protected plant will be isolated to prevent damage. The above equation assumes that the plant has just started operating after being isolated for some time (hence "cold").
When the plant has been running for a period of time, the "hot" characteristic is defined as

$$t = \tau \times \log_n \left\{ \frac{I^2 - I_P^2}{I^2 - (K.In)^2} \right\}$$

Where Ip = Steady state current prior to the overload.

Note that there are actually an infinite number of operating curves for different values of load current from the cold state to full load. A thermal model is created for the protected plant according to parameters entered by the user. The system simulates the thermal state (i.e. temperature) of the protected plant, based on the measured current in one of two ways. If the TOL Operating Mode is set to *Three Pole*, the relay will base the thermal state on the average three-phase current. If the TOL Operating Mode is set to *Single Pole*, the relay will evaluate the thermal state of each phase separately, and operate if any one of them is above the set level.

2.1 Hot/Cold Ratio

The Hot/Cold Ratio determines the percentage of thermal capacity available for the protected plant item running at full load current compared with that available when the circuit is off-line or "cold". It modifies the IEC 255-8 hot curve as below:

$$t = \tau \times \log_n \left\{ \frac{I^2 - \left[(1 - H/C) \times I_P^2\right]}{I^2 - (K.In)^2} \right\}$$

Where H/C = Hot/Cold Ratio (Equal to zero, if Hot/Cold Ratio is disabled)
Note: the setting menu gives the setting (1–H/C) in percentage terms, but it is employed as a factor in the above formula.

The thermal characteristic is modified under normal conditions (i.e. when $I < I_\theta$) by multiplying the predicted final state by (1 –H/C). It is possible to disable this feature in which case the ratio H/C is set to zero and will have no effect on the hot operating characteristic.

For electrical plant with a homogenous characteristic such as a power cable or an overhead line, of one design and installation method over its whole length, the hot/cold ratio setting (i.e 1-H/C) is set to 100% or alternatively set to OFF. In either case, full account is taken of the steady state current in establishing the thermal state of the plant.

If the plant item is known to have non-homogenous characteristics with "hot spots", a setting can be applied to reduce the effects of the prior current, Ip, increasing the thermal capacity available, and thus increasing the trip operating time for any subsequent overload.

2.2 Thermal Overload Alarms

A Thermal Overload Alarm will be given if:

The current exceeds the Thermal Overload level. If left at this level the current would eventually result in a thermal overload trip.

OR

The thermal state of the system exceeds a specified percentage of the protected equipment's thermal capacity (TOL Capacity Alarm).

OR

An abnormal step rise occurs in the load current (TOL Load Inc Alarm).

3 Principle of Operation

3.1 Thermal Overload Characteristic

The relay models the thermal state, θ of the relay (using the equations given below), and will operate the Thermal Overload element when this model of the thermal state reaches 100% of the level set as the thermal capacity of the circuit.

Initially, the thermal state of the relay is zero – equivalent to a “cold” circuit in which no current has flowed for a long time. When current flows, this will have a heating effect, and the thermal state will increase according to the following equation;

$$\theta = \left(I^2 \big/ \left(K \cdot I_n^2\right) \right) \times \left(1 - e^{-t/\tau} \right) \times 100\%$$

When current reduces or ceases to flow, the circuit will cool, and the thermal state will decrease according to the following equation;

$$\theta = \theta_F \times e^{-t/\tau}$$

Where: θ = Thermal State at time t.
θ_F = Final Thermal State before disconnection of the motor.
I = Measured current.
In = Nominal Current.
τ = Thermal time constant.
K = Thermal Overload Setting.

The thermal overload setting in this equation is expressed as a fraction of the relay nominal current using factor, K.

For any steady state value of input current, the final, steady state thermal condition can be predicted since, when t = τ, $\theta = I^2 \big/ KI_n^2 \times 100\%$

3.2 Hot/Cold Curve Ratio.

Normally, the Thermal Overload function will be set at the level of current above which 100% of thermal capacity will be reached, after a period of time. Where the protected plant design results in “hot spots”, the maximum rating of the plant may be somewhat higher than the normal load. In such cases, a factor is added into the equation, which takes advantage of this oversizing, and increases the operating time of the protection accordingly. This factor is known as the Hot/Cold Curve Ratio.

This feature may be enabled or disabled. When enabled this will multiply the present thermal state, θ by the factor (1-H/C) which is selectable from 5 to 100% in the setting menu and represents a factor of between 0.05 and 1.0 applied to the steady state load current Ip. For example, if (1-H/C) is set to 80% (i.e. proportional to $0.8xI_p^2$), then at full load, the protected plant item will have used 80% of its thermal capacity.

3.3 Thermal Overload Alarms

The relay will operate the *TOL Alarm* output under the following circumstances:

The measured current exceeds the Thermal Overload Setting. If the current is maintained at this level, a Thermal Overload Operation will occur after a time delay.

OR

Thermal state exceeds a set percentage (the *TOL Capacity Level*) of the total thermal capacity of the protected plant.

OR

A sudden increase in load is detected. This is set as the *TOL Load Inc Alarm Level*, as a multiple of I_θ

4 Relay Settings

Thermal Overload Prot'n (Disabled / **Enabled**)
This setting will enable or disable the thermal overload element.

Thermal Overload Tripping (Disabled / **Enabled**)
This setting will determine whether the Thermal Overload Element will cause the main trip output to operate.

TOL Operating Mode **Three Pole**/Single Pole
In *Single pole* mode the relay will evaluate the thermal state of the three poles individually, and operate if any the thermal states are above the set levels.
In *Three Pole* mode the relay will find the average of the three phase currents and use these to produce a single thermal state for the system.

TOL Overload Setting (0.5 – 2) **1.05xIn**
This is the level of current above which 100% of thermal capacity will be reached after a set period of time.

TOL Time Constant (1 - 1000) **10.0min**
This is the time constant used in the thermal model of the system.

TOL Hot/Cold Ratio (**Disabled** / Enabled)
Will enable or disable the Hot/Cold Ratio setting.

TOL Hot/Cold Ratio Sett ing (5 – 100) **50%**
This will reduce the effect of the prior current on the operating time of the protection. This setting is equivalent to (1-H/C). For most overhead line and cable applications, this should be set to 100%

TOL Capacity Alarm (**Disabled** / Enabled)
Will enable or disable the TOL Capacity alarm, which will operate the *Thermal O/L Alarm* output if the Thermal state reaches a certain percentage of the Thermal Capacity.

TOL Capacity Level (50-100) **50%**
The percentage of the Thermal Capacity at which the *Thermal O/L Alarm* will operate if the *TOL Capacity Alarm* is enabled.

TOL Load Increase Alarm (**Disabled** / Enabled)
Will enable or disable the TOL Load Increase Alarm, which will operate the *Thermal O/L Alarm* output if the Load suddenly increases by a set percentage.

TOL Load Inc. Alarm Level (50-100) **50%**
The percentage increase in load at which the *Thermal O/L Alarm* will operate if the *TOL Load Increase Alarm* is enabled.

TOL Overload Alarm (**Disabled** / Enabled)

Status Inputs: NONE
Relay Outputs: Thermal O/L Alarm, Thermal O/L Trip

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