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7SG16 Ohmega 406

Protection Relays

Answers for energy

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Contents

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7SG164 Ohmega 400 Series

Distance Protection Relays

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Pre release

2010/02	Document reformat due to rebrand

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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.

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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.

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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

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- 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

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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.

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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:

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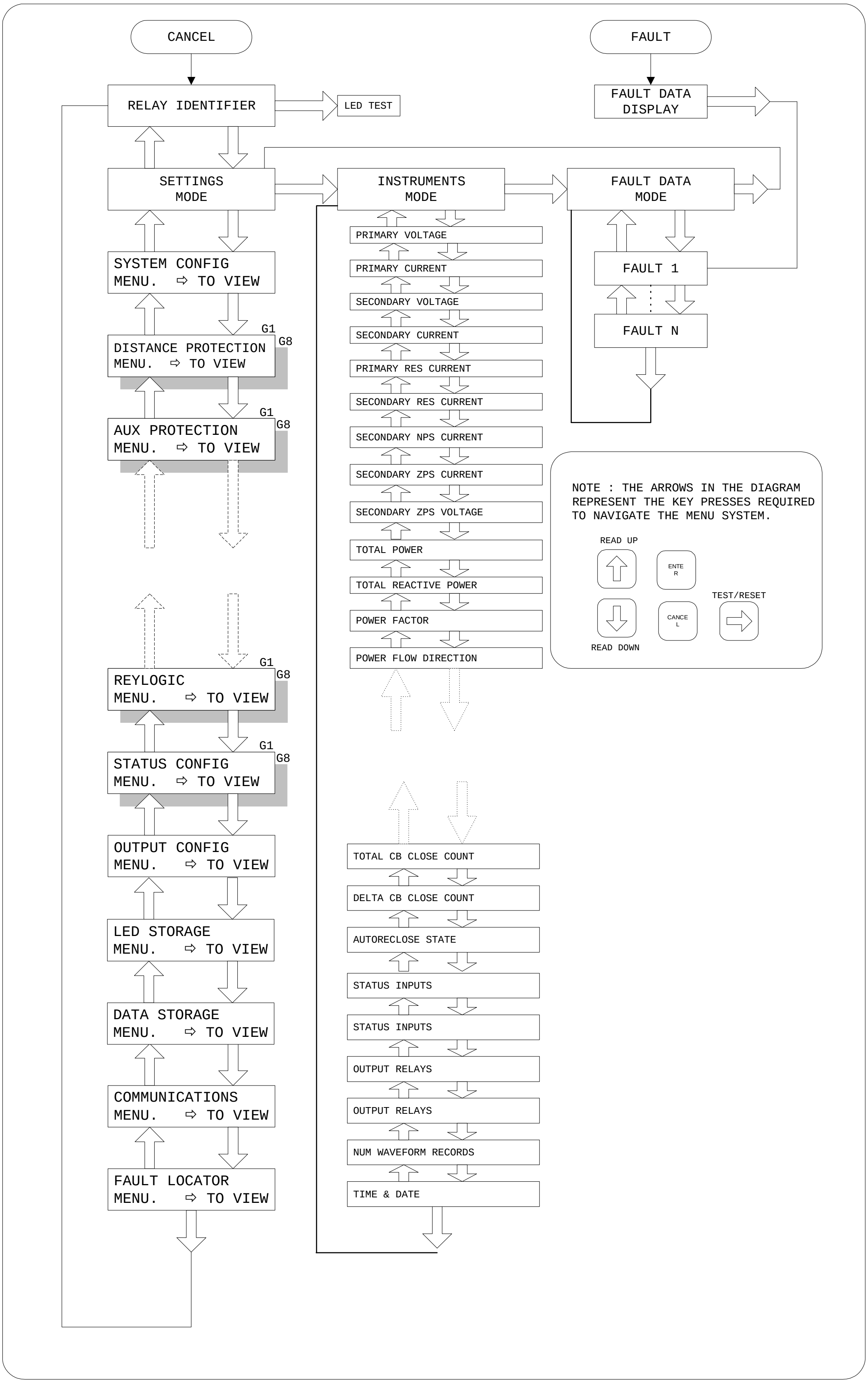

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A sub-menu is opened by pressing the ⇨ key when viewing one of the above title screens. The settings within the sub-menu can then be viewed in turn. Leaving a sub-menu, by scrolling either upwards or downwards, causes it to be automatically closed.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

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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.

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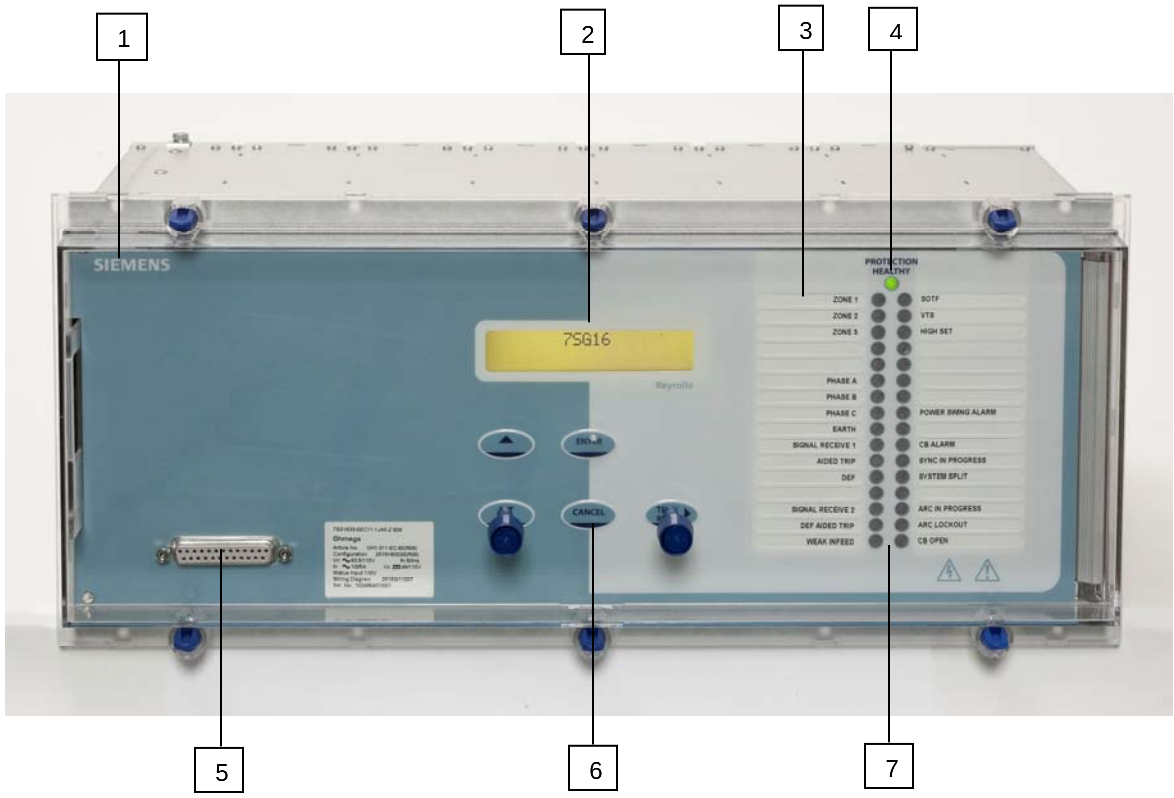

Figure 1 –Human Machine Interface (HMI)

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 Ohmega 400 Series

Distance Protection Relays

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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 Ohmega 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.

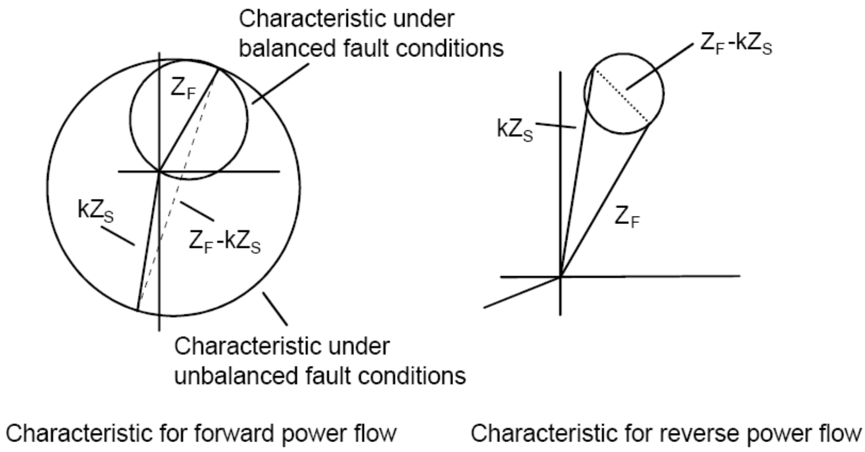

Figure 1, Cross-Polarised Mho Characteristic

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1.1.2 Offset Mho Characteristic

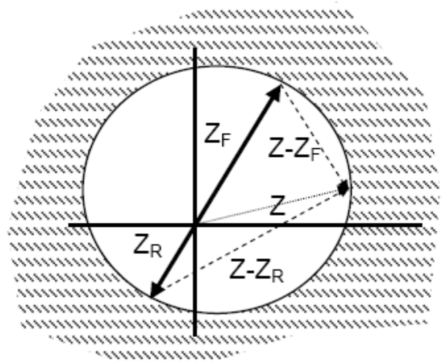

Figure 2 Offset Mho Characteristic

The offset Mho characteristic is shown in figure 2. The characteristic is set with a forward reach, ZF and a reverse reach, ZR. 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).

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 ;

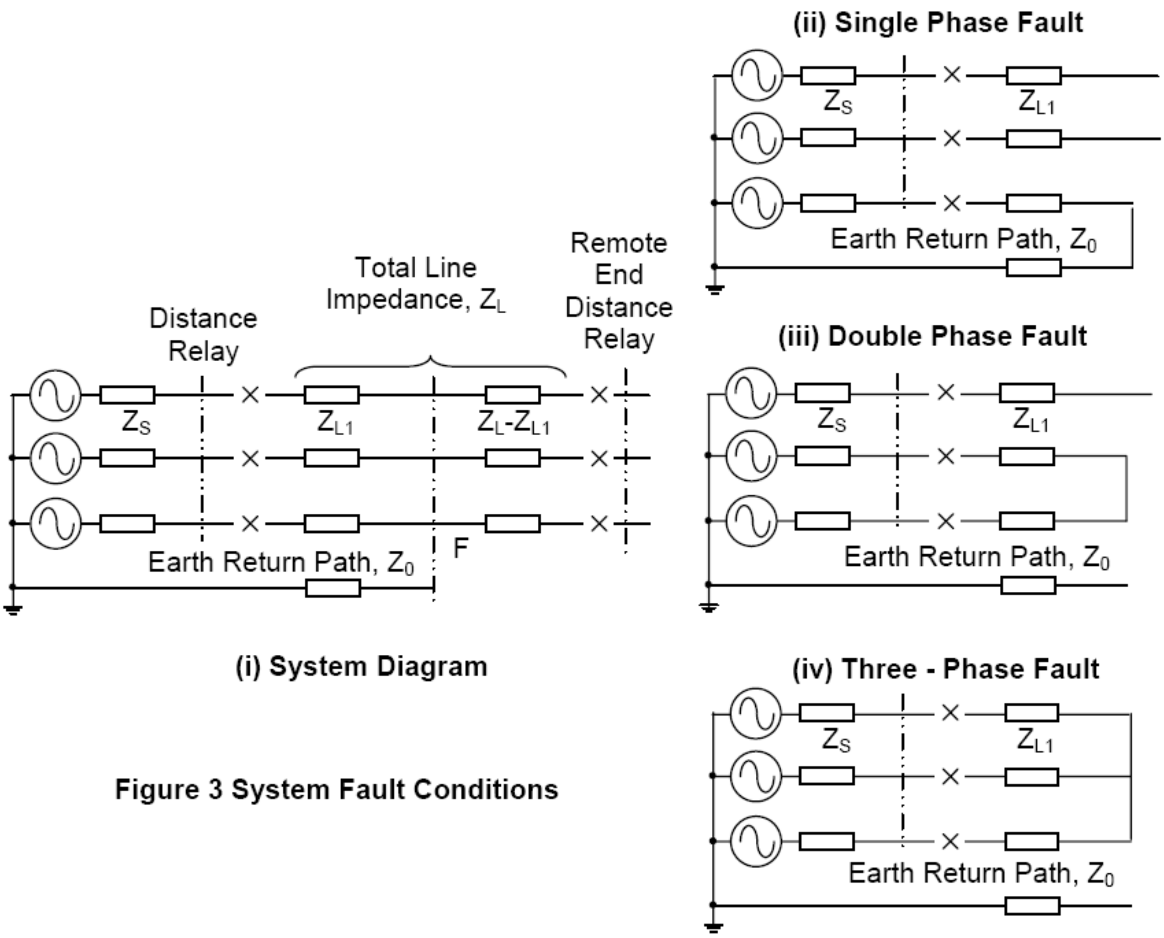

Figure 3 System Fault Conditions

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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 Ohmega 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

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 2ZL.

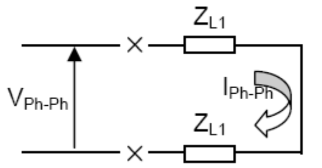

Figure 4 Fault Loop for Phase-Phase faults

1.1.3.2. Earth faults

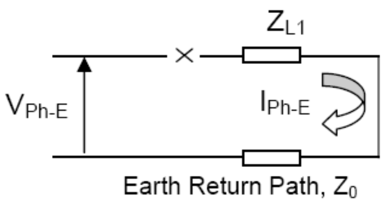

Figure 5 Fault loop for earth faults

When considering earth faults, the relay is actually presented with a loop impedance of ZL + ZN, where ZL is the impedance in the line to the fault and ZN 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 ZN 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.

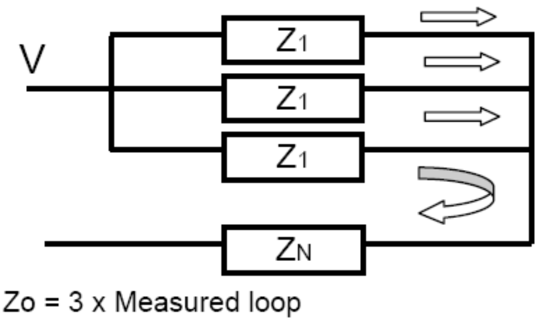

Figure 6 Sequence impedance diagram for an earth fault

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

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

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 Z0 is not required provided the ratio Z 0 / Z1 and the phase angles of Z0 and Z1 are available. The K0 factor described above must of course take into account the phase angles of Z1 and Z0 in the calculation for K0.

The advantage of using the method described above is that the ratio Z0/Z1 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 Z1, the ratio Z0/Z1, the line angle, and the angle of Z0 are entered the relay calculates the composite value.

K0 = 1/3 (Z0/Z1 -1)

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

(IZ + K0 IN Z1) - V within 90° of V + Vp where I = Phase current

Z1 = Positive phase sequence impedance of zone setting
K0 = 1/3 (Z0/Z - 1)
IN = Earth fault current
V = Phase-earth fault voltage
Vp = Polarising voltage

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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).

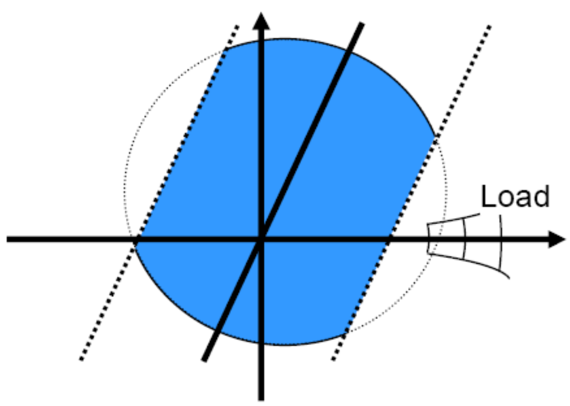

Figure 7a - Shaped Mho Zone 3

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 its 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.

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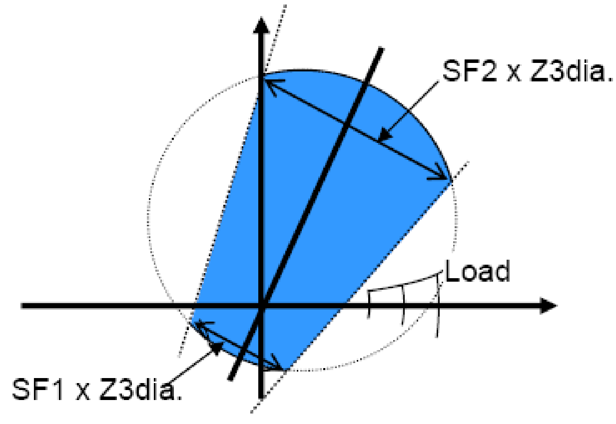

Figure 7b - Unequal Shape Factors

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.

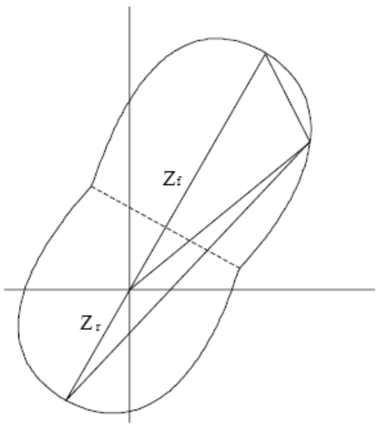

Figure 7b THR shaped characteristic showing waisting.

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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.

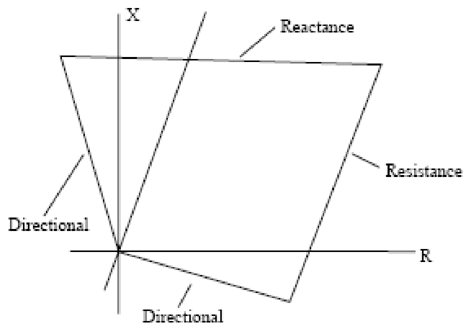

Figure 8 Forward-looking Quadrilateral Characteristic.

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.

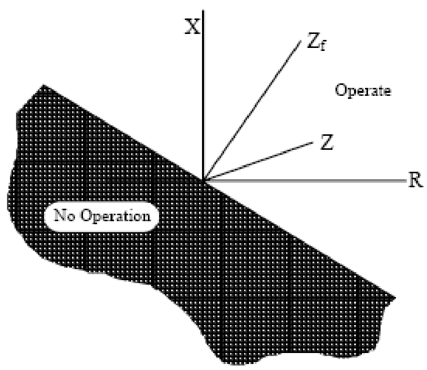

Figure 9

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 polarized characteristic is

$IZF \equiv VP$

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

$ZF \equiv ZS$

The characteristic is shown below.

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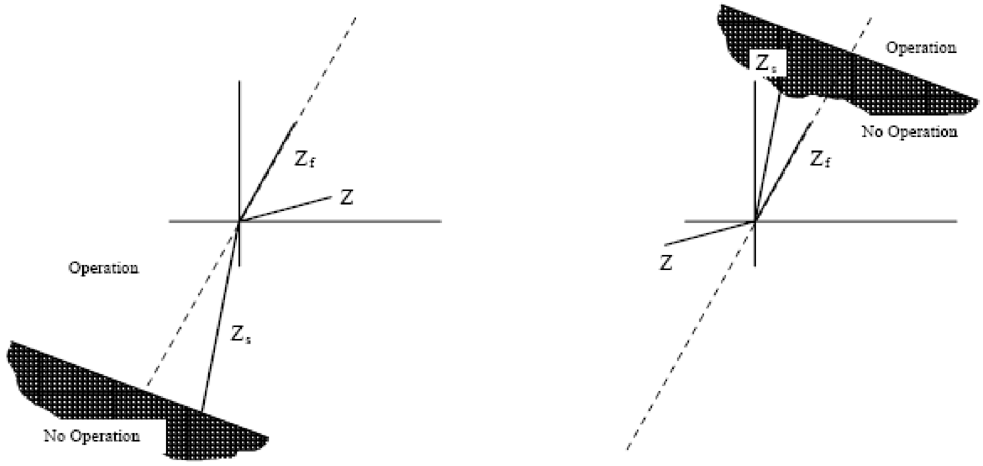

Characteristic for forward power flow   Characteristic for reverse power flow

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 (ZS 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 XF . This requires a replica impedance ZF of magnitude $F\ X\ X \cos$ Φ and angle ΦX . If the reactive component of the fault impedance is less than this value, the comparator operates. The angle ΦX 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.

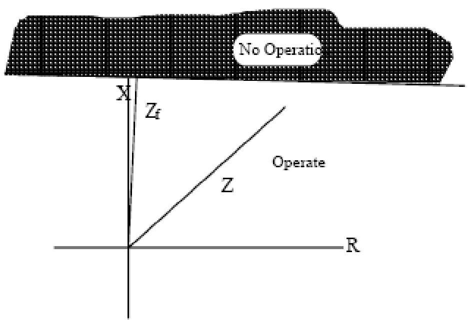

Figure 11 Reactance Characteristic

The vector equation for the reactance characteristic is

$$IZF - V \equiv IZF$$

which becomes

$$ZF - Z \equiv ZF$$

If the angle between ZF and $ZF - Z$ 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 RF , giving increased resistive coverage over the entire line length. The vector equation is again

$$IZF - V \equiv IZ\,F$$

which becomes

$$ZF - Z \equiv Z\,F$$

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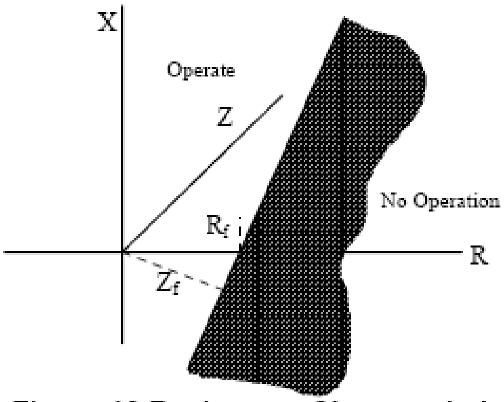
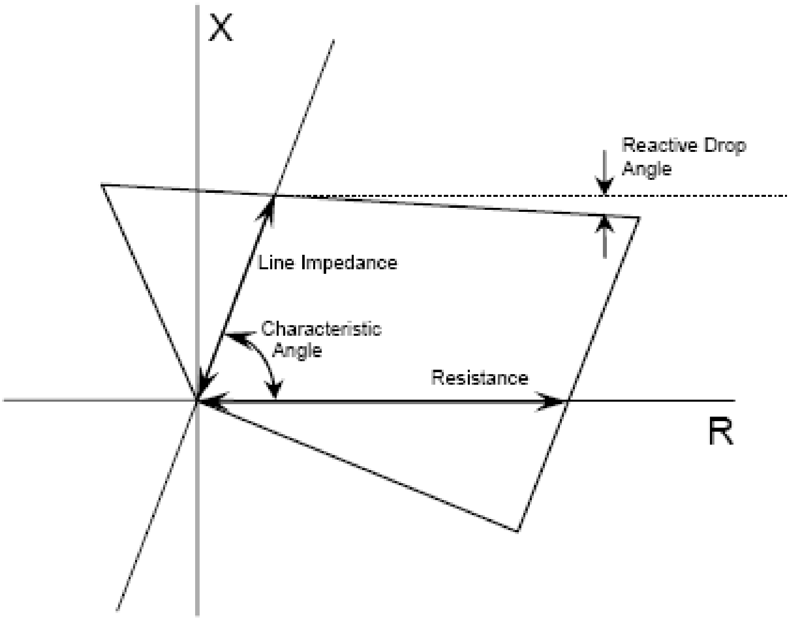


Figure 12 Resistance Characteristic

The replica impedance ZF has magnitude $RF \cos(\Phi L - 90)$ and angle $\Phi\ L - 90°$.
The relay is set using parameters for the line impedance, resistive reach and characteristic angle as shown below:



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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.

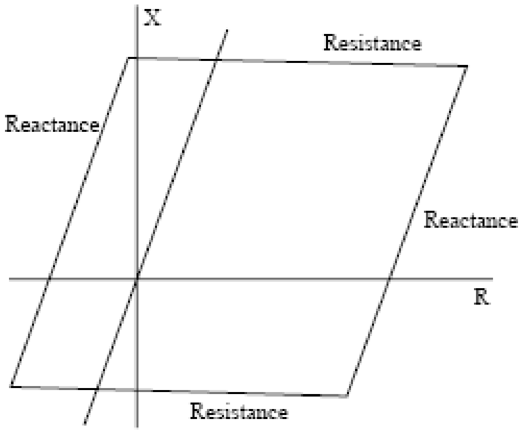

Figure 13 Typical offset quadrilateral distance characteristic

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1.3 Voltage Memory

The relay incorporates a voltage memory feature. This ensures directional security under closein 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.

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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 maltripping, 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. “Ohmega” employs two independent shapes of characteristics for this purpose i.e. polygonal and circular.

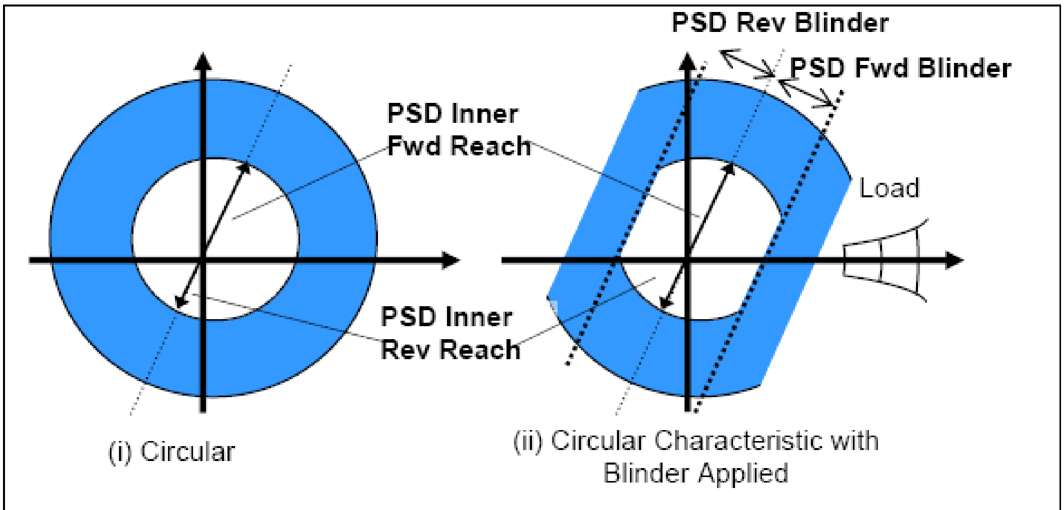

Figure 14 Power Swing Detection Zones

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.

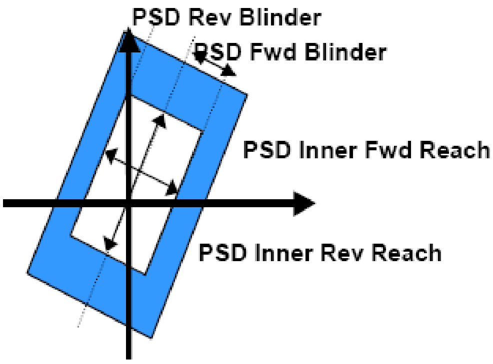

Figure 15
Rectangular Power Swing Detection Zones

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)

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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.

ZPSB(Outer) = k. ZPSB(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**

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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 pickup, 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 Vop = 3V0 for Residual or 3V2 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

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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**

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1.8 Switch On To Fault (SOTF)

1.8.1 Applications

The Zone 1 instantaneous elements of the OHMEGA 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 Ohmega 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

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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 recloses during an auto reclose 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**

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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**

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7SG1642 Ohmega 406

Distance Protection Relays

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Pre release

2010/02	Document reformat due to rebrand

Software Revision History

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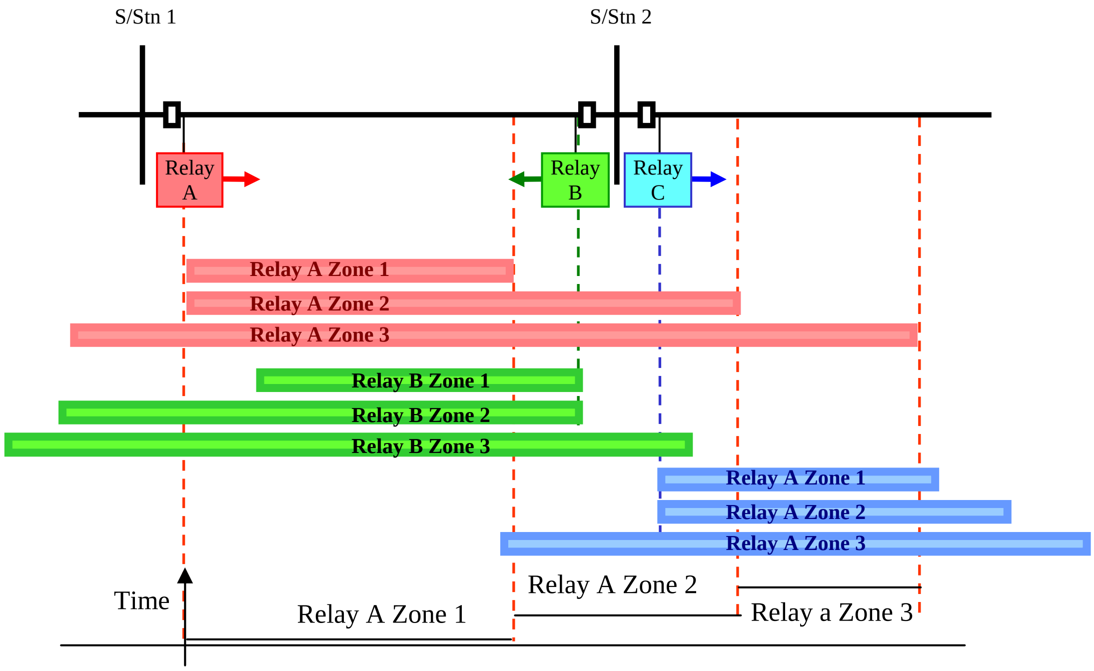
1 Basic Schemes

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.

1.1.2 Settings

Distance Scheme:

Distance Scheme	**TIME-STEPPED**

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

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1.2 Loss of Load

1.2.1 Scheme Operation

The Loss of Load protection scheme is used to give faster fault clearance time for an end zone fault (i.e between the Zone 1 boundary and the line end) when there is no signalling channel available. This allows a faster clearance time than the time-delayed Zone 2 elements.

Consider a fault occurring near to the remote end, i.e outside of the Zone 1 reach, but within the line length. In a normal time stepped distance scheme, the remote end relay would trip in Zone 1 time, and the local end relay would trip after the Zone 2 time delay. The Loss of Load scheme monitors the current in the healthy phases and can remove the Zone 2 time delay, speeding up the local end trip, when the remote end trip occurs.

If the relay detects a drop in current in one or two phases below the *Loss of Load Level*, with the current on the remaining phases above this level, it will remove the time delay from zone 2, for a fixed time delay (the *LOL Time Limit)* to allow the relay to trip instantaneously. This will allow the relay to trip more quickly for single or double phase faults, but will not affect operation for three phase faults.

A short time delay (typically 20ms), known as the *Loss of Load Pole Scatter Delay* or the *LOL CB Op Delay* is introduced to prevent the Loss of Load feature picking up during normal breaker operation.

1.2.2 Settings

The Loss Of Load function (LOL) is made active by selecting the scheme in the scheme selection menu. If a conventional scheme is selected and a communications failure occurs then a group setting change could be used to switch the scheme on until the communications is restored.

Distance Scheme	**LOSS OF LOAD**
LOL Level	0.1..0.9 **(0.5x In)**
LOL CB Op Delay or *LOL Pole Scatter Delay*	0..50 **(20ms)**
LOL Time Limit	0..60000 **(40ms)**

Status Inputs: N/A
Relay Outputs: **AIDED TRIP, LOSS OF LOAD**

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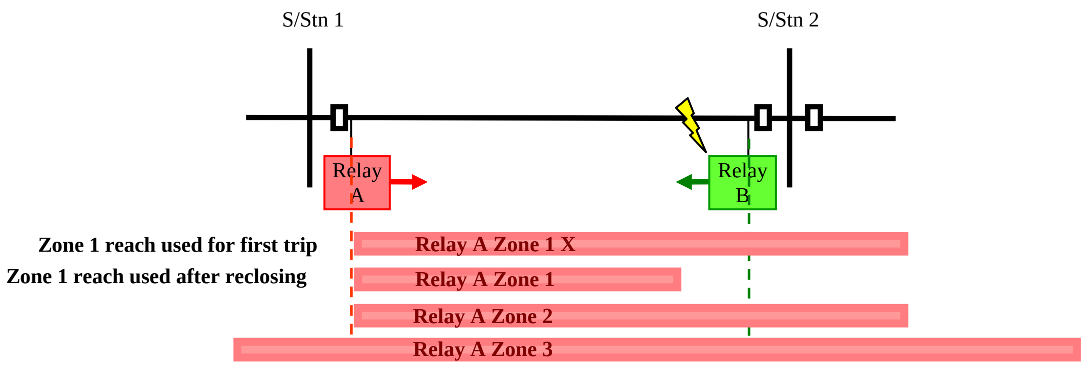
1.3 Reach Extension

This scheme is only available in relays with built-in autoreclose.

1.3.1 Scheme Operation

The Reach Extension is designed to be used in conjunction with an autoreclose system.
The Zone 1 elements within the relay have two settings. The standard Zone 1 settings are set as for the time-stepped distance scheme (i.e. 80% of the total line length). Zone 1 X settings are set to overreach the line length (usually these are set to the same value as the zone 2 setting)

When the reach extension scheme is implemented, the relay will use the extended zone 1 reach for tripping. The relay will trip and attempt to auto-reclose. After the CB has tripped and reclosed, the relay will use the standard (underreaching) Zone 1 reach for tripping. Consider a transient fault (i.e. a fault which is removed by tripping and auto-reclosing) in the last 20 % of the line, as shown in the diagram below. The overreaching Zone 1 will trip and reclose for this fault, and since it is transient, it will be cleared. A permanent fault will be cleared after the Zone 2 time on the second trip. Since the majority of faults are transient in nature, this will allow transient faults to be cleared more quickly.



The disadvantage of this scheme is that since the extended Zone 1 reach is an overreaching Zone, it may operate for faults in the next line section. However, when the relay has reclosed, the Zone 1 reach will be reduced so the relay will trip after the Zone 2 time, allowing the correct relay to trip in Zone 1 after reclosing, if the fault is permanent. Overall this will increase the amount of circuit breaker operations on the system, and thus the amount of circuit breaker maintenance required, but it will improve clearance of transient faults. When a status input assigned *Block Reach Extension* is energised will the relay will use the normal Zone 1 reach.

The extended zone 1 reach will be active regardless of whether the autorecloser is on or out of service. It is advised that the *Block Reach Extension* status input is energised whenever the autorecloser is out of service. If the relay features an internal autorecloser, a normally closed contact should be assigned to Autorecloser in Service and connected back into the “Block Reach Extension” status input.

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1.3.2 Settings

Distance Scheme	**REACH EXTENSION**
Z1 Extension	**ENABLED**
Zone 1 X PF Impedance Reach	
Zone 1 X PF Resistance Reach	
Zone 1 X EF Impedance Reach	These are the settings used by the relay for the first trip
Zone 1 X EF Resistance Reach	

Status Inputs: **BLOCK REACH EXT**.
Relay Outputs: N/A

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2 Schemes Incorporating a Signalling Channel

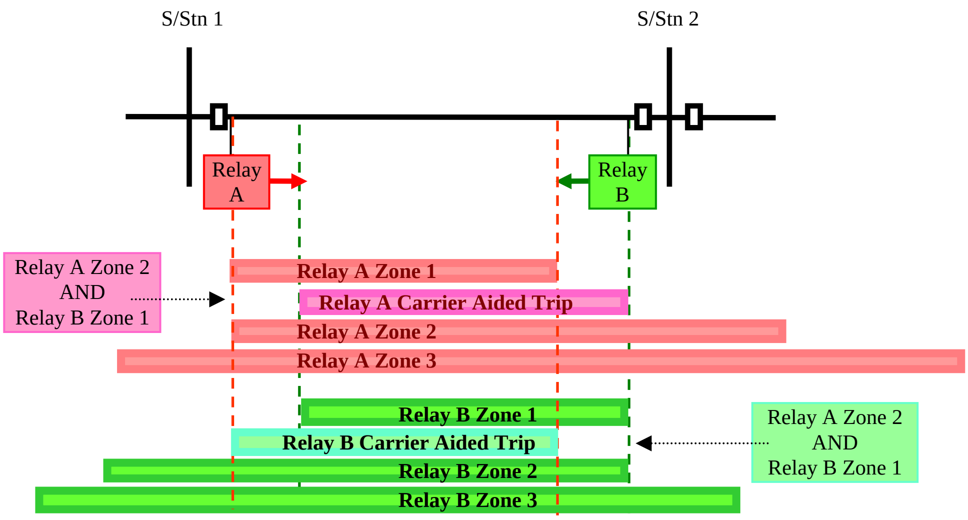
Where a signalling channel is available between ends, the coverage of the relays can be improved. When these Protection Schemes are used, the Zone 1, 2 and 3 are arranged to trip as in the time stepped distance scheme. In addition to this, the relay is also capable of carrying out what is known as a “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.

2.1 Permissive Underreach.

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

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**

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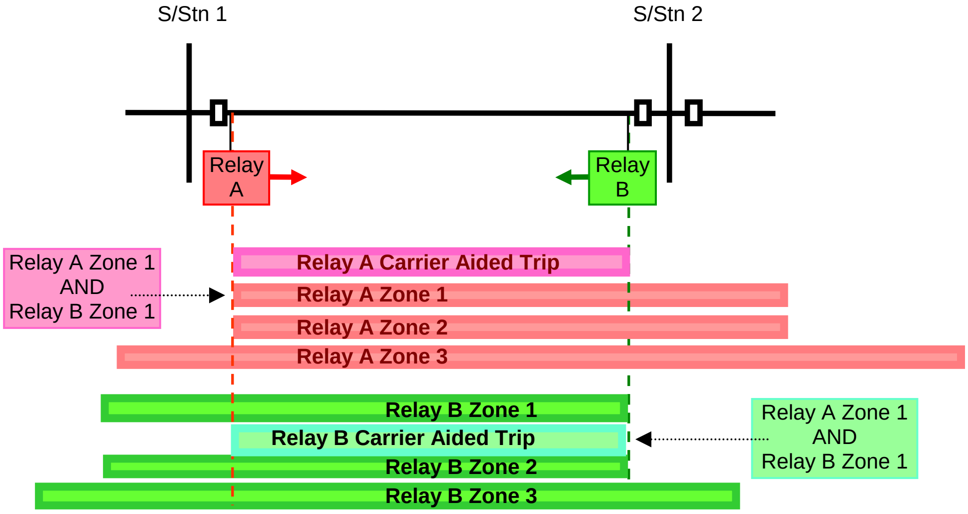
2.2 Permissive Overreach Zone 1 – POR1.

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.

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**

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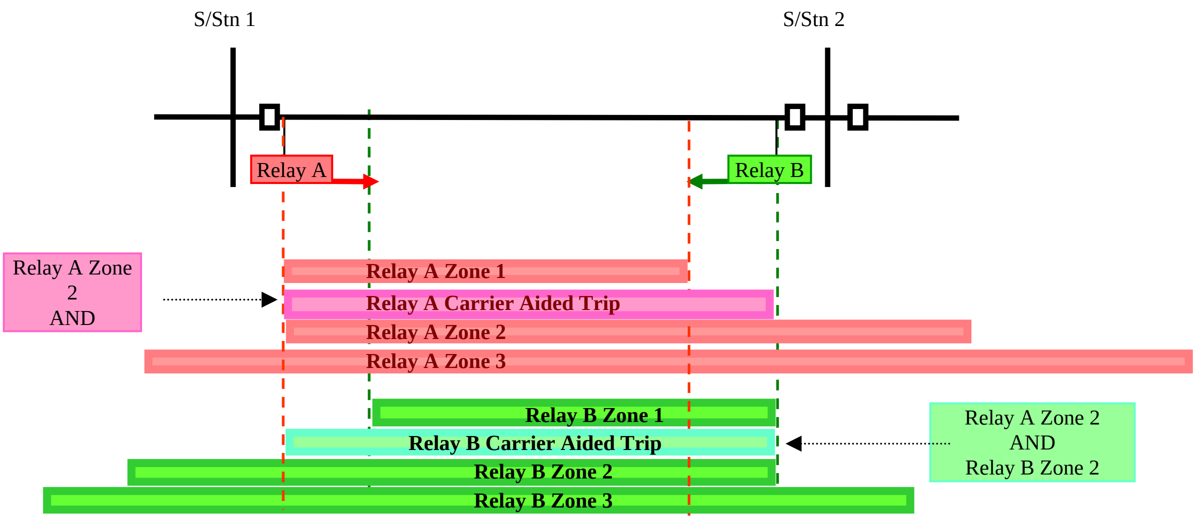
2.3 Permissive Overreach Zone 2 – POR2.

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.

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.

2.3.3 Current Reversal Guard.

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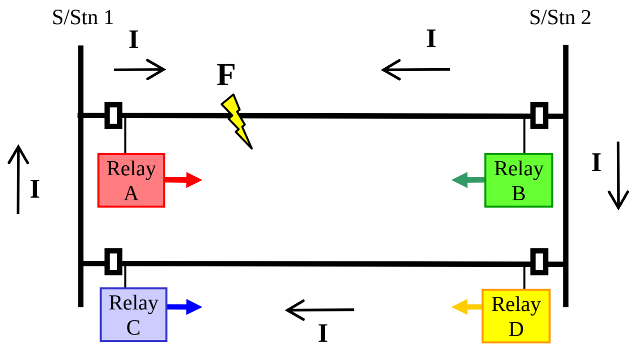
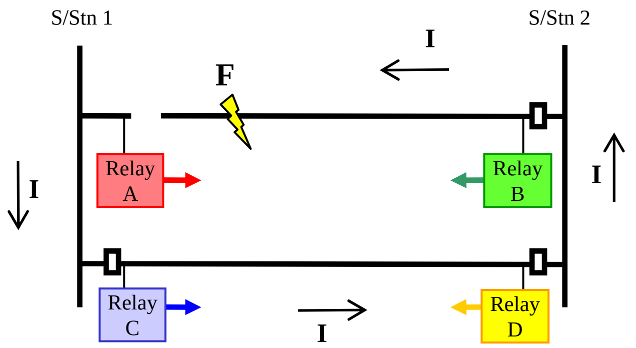
Additional logic is required in cases where the reach of Zone 2 elements is set to 150% or more of the line length and a fault has a current source at both ends of the protected line. Where parallel feeders are used, there is a danger that when a circuit breaker is opened a race condition can arise between 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.

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.

2.3.5 Settings

Distance Scheme **POR2**

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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

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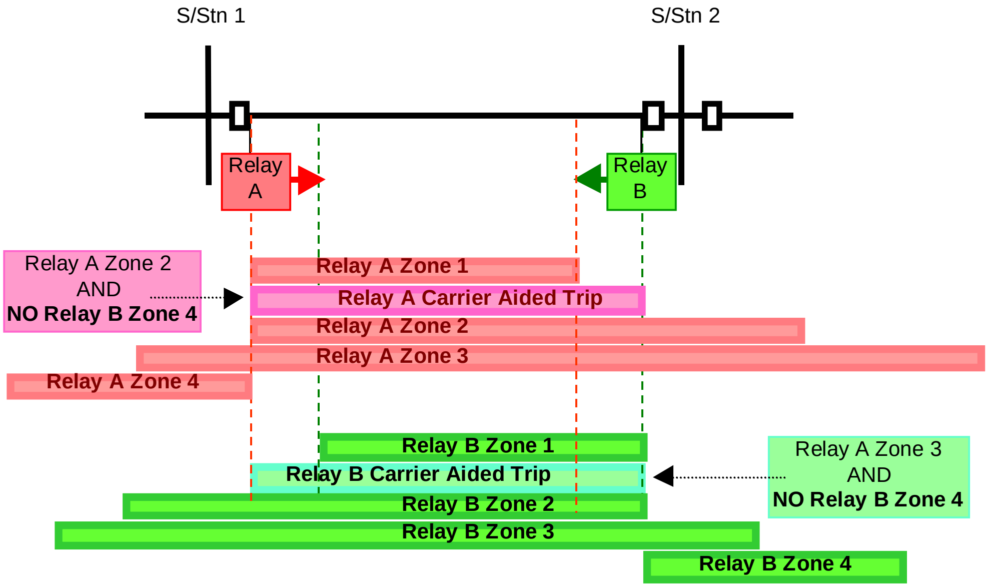
2.4 Blocked Overreach

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

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

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7SG1642 Ohmega 406

Distance Protection Relays

Document Release History

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Pre release

2010/02	Document reformat due to rebrand

Software Revision History

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1 Relay Type

Model No. **OHMEGA406-50**
Software Version 2615H80018R33

1.1 System Configuration Menu

Setting	Range	Definition
CVT in use	**No**..Yes	Specifies whether CVTs or EVTS are being used. If set to YES, this gives extra security to the protection during the case of severe CVT transients.
Autoreclose Option	**None**, External, Internal	Specifies whether autoreclosing is to be carried out Internally, by an external device, or not at all.
CT Ratio	0:1..5000:5 (**2000¦1**)	These values are used in the Instruments menu where Primary Current and Voltage are displayed. Note the setting of the CT secondary should also be made in the Distance Protection menu.
VT Ratio	1000:90..600000:130 (**132000¦110**)	
Alternate Setting Group	**1**..8	This is the group that the relay will switch to if the SI assigned as *Use Alt Setting Grp* is energised. The relay will revert to the previous setting group when the status input is de-energised.
Defaults Screens Timer	Off..**60 Minutes**	Time delay after which display will return to the top of the menu.
Backlight timer	Off..60 **(5 Min)**	If no keys are pressed for this time delay, the relay will turn off the backlight.
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. If the password has been lost then an authorised person must contact a Siemens representative.
Relay Identifier	16 Character String **OHMEGA 406-50**	This is usually set to the circuit name. This is displayed at the top level of the menu system.

1.2 Distance Protection Menu

Setting	Range	Definition
Distance Scheme	**Time Stepped**, Loss of Load, Reach Extension, PUR ,POR WI 1, POR WI 2, BOR	This defines the current active scheme in the relay. A full description of all schemes is given in Section 3 of the manual.
CT Secondary	**1**, 2, 5A	Specifies the rating of the secondary winding of the current transformer.
Line Angle	0..90 **(75°)**	Angle of the positive sequence impedance.
EF Comp Z0/Z1 ratio	0..10 **(2.5°)**	Simple ratio between magnitudes of the zero and positive sequence impedances.
EF Comp Z0 angle	0..355 **(75°)**	Angle of the zero sequence impedance.
POR Weak Infeed	**Disabled, Enabled**	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	Allows the main trip contacts to operate for a weak infeed fault detection.
WI Voltage Level	5..85 (54v)	Level below which a voltage depression will be considered to be a fault by the Weak Infeed detector.

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Quad Auto Load Comp	**Disabled**, Enabled	Compensation applied to the reactance line of the quad characteristic to allow for load current during a fault.
Reactive Drop Angle	-20..20 **(-3°)**	Defines the angle of the reactance comparator to the vertical, for the quad characteristic
Z1 Extension	Disabled, **Enabled**	Allows the Z1 Extension scheme to be enabled or disabled. If it is set to disable the scheme and settings are not used.
Z1 Phase Fault	Disabled, **Enabled**	Allows the phase fault comparators to be turned on or off.
Z1 PF Impedance	0.1..250 **(8Ω)**	Positive sequence impedance reach of the Zone1 phase fault comparator along the line angle
Z1X PF Impedance	0.1..250 **(12Ω)**	When the *Reach Extension* scheme is active, this defines the extended Zone 1 phase fault reach used for the first trip. See Section 3 of this manual for more detail on relay schemes. If the active scheme is not set to *Reach Extension*, this setting has no effect on the relay.
Z1 PF Time Delay	0..10000 **(0ms)**	Set time delay for the Zone 1 phase fault comparators. Normally set to zero unless the *POR1* scheme is selected.
Z1 Earth Fault	Disabled, **Enabled**	Allows the Zone 1 earth fault comparators to be turned on or off.
Z1 EF Type	**Fwd Mho,** Fwd Quad	Sets the earth fault comparators as Mho or Quad characteristic.
Z1 EF Impedance	0.1..250 **(8Ω)**	This defines the positive sequence impedance reach of the Zone 1 earth fault comparator along the line angle.
Z1 EF Resistance	0.1..250 **(4Ω)**	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.
Z1X EF Impedance	0.1..250 **(12Ω)**	When the *Reach Extension* scheme is selected, this defines the extended Zone1 earth fault reach used for the first trip. See manual for more detail on relay schemes. If the active scheme is not *Reach Extension*, this setting has no effect on the relay.
Z1X EF Resistance	0.1..250 **(6Ω)**	
Z1 EF Time Delay	0..10000 **(0ms)**	Set time delay for the Zone 1 phase fault comparators. Normally set to zero unless the *POR1* scheme is selected
Z2 Phase Fault	Disabled, **Enabled**	Settings as per Zone 1
Z2 PF Impedance	0.1..250 **(16Ω)**	
Z2 PF Time Delay	0..10000 **(1000ms)**	
Z2 Earth Fault	Disabled, **Enabled**	
Z2 EF Type	**Fwd Mho**, Fwd Quad	
Z2 EF Impedance	0.1..250 **(16Ω)**	
Z2 EF Resistance	0.1..250 **(8Ω)**	
Z2 EF Time Delay	0..10000 **(1000ms)**	
Z3 Phase Fault	Disabled, **Enabled**	Allows the Zone 3 phase fault comparators to be turned on or off.
Z3 PF Type	Fwd Mho, Rev Mho, **Offset Mho**, Offset Shaped	Allows the direction of the Zone 3 phase fault element to be set either as forward, reverse or offset, or offset shaped.
Z3 PF Impedance Fwd	0.1..250 **(24Ω)**	Positive sequence impedance reach of the Zone 3 phase fault comparator, in the forward direction
Z3 PF Impedance Rev	0.1..250 **(8Ω)**	Positive sequence impedance of the Zone 3 phase fault comparator, in the reverse direction
Z3 PF Shape Factor 1	0..1 **(1Ω)**	Setting of these allows the shape of the Zone 3

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Z3 PF Shape Factor 2	0..1 **(1Ω)**	characteristic to be altered. This only applies if Shaped Characteristics are selected. See Section 2 for more details on this function.
Z3 PF Time Delay	0..10000 **(2000ms)**	Set time delay for the Zone 3 phase fault comparators.
Z3 Earth Fault	Disabled, **Enabled**	Allows the Zone 3 earth fault comparators to be turned on or off.
Z3 EF Type	Fwd Mho, Rev Mho, **Offset Mho**, Fwd Quad, Rev Quad, Offset Quad	Allows the direction of the Zone 3 earth fault element to be set either as forward, reverse or offset, and the shape to be set as a mho or quad.
Z3 EF Impedance Fwd	0.1..250 **(24Ω)**	This defines the positive sequence impedance of the Zone 3 earth fault comparator, in the forward direction.
Z3 EF Resistance Fwd	0.1..250 **(12Ω)**	With Quad characteristics selected, this defines the reach along the resistive axis. Note that residual compensation is not applied to this part of the characteristic.
Z3 EF Impedance Rev	0.1..250 **(8Ω)**	This defines the positive sequence impedance reach of the Zone 3 earth fault comparator, in the reverse direction.
Z3 EF Resistance Rev	0.1..250 **(4Ω)**	When Quad characteristics are selected, this defines the reverse reach along the resistive axis. Note that residual compensation is not applied to this part of the characteristic.
Z3 EF Time Delay	0..10000 **(2000ms)**	Set time delay for the Zone 3 earth fault comparators.
Direct Zone 4 Trip	Disable, **Enable**	Allows direct tripping on operation of the Zone 4 elements.
Z4 Phase Fault	Disable, **Enable**	Settings as per Zone1.
Z4 PF Impedance	0.1..250 **(8Ω)**	
Z4 PF Time Delay	0..10000 **(0ms)**	
Z4 Earth Fault	Disabled, **Enabled**	
Z4 EF Type	**Rev Mho**, Rev Quad	
Z4 EF Impedance	0.1..250 **(8Ω)**	
Z4 EF Resistance	0.1..250 **(4Ω)**	
Z4 EF Time Delay	0..10000 **(0ms)**	

1.3 Power Swing Menu

Setting	**Range**	**Description.**
Power Swing Detector	Disable, **Enable**	Allows the Power Swing Detector to be turned on or off.
PSD Zone blocking	Z1, Z2, Z3, Z4 **(Z2, 3, 4 only)**	Selects the zones of operation for which tripping is blocked during a Power Swing Condition
PSD Shape	**Circular,** Rectangular	Defines the shape of the Power Swing detection element.
PSD Blinders	**Disable**, Enable	Enables the blinders which can be used to prevent the Power Swing Characteristic encroaching upon the load impedance.
PSD Inner Fwd Impedance	0.1..250 **(24Ω)**	These settings define the reach of the power swing element along the line angle in the forward and reverse directions. Usually set the same as the Zone 3 impedance forward and reverse reach, or just outside of them.
PSD Inner Rev Impedance	0.1..250 **(8Ω)**	
PSD Inner Fwd Blinder	0.1..250 **(16Ω)**	Defines the perpendicular distance between the line angle and the *PSD Blinders*. If the blinders are not enabled, then these settings have no effect.
PSD Inner Rev Blinder	0.1..250 **(16Ω)**	
PSD Outer Multiplier	1.05..2 **(1.5x)**	The outer reach of the PSD zones are set as a multiple of the *Inner fwd and rev impedance* reaches.

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PSD Transit Time	0..1000 **(50ms)**	This is the length of time for which the impedance characteristic must remain between the inner and outer zones before the power swing detector operates.

1.4 Auxiliary Protection Menu.

Setting	**Range**	**Definition**
High Set	Disable, **Enable**	The *Highset Overcurrent* is a non-directional DTL element, which will cause a main distance trip on operation.
HS Level	0.1..35 **(4x In)**	
HS Time Delay	0..1000 **(0ms)**	
Stub Protection	Disable, **Enable**	The Stub Protection is a simple DTL overcurrent element which is enabled whenever the *Stub Protection SI* is energised from the disconnector auxiliary switch.
SP Level	0.1..2 **(1x In)**	
SP Delay	0..1000 **(0ms)**	
LOL Level	0.1..0.9 **(0.5x In)**	Where the *Loss of Load* scheme is used, a LOL condition occurs if the current level in one or two phases drops below this level, and the current in the remaining phase(s) is above the level, and there is a residual voltage on the system. The relay will detect a loss of load condition (i.e the remote end breaker has opened) and allow instantaneous tripping of the zone 2 element, for a fixed time window.
LOL Pole Scatter Delay	0..50 **(20ms)**	This delay allows for pole scatter between phases when the breaker opens.
Directional Earth Fault	Disable, **Enable**	This setting enables or disables the *Directional Earth Fault* Protection.
DEF Scheme	Def Direct Trip Def POR	*DEF POR* is designed for use with a signalling channel. The relay will carry out a *DEF aided trip* if the local DEF element operates AND a permissive signal is received from the remote end. In the direct trip mode operation of the DEF element will trip the relay directly.
DEF Char Angle	-95..95 **(45º)**	This is the maximum torque angle for the DEF element between the residual current and the residual voltage. The residual current is taken as the reference, so for an inductive circuit the angle will be positive.
DEF Weak Infeed Trip	**Disable**, Enable	When enabled this allows the DEF scheme to work if the source at one end is weak or non-existent. If the forward and reverse elements are both not operated, and signal is sent from the remote end DEF, the relay will trip and send a permissive signal back to the remote end (Signal Send 2).
DEF Pole Open Block	Disable, **Enable**	When the relay carries out a single pole trip, the resulting unbalance in the phases may operate the DEF element. With this setting enabled the DEF element will be blocked during a single pole autoreclose.
DEF1 Direction	**Forward**, Reverse	The DEF can be set to operate in either the forward or reverse direction. Usually set to forward.
DEF1 Direct Trip	**Disable**, Enable	When enabled, a DEF1 fault detection will result in operation of the main trip output contact
DEF1 Current Setting	0.05..4 **(1x In)**	Pickup level of the DEF 1 element
DEF1 Time Delay	0..20000 **(1000ms)**	Time delay for DEF tripping. This will applied for the aided tripping if DEF POR is selected or direct tripping if the DEF Direct Trip is selected.
DEF2 Direction	Forward, **Reverse**	Settings as for DEF 1. The DEF 2 element is usually set to operate in the reverse direction.
DEF2 Direct Trip	**Disable**, Enable	
DEF2 Current Setting	0.05..4 **(1xIn)**	
DEF2 Time Delay	0..20000 **(1000ms)**	

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DEF WI Res OV Level	0..20 **(5V)**	This is the residual overvoltage detector applied as a guard feature in the *DEF Weak Infeed Tripping*, The residual voltage must be greater than this value for the *DEF Weak Infeed Trip* to operate.
Overvoltage Prot.	Disable, **Enable**	Enables or disables the Overvoltage Protection.
OV Stage 1 Level	5..85 **(68V)**	Defines the pickup level, time delay, and hysteresis of the OV stage 1 element. The element will pick up at 100% of setting and will drop off at 100%-Hystersis level.
OV Stage 1 Time Delay	0..600 **(5s)**	
OV Stage 1 Hysteresis	1..90 **(2%)**	
OV Stage 1 O/P Phases	**Any Phase**, All Phases	Defines whether the Overvoltage should be a single phase or a three-phase condition.
OV Stage 1 Trip	**Disable**, Enable	Determines whether operation of the stage 1 Overvoltage will trip the relay or not.
OV Stage 2 Level	5..85 **(73V)**	Settings as per Stage 2. The element will pick up at 100% of setting and will drop off at 100% - Hystersis level
OV Stage 2 Time Delay	0..600 **(5s)**	
OV Stage 2 Hysteresis	1..90 **(2%)**	
OV Stage 2 O/P Phases	**Any Phase**, All Phases	
OV Stage 2 Trip	**Disable**, Enable	
Undervoltage Prot.	**Disable**, Enable	Enables or disables the Undervoltage Protection
UV Low V Blocking	**Disable**, Enable	When enabled this will prevent operation of the undervoltage detectors when the voltage drops below the block level. Prevents nuisance alarms when the line is dead.
UV Block Level	3..60 **(10V)**	
UV Stage 1 Level	5..85 **(55V)**	Settings as per Overvoltage (See Above) The element will pick up at 100% of setting and will drop off at 100% + Hysteresis level.
UV Stage 1 Time Delay	0..600 **(5s)**	
UV Stage 1 Hysteresis	1..90 **(2%)**	
UV Stage 1 O/P Phases	**Any Phase** All Phases	
UV Stage 1 Trip	**Disable**, Enable	
UV Stage 2 Level	5..85 **(55V)**	Settings as per Overvoltage (See Above) The element will pick up at 100% of setting and will drop off at 100% + Hysteresis level.
UV Stage 2 Time Delay	0..600 **(5s)**	
UV Stage 2 Hysteresis	1..90 **(2%)**	
UV Stage 2 O/P Phases	**Any Phase,** All Phases	
UV Stage 2 Trip	**Disable**, Enable	
Switch On To Fault	Disable, **Enable**	The SOTF logic caters for a situation in which a close-up three-phase fault occurs, and there is not enough voltage in the fault path to operate the forward looking distance protection elements of the relay.
SOTF Mode	**AC SOTF** DC SOTF	*AC SOTF* is the preferred algorithm to use, but can only be used where VTs are positioned on the Line side of the circuit breakers. Where busbar VTs are applied the *DC SOTF* logic must be selected.
SOTF O/C Operate Level	0.3..4 **(0.3xIn)**	When the breaker has been open for a set time delay (see *AC SOTF pickup delay* in the Reylogic Menu) and the relay detects current above this level, when the voltage is below 20% of nominal the AC SOTF logic will be enabled for 200ms.
VT Supervision	Disable, **Enable**	Failure of the VT can cause a maltrip, as the relay will see the voltage (and hence the impedance) drop to zero. *Voltage Transformer Supervision* will check the output from the VTs.
VTS Latched Operation	Disable, **Enable**	If residual/NPS current is detected above the VTS Ires level, the VTS protection blocking will reset unless this setting is enabled. If Enabled the current will only reset the VTS if it is detected before the VTS Latch Op. Delay expires.

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VTS Mode	Alarm Only Alarm & Inhibit	On detecting a VT failure, the relay can either raise an alarm only or inhibit tripping and raise an alarm.
VTS Phase Fault Inhibit	Disable, **Enable**	If this is enabled, the relay will inhibit tripping of the phase fault element whenever a VT fail condition occurs. The relay will not trip however, if a phase fault occurs after a VT has failed. With this setting disabled, the relay will not restrain the distance elements if two phases of the VT fail. Under such conditions the relay will trip.
VTS Input Source	Res.I/V, NPS I/V **(Res.I/V)**	This selects to use either Residual voltage and current or Negative Phase Sequence voltage and current to detect VT failure.
VTS Ires Level	0.05..2 **(0.3 x In)**	The relay will raise a VTSalarm if it detects residual voltage greater than the *Vop Level*, AND residual current less than the *Ires Level*.
VTS Vop Level	1..100 **(20)**	

1.5 Autoreclose Menu

Setting	Range	Description
A/R In Service	In..**Out**	Switches the autorecloser in and out of service.
Close Mode Selection	Off, 1p, **3p**, 1p/3p, 1p3p/3p, 3p3p, 1p1p, 1p1p/3p3p	Defines the Mode of tripping and closing as single-pole or three-pole, and multishot or single shot. The “/” is used to separate relay operation, for a single pole trip, and secondly for a three pole trip.

During the autoreclose cycle, (either during or at the end of the Deadtime), the relay goes through a number of checks to determine whether a close pulse should be issued or not. The following are the checks carried out by the relay before the close pulse is issued.
If all these conditions are all disabled, the relay will not issue a close pulse.

Setting	Range	Description
Dead Bar Charge	Enable, **Disable**	Checks that the bar is dead.
Dead Line Charge	Enable, **Disable**	Checks that the line is dead.
Dead Line & Dead Bar Close	Enable, **Disable**	Checks that both line & bar are dead.
Check Sync Close	**Enable**, Disable	Checks synchronism between line and bus before allowing a close pulse. See check sync settings.
Unconditional Close	Enable, **Disable**	Allows a close pulse regardless of the conditions at the end of the deadtime.

The remainder of the settings are to do with the general operation of the autorecloser.

Setting	Range	Description
First 1P Deadtime	0.05..100 **(1s)**	This setting determines the length of the deadtime under the various trip conditions. The conditions for starting the deadtime are defined below.
Second 1P Deadtime	0.05..100 **(1s)**	
First 3P Deadtime	0.1..900 **(5s)**	
Second 3P Deadtime	0.1..900 **(5s)**	
Start Deadtime	Trip Make **Trip & CB Open**	Defines whether the deadtime is started when the relay trips or when the relay has tripped and the CB has opened.
3P Deadtime Initiate	**1P/2P/3P,** 1P/2P	This determines whether the autorecloser operates for single phase and phase faults only, or 1, 2 AND 3 phase faults.
Live Line Check	**Enable,** Disable	With this setting enabled, in addition to the Start Deadtime condition defined above, the relay will check that the line goes dead before the deadtime is started. This is to ensure that breakers at both ends of the line have tripped before the start of the deadtime.

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		Note: This should not be used in conjunction with single pole tripping
CB Aux Switches	**Type a,** Type b Type a & b	Determines whether the SI should be energised when the breaker is open (Type a) or energised when the breaker is closed (Type b) or both. Note that if type a is selected, the SI CB A, B, C Aux One SI should be used, and if type b is selected, then the SI CB A, B, C Aux Two SI should be used. Obviously, if type a & b are selected, all these SI must be used.
CB Close Pulse	0.2..20 **(2s)**	This is the length of the close pulse issued by the relay.
Reclaim Time	1..600 **(5s)**	This is the time after the end of the close pulse before the Autoreclose cycle resets itself. If a fault occurs during the reclaim time, the relay will lockout the autorecloser, or carry out a second autoreclose shot depending on the close mode selected.
Sync Close Delay	0..60 **(30s)**	This is the maximum length of time allowed between the end of the deadtime, and the line and bus voltages coming into synchronism. If synchronism is not achieved within this time, the relay will lockout.
Permissive Close Delay	Off..600 **(60s)**	If the SI assigned to Block Autoreclose remains energised for longer that this time delay the relay will lockout the autorecloser.
Overall Sequence Timer	Off..3000 **(Off)**	This acts as a check on the timing of the overall autoreclose system. Its starts when the autoreclose is initiated, and is reset when the autoreclose cycle has been successfully completed. If the sequence is not completed within this time the relay will lockout.
Sequence Fail Timer	Off..200 **(120s)**	This is the maximum time between the start of the autoreclose sequence and the start of the deadtime. If the conditions set for *3P Deadtime Initiate* (see above), the relay will lockout the autorecloser.
Persistent Intertrip	1..180 **(60s)**	If the *Intertrip Receive* status input is energised for longer than this time delay the relay will lock out the autorecloser.
CB Fail To Open Delay	50..2000 **(100ms)**	Time between the trip command and the breaker issuing a CB Fail to Open alarm.
Minimum LO Timer	0..60 **(2s)**	Normally, the AR lockout will be reset automatically when the Breaker is successfully re-closed. Alternatively, it is possible, to reset the Lockout after a time delay as set here.
Reset LO By Timer	Enable, **Disable**	
CB Indeterminate	50..200 **(80ms)**	
CB Memory Timer	0..5 **(2s)**	This setting allows a delay in dropoff of the CB in service function. The CB is said to be out of service if the breaker is open or the line voltage is dead. If either of these conditions exist for longer that this timer the CB not in service alarm will operate. The autorecloser will not start if the CB is not in service
Set Type	**Master**, Slave	Where two auto-reclose relays are applied for one CB the relay which is designated Master can be set to override the Slave. This requires that the Master's output A/R In Progress is wired to the Master Slave input of the Slave. When the Master Slave input of the Slave is active it will cancel any auto-reclose sequence, reset and wait in its ready state until the A/R In Progress of the Master is released.
Total Close Counts to Alarm	1..999 (100)	Total number of close pulses issued be the relay before the Total CB Count Alarm operates.
Delta Close Counts to Alarm	1..999 (20)	Total number of close pulses issued be the relay before the Delta CB Count Alarm operates.

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1.6 Pole Discrepancy Time

A mismatch of CB positions across the three phases might indicate CB problems. Generally if one or two of the phases is indicating closed whilst the others are open, and vice versa, for longer than a time delay setting then an alarm will be issued.

Setting	Range	Definition
Pole Discrepancy Time	Off..20 (1.6s)	

1.7 Check Sync Menu

Setting	Range	Default	Description
Sync Connection	Phase B Earth Phase A-Phase B	Phase B-Earth	This describes the connection of the VT used to provide the sync voltage.

The next two settings are used when the relay is set to Dead Line or Dead Bar charge or both

Setting	Range	Default	Description
Bus : Dead | Live	5:10..150:155	20¦90%	These settings define the “live” and “dead” conditions of the relay. Once the voltage goes below the “dead” level, the line will remain dead until the voltage rises above the “live” level. Similarly when the voltage goes above the live level it will remain live until it goes below the “dead” level.
Line: Dead | Live	5:10..150:155	20¦90%	

The following settings determine the conditions which must be met for, a Check Sync Close

Setting	Range	Description
Bus Undervolts	Off..150 **(90%)**	These set the maximum allowable undervoltage on the bus and the line for a check sync close.
Line Undervolts	Off..150 **(90%)**	
Voltage Differential	Off..100 **(10%)**	This is the maximum allowable difference in magnitude between the line voltage and the busbar voltage for a check sync close
Split Angle	Off..**(175º)**	This is the angle at which the relay will switch from check sync mode to system sync mode.
MC Split Action	**System Sync** Check Sync	This is the action that will be carried out, if a manual close is attempted, when a system split condition is detected.
ARC Split Action	System Sync **Lockout**	This defines the relay operation when the angle between line and bus voltage reaches the Split angle during an autoreclose operation.
Check Sync Angle	5..90 **(20Deg)**	These are the conditions that must exist for the relay to indicate that the voltages are In Sync, during a Check Sync operation. Also the angle between the two signals must be decreasing.
Check Sync Slip	Off..2000 **(50mHz)**	
Check Sync Timer	Off..100 **(Off)**	Once the synchronising conditions are met, they must remain in sync for this time delay, before the in sync command is issued.
System Sync Angle	5..90 **(10Deg)**	These are the conditions that must exist for the relay to indicate that the voltages are In Sync, during a **System Sync** operation. Also the angle between the two signals must be decreasing. The conditions are more onerous than for a check sync condition.
Sys Sync Slip Frequency	Off..2000 **(125mHz)**	
System Sync Timer	Off..100 **(Off)**	

1.8 Reylogic Config

Each of these timers has a settable range of 0, 60000ms

Settings	Default	Definition
LOL Time Limit	40ms	Maximum time after a loss of load condition is detected for which the Zone2 time delay will be removed.

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SR Dropoff	1ms	Delay on dropoff of the Signal Received 1 (Distance) output of the relay.
POR Current Rev Reset	200ms	When there is a change indirection of the flow of current (due to remote circuit breaker operation), the relay will restrain for this time delay to prevent race conditions between the dropoff of the remote end signal send and the drop off of the local measuring element. (Used only with DEF POR scheme).
POR CB Echo Pulse	250ms	Length of pulse returned to sending end if local CB is open in POR scheme.
WI Sig Recv PU Delay	0ms	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 slow local fault detection with a particularly fast re mote fault detection combined with a fast signalling system.
SS Dropoff	1ms	Delay on dropoff of the Signal Send 1 (Distance) output of the relay.
Permissive Trip Time	1ms	Time delay used by the BOR scheme to allow for a blocking signal to be received before carrying out an aided trip.
SR2 Dropoff	1ms	Delay on drop off of the Signal receive 2 (DEF) input to the relay.
DEF Current Rev Reset	200ms	When there is a change indirection of the flow of current (due to remote circuit breaker operation), the relay will restrain for this time delay to prevent race conditions between the drop-off of the remote end signal send and the drop off of the local measuring element. (Used only with DEF POR scheme).
CB Echo Pulse Width	250ms	When a DEF signal is received from the remote end and the local breaker is open, the relay will issue a signal send to allow a DEF aided trip at the remote end. The length of pulse “Echoed” back to the remote end in this way is defined here. Used only with DEF POR scheme.
DEF Backup Trip Delay	1ms	If the relay detects a DEF condition, but does not receive a permissive signal from the remote end it will perform a backup trip after this time delay.
SS2 Dropoff	1ms	Delay on drop off of the Signal Send 2 (DEF) output of the relay.
AC SOTF Pickup Delay	10000ms	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	100ms	This is the minimum time for which the VT fail conditions must remain on the system before the VT alarm is operated. It is usually set to 1000ms to avoid nuisance alarms.
VTS Latch PU Delay	5000ms	This is the minimum time that the VT fail conditions must remain on the system before the VT condition will latch. When latched, the VTS condition will only reset if the voltage is restored, i.e. it will not reset if residual current is measured above the setting. It is usually set to 5000ms.
TCS 1 Alarm Pick Up	400ms	Delay on Pick-up of the Trip Circuit Supervision Status Inputs, to avoid nuisance alarms.
TCS 2 Alarm Pick Up	400ms	
TCS 3 Alarm Pick Up	400ms	

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1.9 Status Config

Setting	Definition
Reset LED Flags	Energising this SI will reset all LED flags, in the same way as pressing the TEST/RESET button on the relay.
Enable Stub Prot'n	Energising this SI will start the *Stub Protection* (if it has been enabled in Aux protection menu). It will be energised from a disconnector auxiliary switch.
Inputs 1-8	Connection points for unallocated logic inputs 1-8.
3 Pole Trip Select	Energising this SI will cause the relay to carry out a three-phase trip for all fault types.
Block Reach Ext	Energising this SI will block operation of the *Reach Extension* scheme, i.e. it will cause the relay to operate as a time stepped distance scheme. It allows the Reach extension to be easily disabled from a panel switch.
Carrier Recv Guard	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	Signalling channel used for Distance Protection.
Unstabilise Relay	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	Will inhibit operation of the *Blocked Overreach* scheme (where selected)
Block DEF	Energising this status input will prevent operation of the DEF function.
Signal Receive 2	Signalling channel used for *DEF Protection* depending on the selected scheme.
Manual Close	This SI is required where *DC SOTF* has been specified. It should be connected to the manual close handle of the breaker. For 400ms after this SI is energised, it will allow instantaneous tripping of the Zone3 element and indicate an *SOTF* condition.
VT Circuits Isolated	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 1 Fail	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*.
Trip Cct 2 Fail	
Trip Cct 3 Fail	
Trigger Storage	Energising this SI will trigger waveform storage.
Block Reclose	This will halt the auto-recloser at whatever point it is at. All timers will stop until this Status Input is de-energised. If this status input is energised for longer than the *Reclose Blocked Delay*, the relay will lockout.
Inhibit Close	Energising this SI will prevents the close pulse being issued from a Manual Close command.
Intertrip Receive	Dedicated Intertripping channel.
Master/Slave	Where two auto-reclose relays are applied for one CB the relay which is designated Master can be set to override the Slave. This requires that the Master’s output A/R In Progress is wired to the Master/Slave input of the Slave. When the Master/Slave input of the Slave is active it will cancel any auto-reclose sequence, reset and wait in its ready state until the A/R In Progress of the Master is released.
A/R Out	These control the autorecloser. A pulse to the “AR in” SI will switch it into service, one to the “AR out” will switch it out of service. If both are high simultaneously, the autorecloser will be switched out of service
A/R In	
Go Direct To Lockout	This will cause the relay to go into lockout regardless of the status of the Autorecloser.
External A/R Start	Energising this SI will cause the relay to start an autoreclose sequence. All conditions for autoreclosing must still be met.
Reset Lockout	Energising this SI will reset the relay from a lockout condition. This is not normally required because the lockout condition will be reset when the breaker is successfully reclosed.
Sync Override	Used where an external Synchronising device is applied.

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Manual Sync Override	Used directly to override synchronisation under manual close conditions.
CB A Aux One	Used where *Type a* CB Auxiliary Switches are specified.
CB B Aux One	
CB C Aux One	
CB A Aux Two	Used where *Type b* CB Auxiliary Switches are specified.
CB B Aux Two	
CB C Aux Two	
Reset Total CB Close	Resets the *Total CB Close* Count.
Reset Delta CB Close	Resets the *Delta CB Close* Count.
Block Output Relays	When this SI is energised, operation of the relays selected as 'inhibit outputs' in the output menu, will be blocked.
Switch Settings Grp	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	Energising this status input will prevent the relay from changing groups when the Switch Settings group Input is energised.
Inverted Inputs	All input selected here will have their logic sense reversed, i.e. no connection or connection to 0v will constitute a switched on input.

1.10 Output Config

Setting	**Definition**
Protection Healthy	Operates when the Protection is healthy. Will drop off when the relay watchdog identifies any problem with the relay, or the DC supply is removed.
Output 1-8	Outputs driven by energisation of the unallocated inputs 1-8.
Loss Of Load	Operates when the *Loss of Load* trip has occurred.
Aided Trip	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.
Z1 Extension	Operates when a fault is detected by Zone 1 whilst zone 1 extension is in service.
Signal Received 1	Operates on receipt of a signal from the remote end distance relay.
POR Weak Infeed	
Signal Send 1	Operates according to the selected scheme to send either a permissive signal or a blocking signal to the remote end.
DEF1 Alarm	Operates when the DEF1 element has picked up.
DEF2 Alarm	Operates when the DEF2 element has picked up.
Signal Received 2	Operates on receipt of a permissive DEF signal from the remote end.
DEF Aided Trip	Operates when the DEF carries out an aided trip.
DEF POR Weak Infeed	Operates in DEF POR mode when a signal is received from the remote end, the breaker is closed, and the forward and reverse DEF elements have not operated.
Signal Send 2	Operates in DEF POR mode when the forward-looking DEF element operates.
Zone 1	Indicates the Zones involved in the fault.
Zone 2	
Zone 3	
Zone 4	
High Set	Indicates operation of the Highset Overcurrent element.
Stub Protection	Indicates operation of the Stub Protection.
OV Alarm	Operates when the Overvoltage Stage 1 Element picks up.
OV Trip	Operates when the Overvoltage Stage 2 Element picks up.
UV Alarm	Operates when the Undervoltage Stage 1 Element picks up.
UV Trip	Operates when an Undervoltage Stage 2 Element picks up.
SOTF Operated	Indicates that a Switch-onto-fault Operation has occurred.

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VTS Alarm	Operates when one or more phases of the Voltage Transformer fails.
DAR Lockout	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	Main trip segregated tripping output contacts.
Pole B Trip	
Pole C Trip	
3 Pole Trip	Alarm contact which operates when the relay has carried out a three pole trip.
Trip Cct 1 Failed	When a Trip circuit fails, this indicates which phases are involved.
Trip Cct 2 Failed	
Trip Cct 3 Failed	
Phase A Fault	Indicates the phase(s) involved in the fault condition
Phase B Fault	
Phase C Fault	
Earth Fault	Operates when the fault involves an earth path.
Power Swing Alarm	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	Operates when the carrier guard SI has operated because of a faulty signalling channel.
Start A	Indicates the phase(s) which have starters initiated.
Start B	
Start C	
Close Pulse	Operates when the relay carries out a close command during an autoreclose cycle.
Lockout	Operates when the Autorecloser has locked out.
A/R In Service	Operates whenever the Autorecloser is in service.
A/R In Progress	Starts when the relay carries out a trip which will start an autoreclose, and drops off at the end of the reclaim time. If the Autorecloser locks out this will remain operated until the Lockout condition is reset.
Live Line	Operates when the line is live according to the settings made for *Line Live : Dead* in the Check Sync Menu
Live Bus	Operates when the bus is live according to the settings made for *Bus Live : Dead* in the Check Sync Menu
In Sync	Operates whenever the bus and line voltages are in sync. This will run constantly, not just during a *Check Sync* operation.
VT Failure	This alarm is generated when the relay detects either Live line and CB Closed and dead bus OR Live bar and CB Closed and dead line for greater than 2 seconds.
CB A Open	Indicates the position of the three phases of the circuit breaker.
CB B Open	
CB C Open	
CB Failed To Open	Operates if the relay trip and the breaker fails to open within the *CB Fail To Open Delay*
CB Failed To Close	Operates if the CB fails to close by the end of the close pulse.
CB Pole Discrepancy	Operates if detection of CB Open from separate phases differs by more than the pole discrepancy time.
Successful Close	Operates when a close pulse is issued and the CB closes successfully.
System Split	Operates when the angle between Bus and Line voltages becomes greater than the *Split Angle* (See Check Sync Menu).
Check Sync Start	Operates when the synchronising conditions are being checked during an autoreclose cycle.
Sync In Prog Flag	Operates when the relay is checking the synchronising conditions.
Close Onto Fault	Operates when the relay recloses on a permanent fault and thus locks out.
Delta CB Count Alarm	Operates when the *Delta Close Counter* reaches its target.

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Total CB Count Alarm	Operates when the *Total Close Counter* reaches its target.
CB Not In Ser Alarm	This will operate when the CB is open or the line is dead for longer than the *CB Memory Time*. Either of these conditions must exist for the CB to be not in service. A circuit breaker's service status is determined by its position and its voltage references. The circuit breaker is defined as being in service when it is closed and its voltage references are live. If either of these conditions are not in place the relay will raise this alarm after the *CB Memory Time*.
CB Memory	This indicates that the CB is in service (opposite to the above setting).
A/R Not Allowed	Operates when a system condition prevents the operation of the autorecloser.
Zone 1 Start Zone 2 Start Zone 3 Start Zone 4 Start	Operates for any fault detection by individual zone instantaneous pick-up without expiry of the zone timer. Simulates 'Starter' pick-up of previous generation relays.
Hand Reset Outputs	Indicates which Outputs are latched.
Fast Reset Outputs	Logic outputs driving these output contacts are checked for drop off more frequently than standard outputs to provide contacts with accurately timed drop off where necessitated by certain functions.
Inhibit Outputs	Operation of outputs specified here will be blocked when the inhibit outputs status input is energised.

1.11 Output Relay Dwell Time Menu

All relays are individually set for minimum operating time.

Setting	**Range**	**Default**
Min. Op. Time 1	0 … 2000ms	100ms
:	:	:
Min. Op. Time *	0 … 2000ms	100ms

1.12 LED Config

Settings as per the Output Configuration.

Setting	
Self Reset leds	List which leds will self extinguish when the applicable function resets. Any leds not listed here will latch on, once operated, until they are manually reset.

1.13 Data Storage Menu

The relay is capable of storing up to 10 fault records. The records are stored as a 1 second rolling window, with a set pre-fault time – thus with the setting below, the relay will record 100 ms of data prior to the fault and 900ms after the fault.

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

1.14 Communications Menu

More details on the communications can be found in Section 6 of this manual.

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	19200
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,	19200

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	57600, 115200	
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	AUTO-DETECT

1.15 Fault Locator Menu

The setting here are used for the Fault locator calculation.

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

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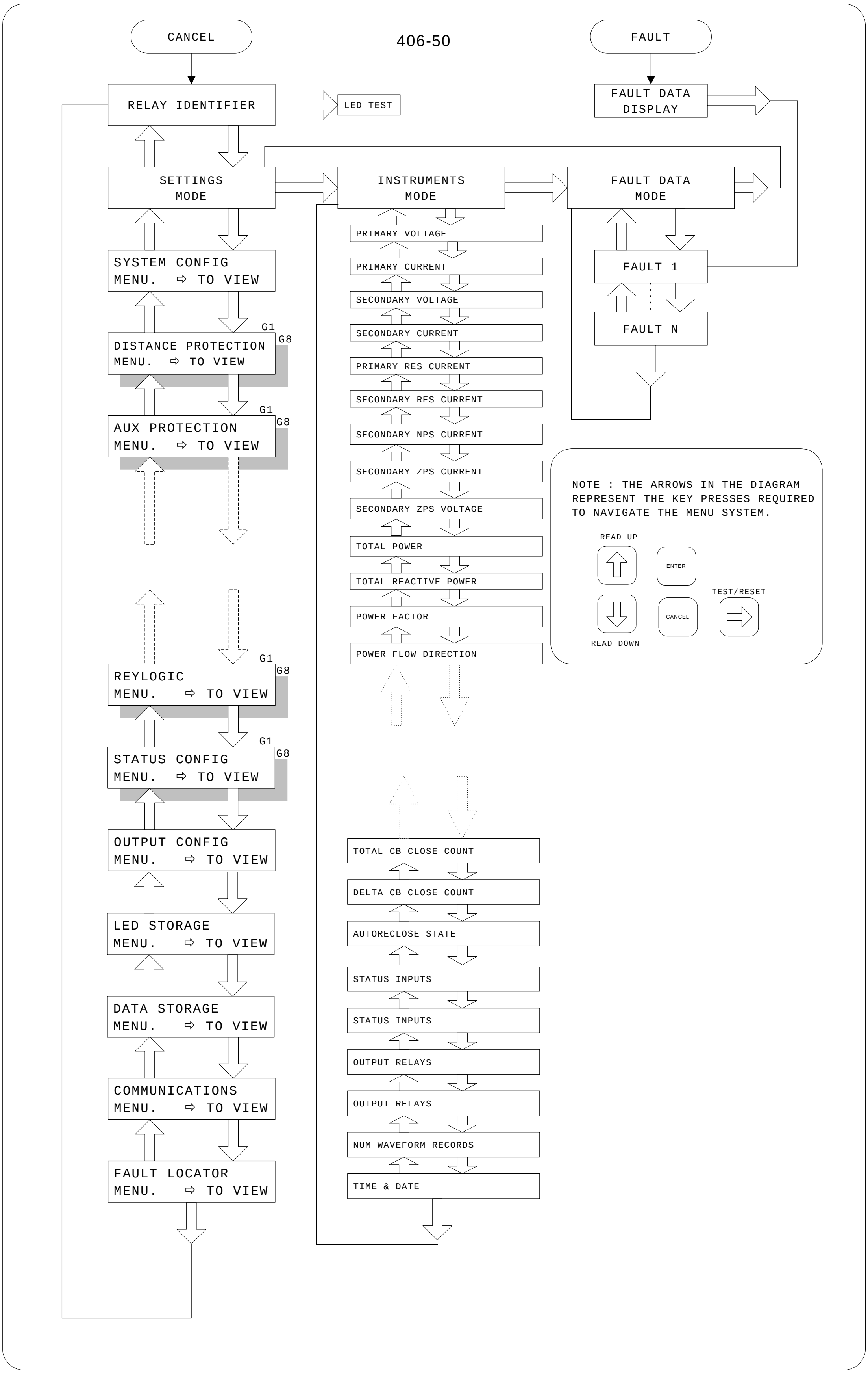
2 Menu Structure



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7SG164 Ohmega 400 Series

Distance Protection Relays

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

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Contents

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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.

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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

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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.

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7 Optional Features

7.1 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

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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.

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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

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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

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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

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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

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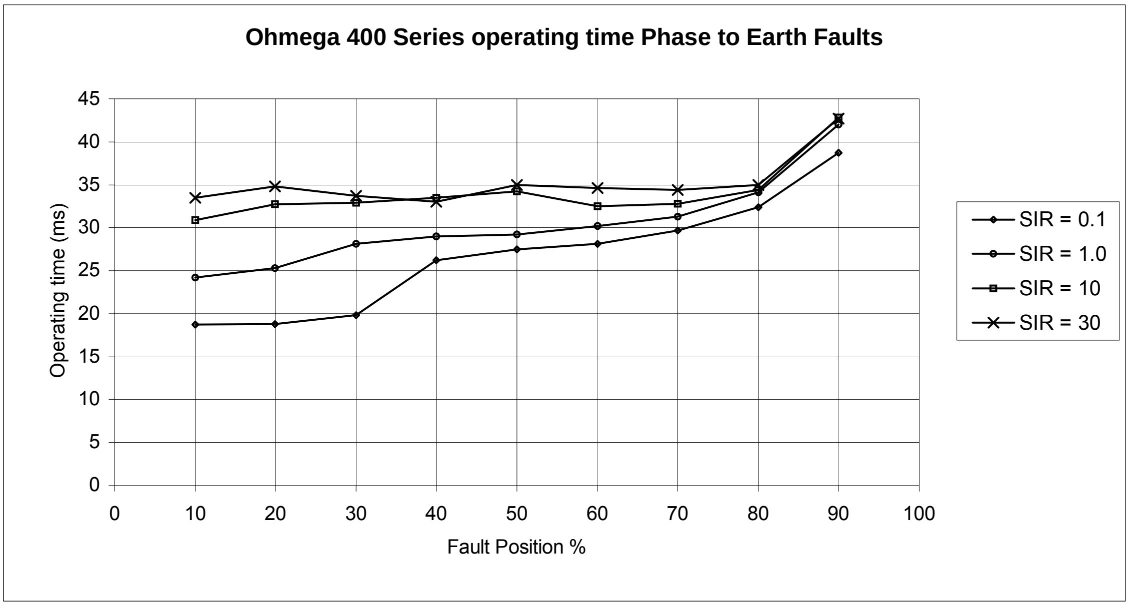

Figure 1

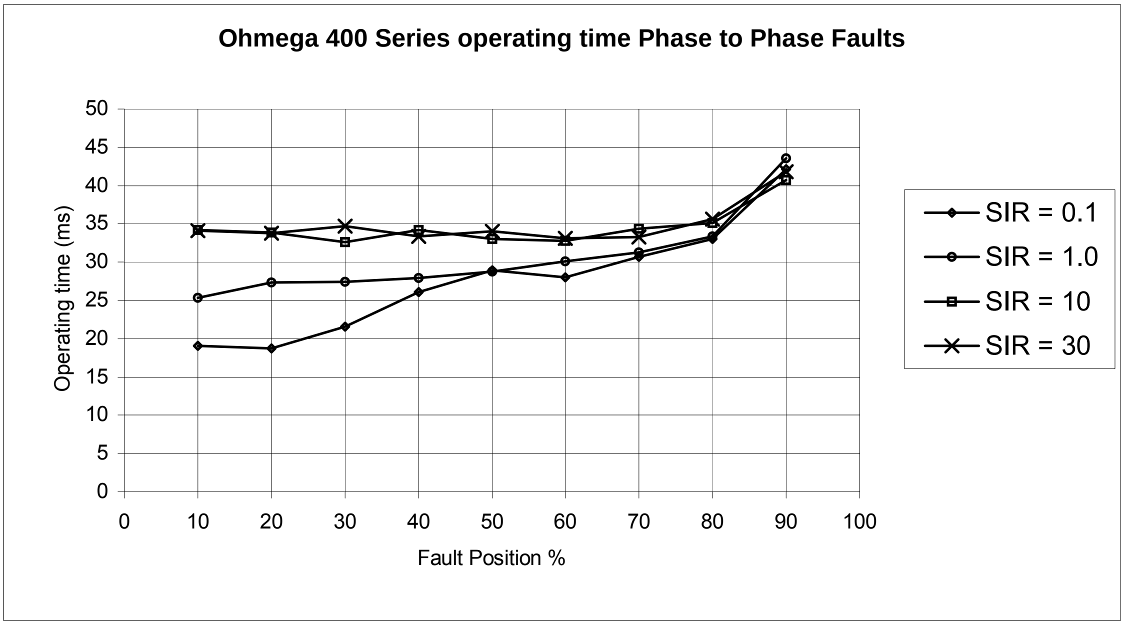

Figure 2

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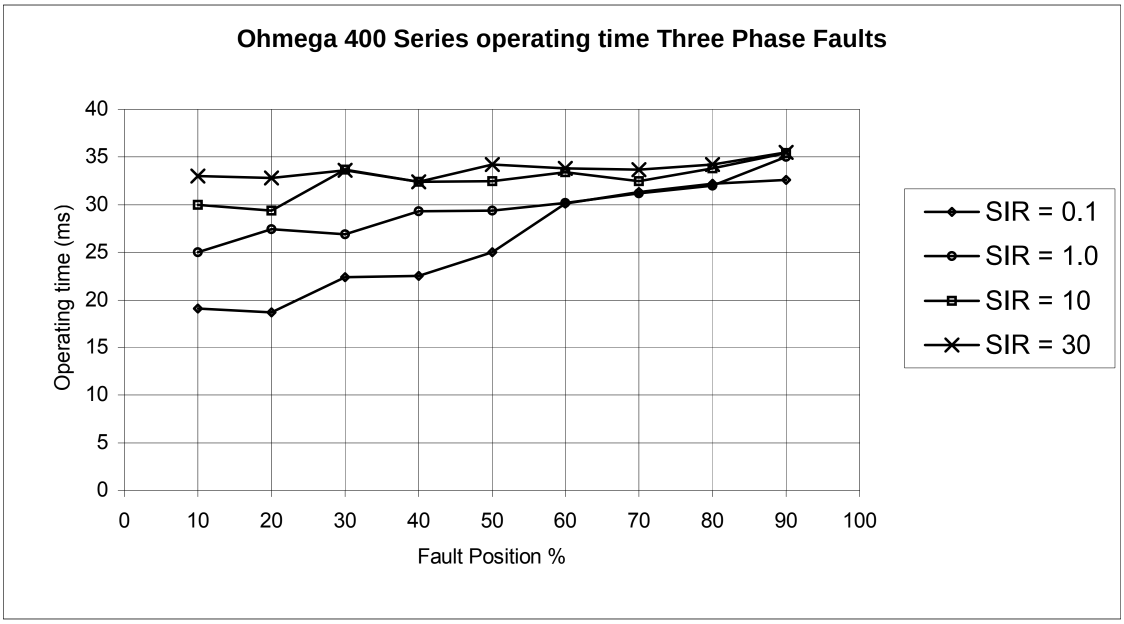

Figure 3

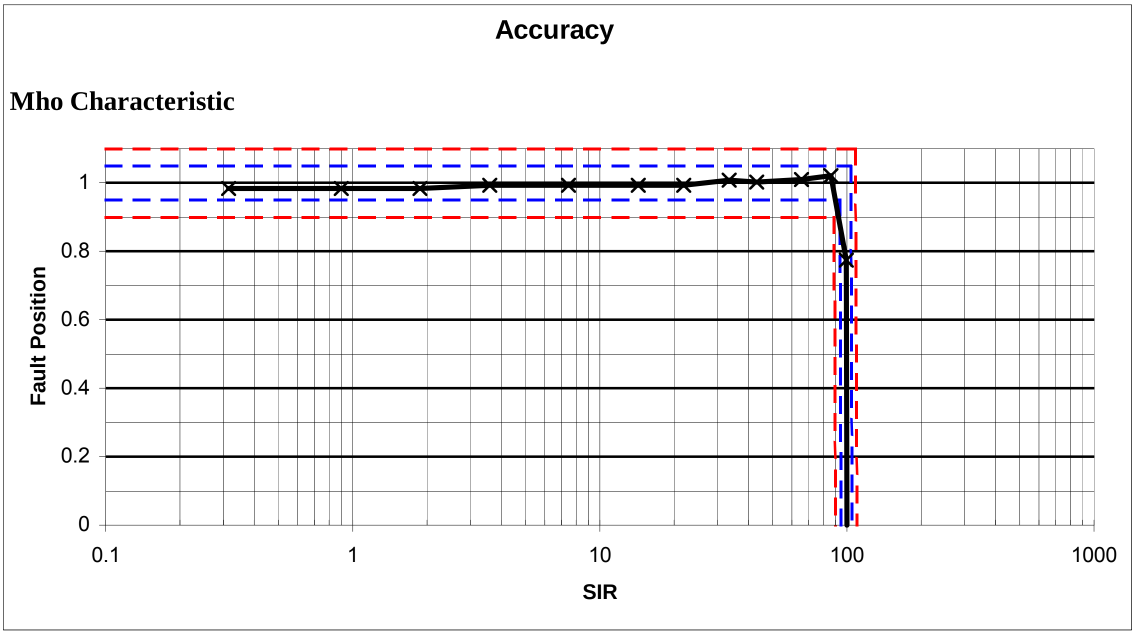

Figure 4

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Distance Protection Relays

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

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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.

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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

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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 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.

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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.

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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.

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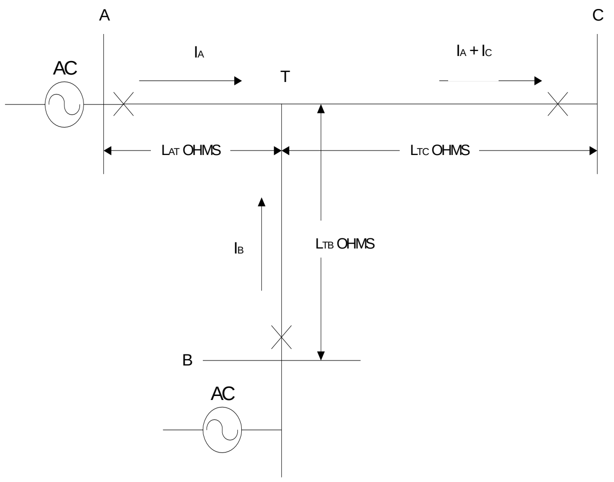

The Zone 2 reach is obtained by adjusting the impedance setting.

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

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.

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

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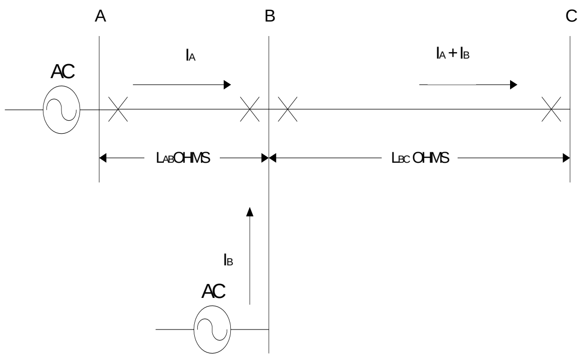

3.2.6 Zone 4 Impedance Setting

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.

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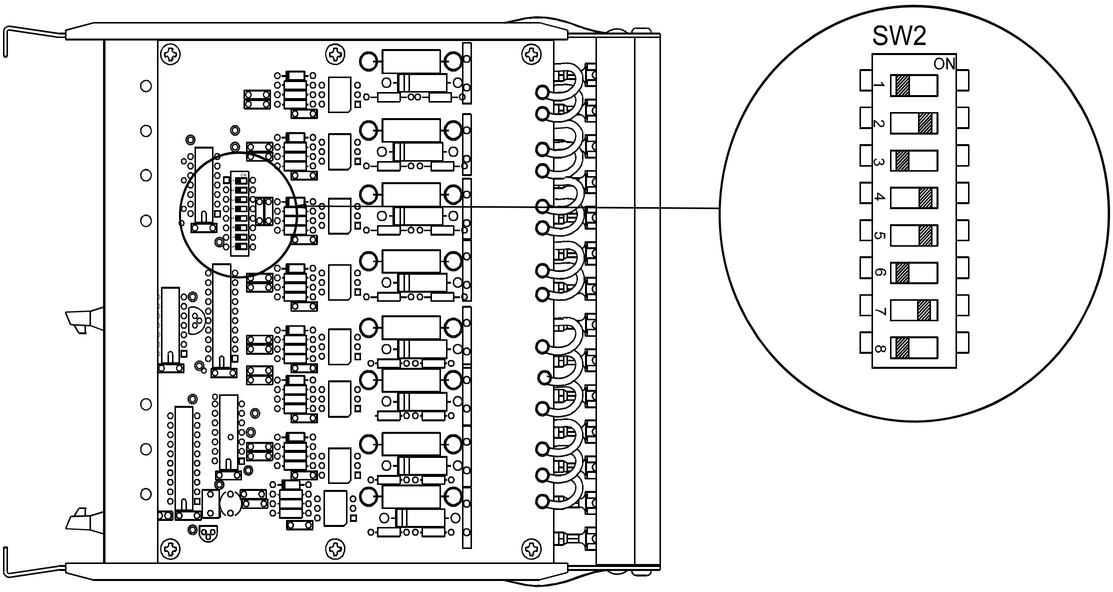
APPENDIX A Status Inputs

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, using the Defect Report Form in the Maintenance section of this manual.

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

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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.

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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.

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- 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

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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)

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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.		

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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.

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3 Defect Report Form

Form sheet for repairs and returned goods (fields marked with * are mandatory fields)

Sender:

*** Name, first name:**	Complete phone number (incl. country code):	Complete fax number (incl. country code):
Email address:	*** Org-ID and GBK reference:**	*** AWV:**

*** Order-/ reference-no (choosing at least 1 option):**

Order-no for repair:	order-/ delivery note-no for return of commission failure:	Beginning order-no for credit note demand:

Information concerning the product and its use:

*** Order Code (MLFB):**	Firmware version: V	*** Serial number:**	
* Customer:	Product was in use approximately since:	Station/project:	Hotline Input no.:
Customer original purchase order number:	Delivery note number with position number:	Manufacturer:	

*** Type of order (choosing at least 1 option):**

☐ Repair
☐ Return of commission failure
☐ Credit Note
☐ Upgrade / Modification to …
☐ Warranty repair
☐ Quotation (not repair V4 and current products! See prices in PMD)
☐ For collection

Type of failure:

☐ Device or module does not start up
☐ Mechanical problem
☐ Overload
☐ Sporadic failure
☐ Knock sensitive
☐ Transport damage
☐ Permanent failure
☐ Temperature caused failure
☐ Failure after ca ☐ hrs in use
☐ Repeated breakdown
☐ Failure after firmware update

Error description:

☐ Display message:
(use separated sheet for more info)

☐ Active LED messages:

☐ Faulty Interface(s), which?
☐ Wrong measured value(s), which?
☐ Faulty input(s)/output(s), which?

***Detailed error description** (please refer to other error reports or documentation if possible):

*** Shall a firmware update be made during repair or mechanical upgrade of protective relays? (choosing at least 1 option)**

☐ Yes, to most recent version
☐ No
☐ Yes, actual parameters must be reusable

repair report:

☐ Yes, standard report (free of charge)
☐ Yes, detailed report (charge: 400EUR)

Shipping address of the repaired/upgraded product:

Company, department

Name, first name

Street, number

Postcode, city, country

Date, Signature

Please contact the Siemens representative office in your country to obtain return instructions.

E D EA MF TCC 6 release from 11/2009

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7SG1642 Ohmega 406

Distance Protection Relays

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

2006/05	2615H80018R33	

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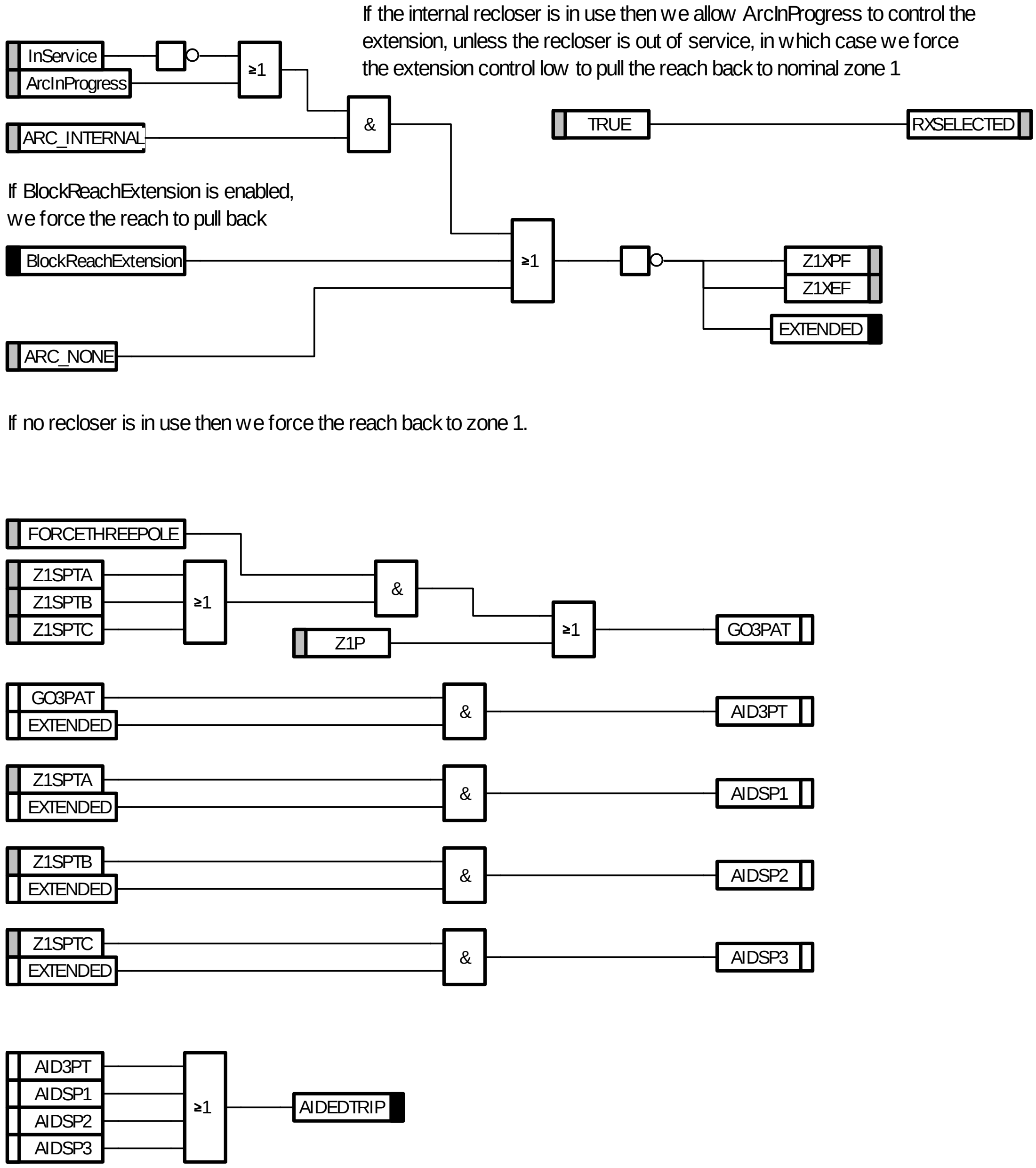
This diagram performs the reach extension logic.

Basically, it directs the inverted ARC in Progress flag at the Z1X enable inputs, so that extension is enabled for first trip, then removed during the autoreclose sequence.

This is an enhanced version of the scheme which now incorporates checks to remove the overreach when the recloser is in local mode and out of service, or when no autorecloser is in use (though Reach Extension should not have been selected with no recloser).



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1 Relay Connections

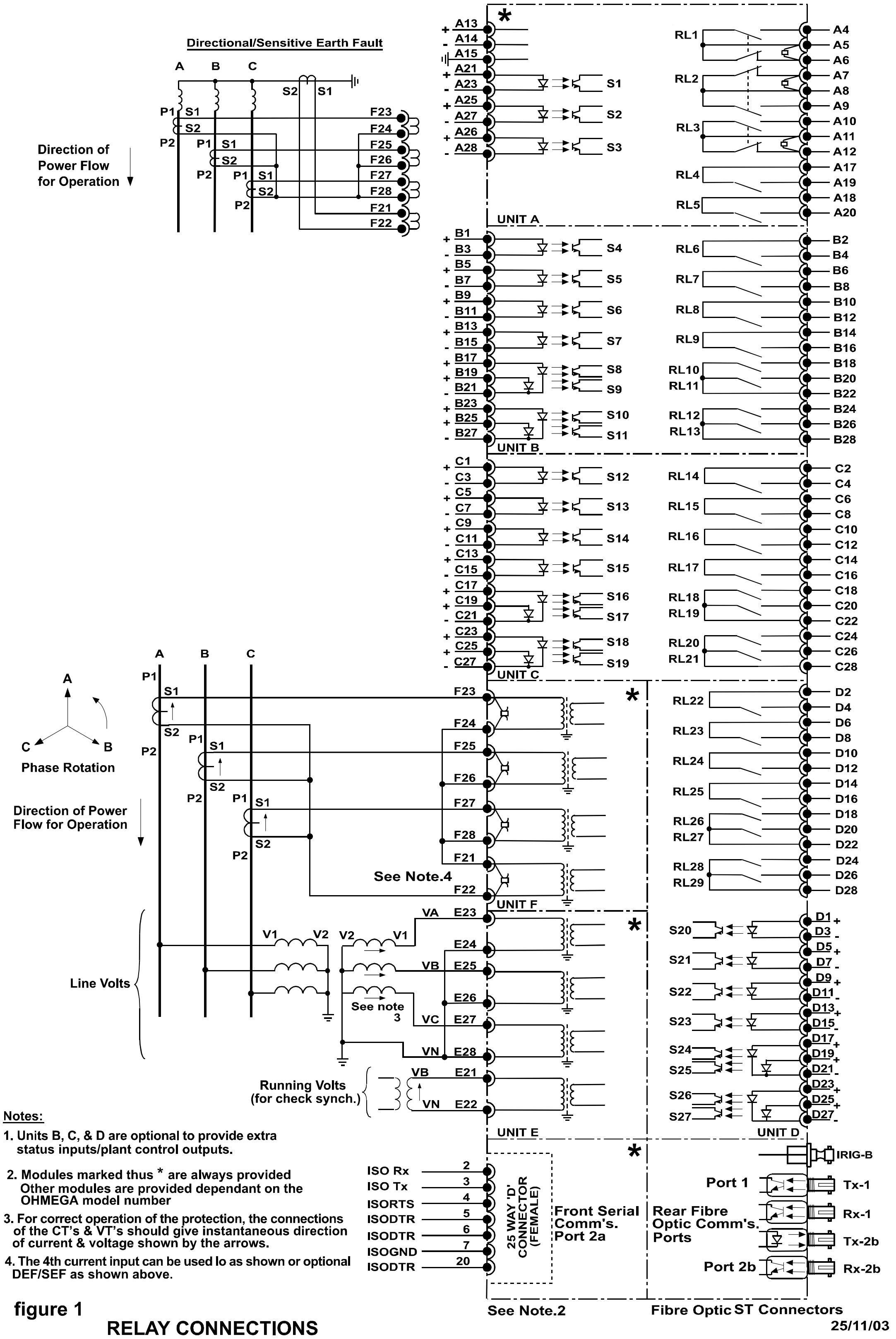

figure 1

RELAY CONNECTIONS

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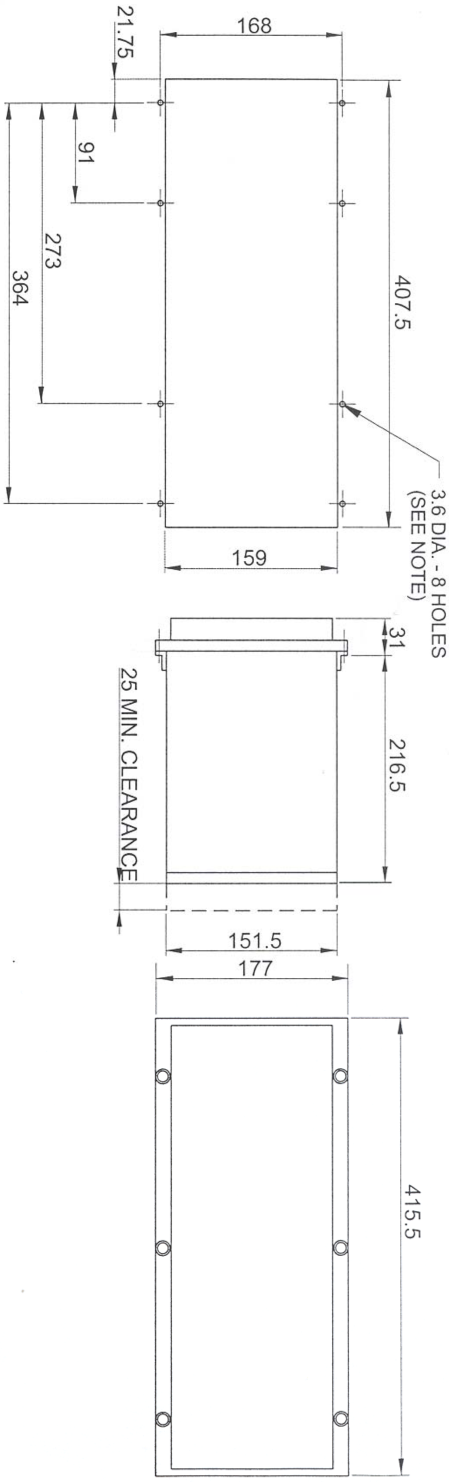
2 Overall dimensions and panel drilling for Epsilon E16



NOTE:
THE 3.6 DIA. HOLES ARE FOR M4 THREAD FORMING (TRILOBULAR) SCREWS. THESE ARE SUPPLIED AS STANDARD AND ARE SUITABLE FOR USE IN FERROUS/ALUMINIUM PANELS 1.6mm THICK AND ABOVE. FOR OTHER PANELS, HOLES TO BE M4 CLEARANCE (TYPICALLY 4.5 DIA.) AND RELAYS MOUNTED M4 MACHINE SCREWS, NUTS AND LOCKWASHERS (SUPPLIED IN PANEL FIXING KIT).

figure 2
OVERALL DIMENSIONS AND PANEL DRILLING FOR EPSILON E16 CASE

24/8/99

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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.

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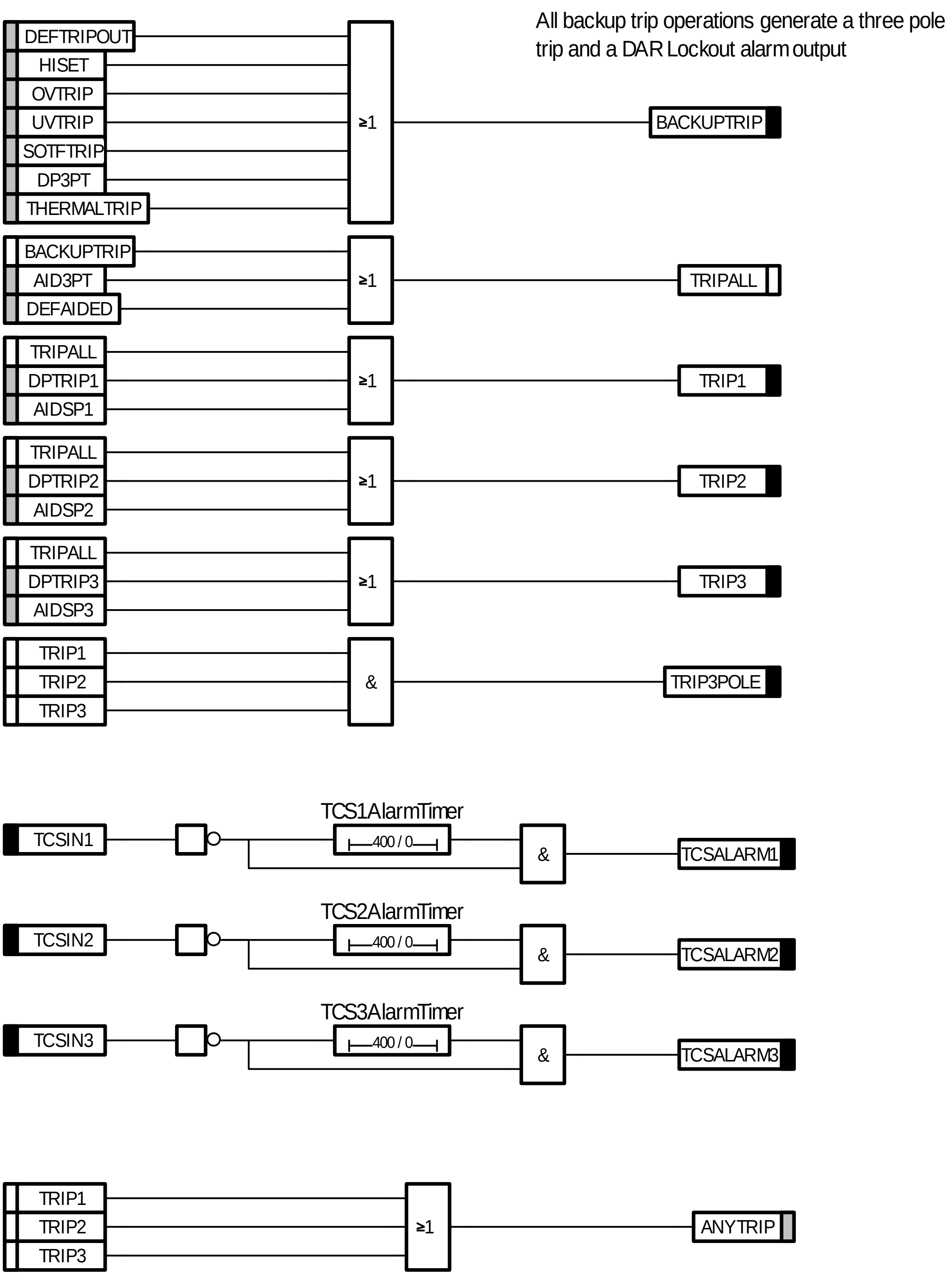
3.1 Distance Protection

3.1.1 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.



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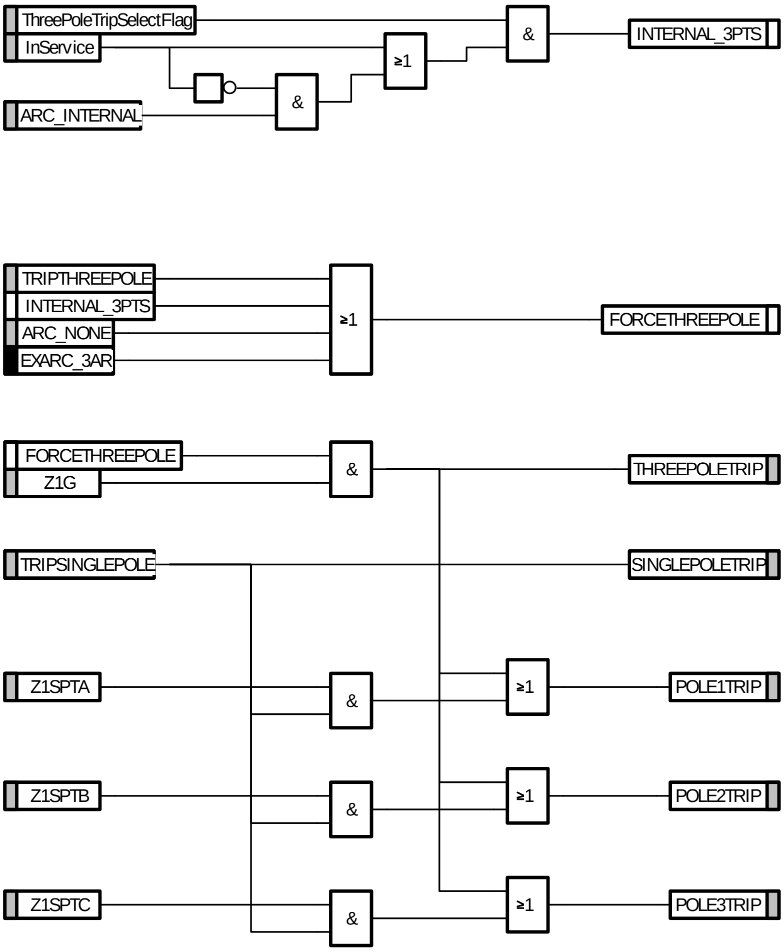
3.1.2 Single Pole Tripping

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.



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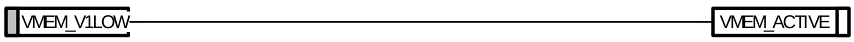
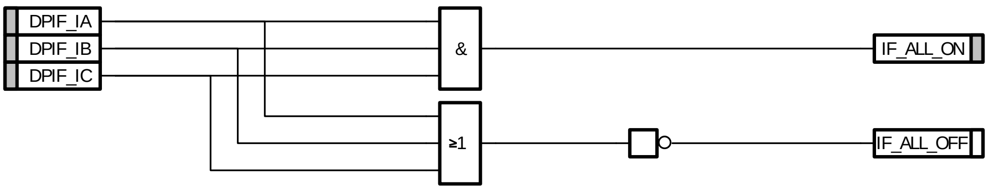
3.1.3 Voltage Memory

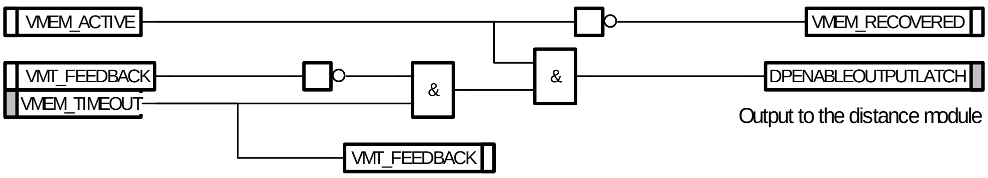
When a heavy three phase fault occurs, the fault voltage will collapse and the voltage memory will start timing out. After approx 100ms, the memory output will clamp off and the memory timeout signal will go active. This applies an inhibit to zone 1 and (where fitted) zone 4. The latch operation is required 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.



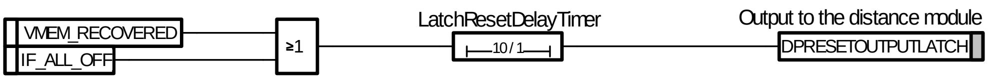
Next, we generate a reset control from the distance fault current detectors



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



Now the latch reset signal



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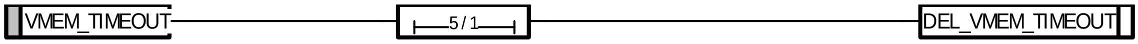
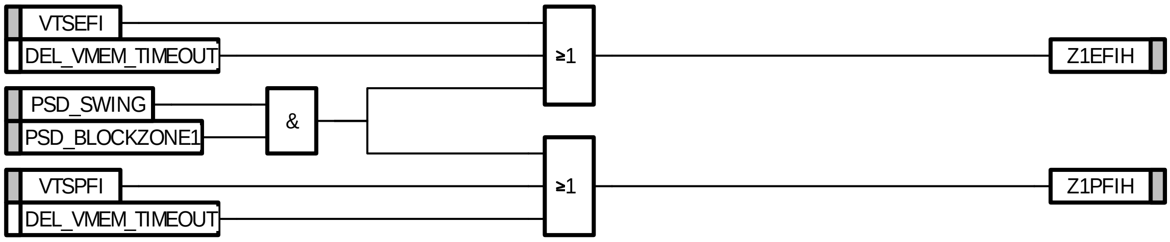
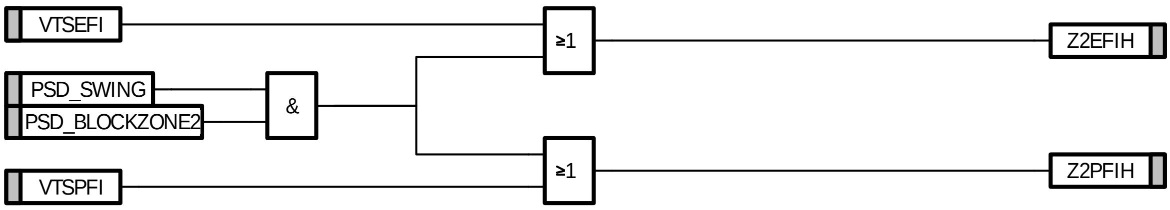
3.1.4 Trip Inhibit Logic



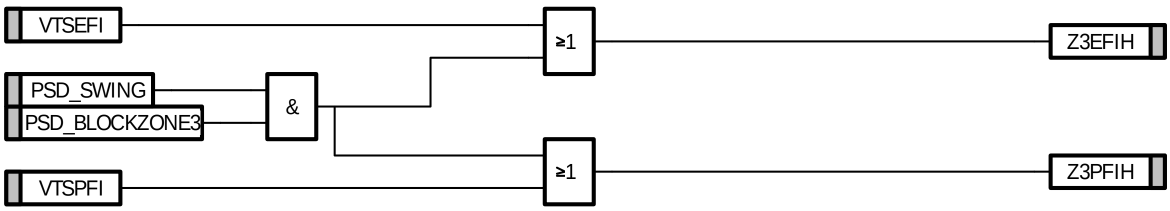
Allow Zone 1 to be inhibited by Power Swing, VTS, or Voltage Memory timing out.



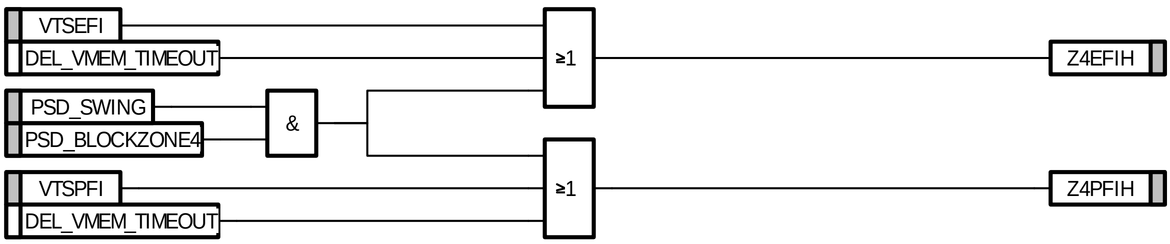
Allow Zone 2 to be inhibited by the same; Power Swing, VTS, or Vmem timed out.



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.



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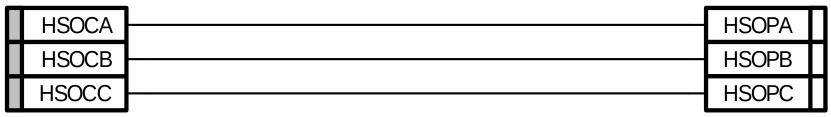
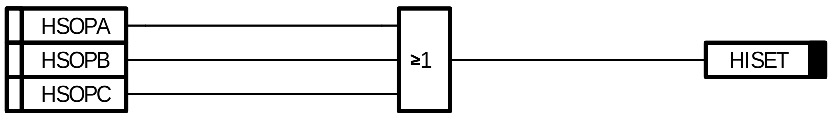
3.2 Auxilary Functions

3.2.1 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



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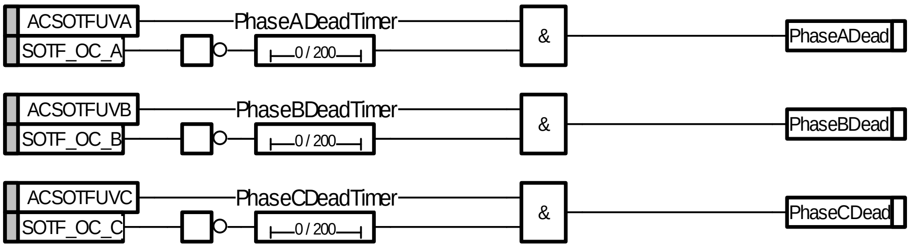
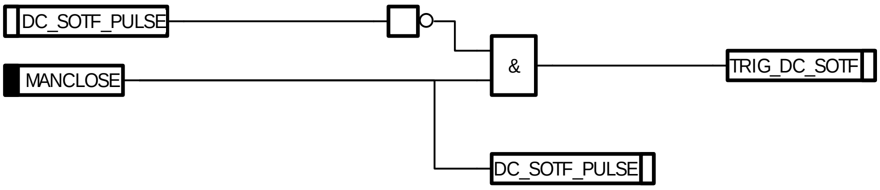
3.2.2 Switch-onto-Fault

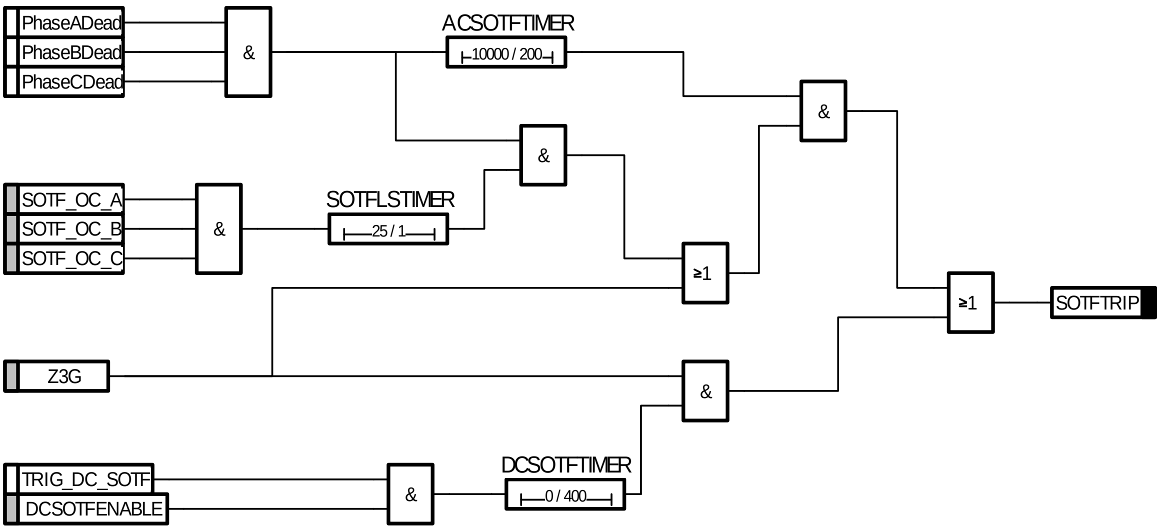
First test each pole to see if it's 'dead'



Generate a pulse from the manual close input.



Now use this to evaluate the SOTF logic



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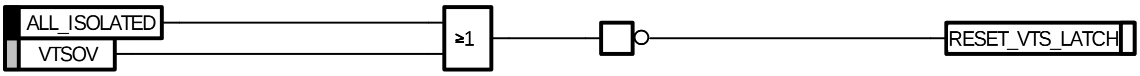
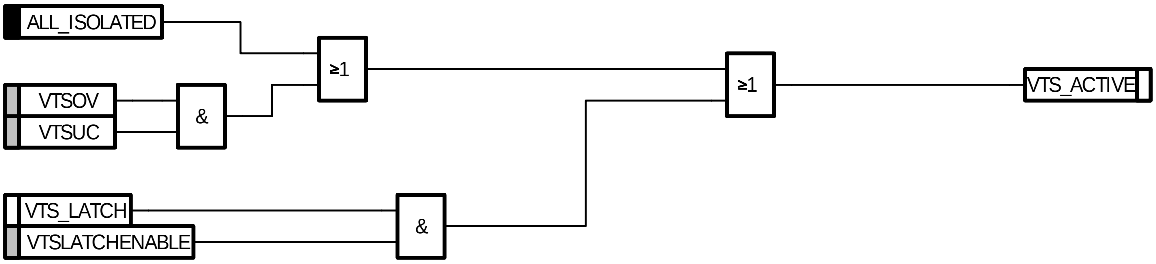
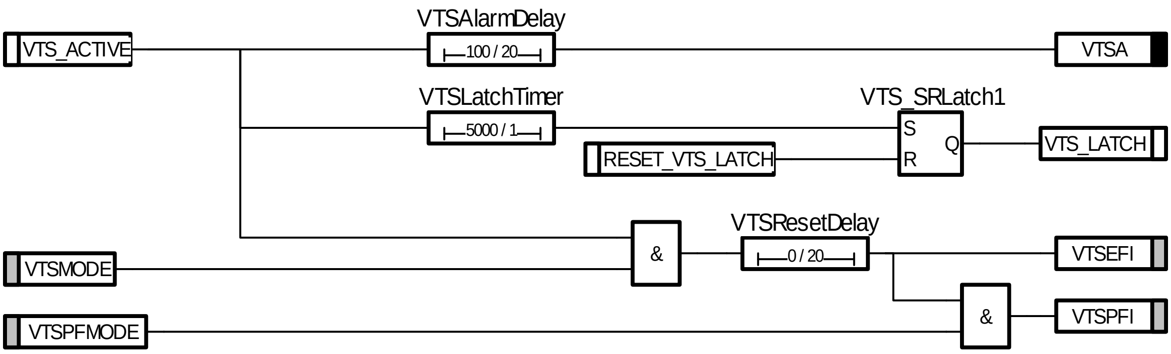
3.2.3 Voltage Transformer Supervision

Generate the latch reset from the voltage recovery



Now the actual VTS logic





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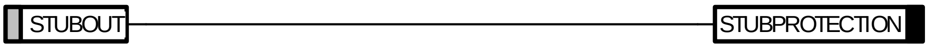
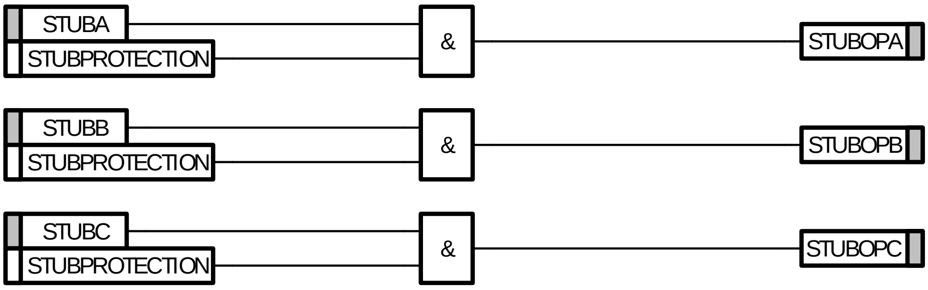
3.2.4 Stub Protection

Generate an alarm/flag output for stub operation



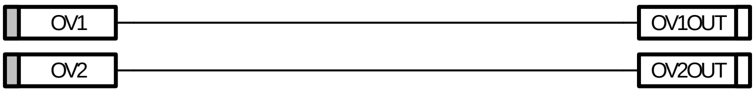
Qualify the stub outputs for flagging.



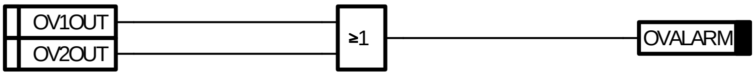
3.2.5 Overvoltage Protection

This diagram provides the indication and trip logic for the Ohmega 400 undervoltage protection

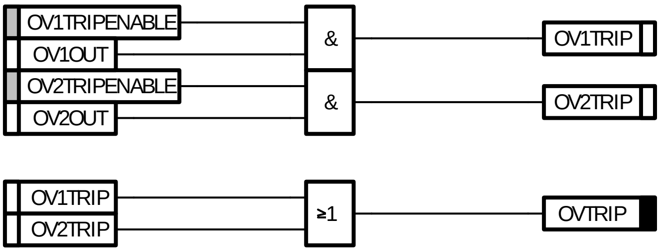
Firstly, copy the OV element operate outputs to the alarm output booleans



Next, create an alarm/flag output



Next, generate a trip signal if UV tripping is enabled. This is used in the trip output diagram



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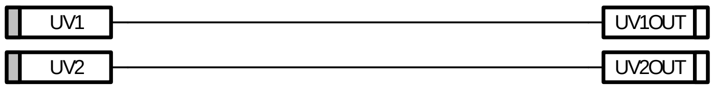
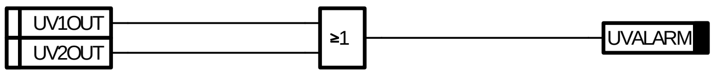
3.2.6 Undervoltage Protection

This diagram provides the indication and trip logic for the Ohmega 400 undervoltage protection

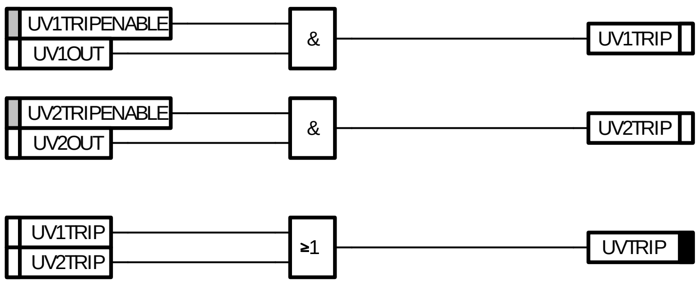
Firstly, copy the UV element operate outputs to the alarm output booleans



Next, create an alarm/flag output



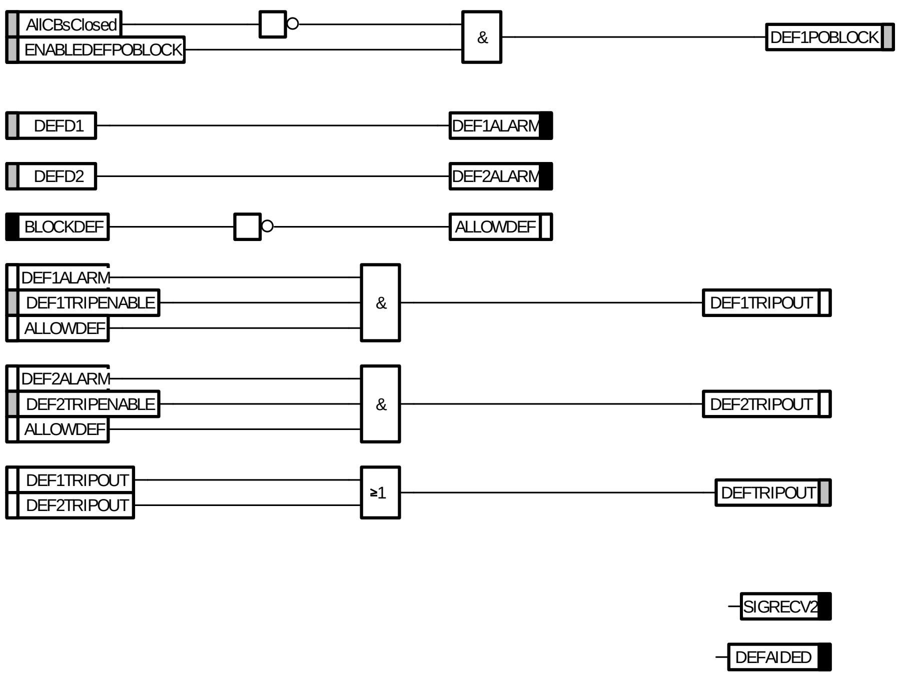
Next, generate a trip signal if UV tripping is enabled. This is used later in the trip output diagram



3.3 DEF

3.3.1 DEF Direct Trip

Allow DEF elements to be blocked if one or more CB poles are open



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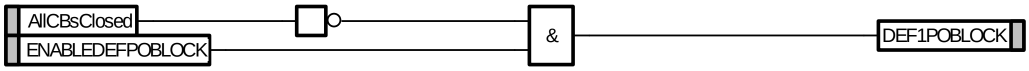
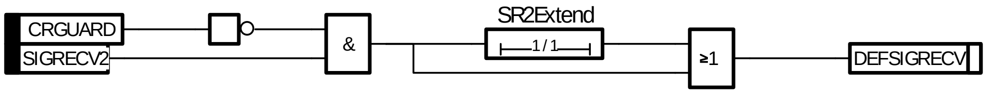
3.3.2 DEF POR

Allow DEF elements to be blocked if one or more CB poles are open



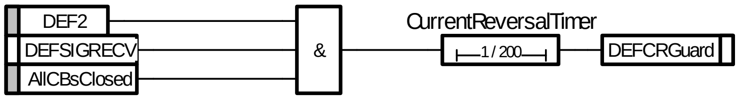
Signal Receive pre-processing



Current Reversal logic

If we have SigRecv, but the fault is behind there's a danger of a current reversal trip.

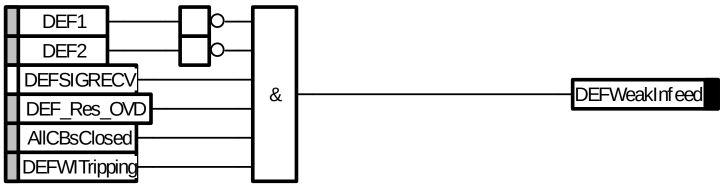
In this circumstance block DEF until SigRecv goes away.



Weak Infeed

SigRecv with neither forward nor reverse DEF operation could be due to a Weak Infeed fault.

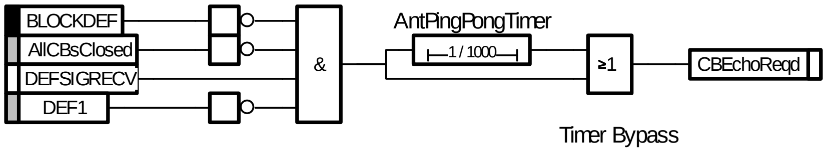
We can use a residual overvoltage detector to detect that there is some sort of earth fault on the system and trip.



CB Echo

If the circuit breaker at this end is open, and a signal is received,
reflect it straight back to the remote end to allow tripping.

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
CBEcho signal and Keep the CB Echo Required signal asserted until
the trigger condition has been absent for 1 second



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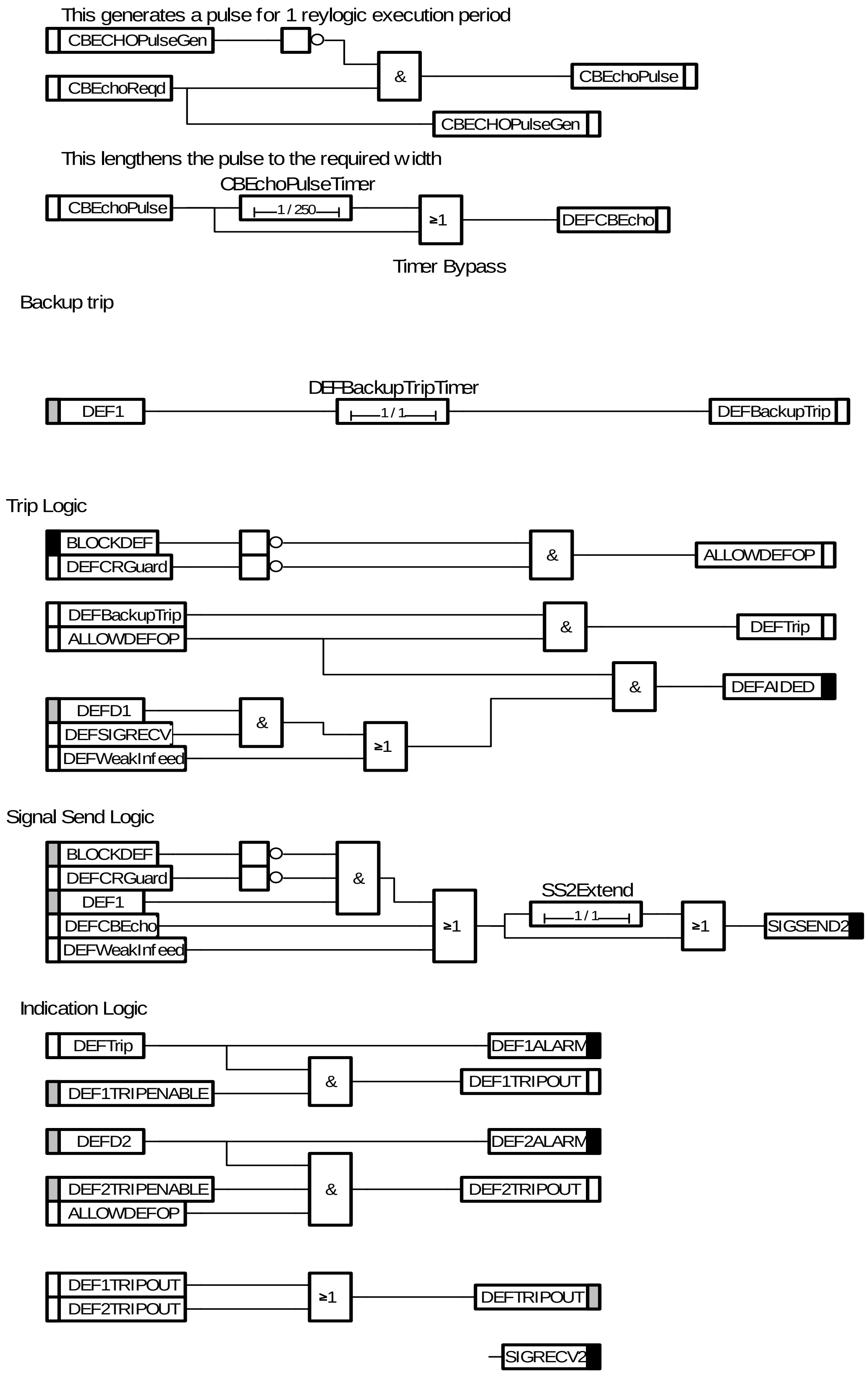

This generates a pulse for 1 reylogic execution period
CBECHOPulseGen
CBEchoReqd
&
CBEchoPulse
CBECHOPulseGen
This lengthens the pulse to the required width
CBEchoPulseTimer
CBEchoPulse
1 / 250
≥1
DEFCBEcho
Timer Bypass
Backup trip
DEFBackupTripTimer
DEF1
1 / 1
DEFBackupTrip
Trip Logic
BLOCKDEF
DEFCRGuard
&
ALLOWDEFOP
DEFBackupTrip
ALLOWDEFOP
&
DEFTrip
&
DEFAIDED
DEFD1
DEFSIGRECV
DEFWeakInfeed
&
≥1
Signal Send Logic
BLOCKDEF
DEFCRGuard
DEF1
DEFCBEcho
DEFWeakInfeed
&
≥1
SS2Extend
1 / 1
≥1
SIGSEND2
Indication Logic
DEFTrip
DEF1ALARM
DEF1TRIPENABLE
&
DEF1TRIPOUT
DEFD2
DEF2ALARM
DEF2TRIPENABLE
ALLOWDEFOP
&
DEF2TRIPOUT
DEF1TRIPOUT
DEF2TRIPOUT
≥1
DEFTRIPOUT
SIGRECV2

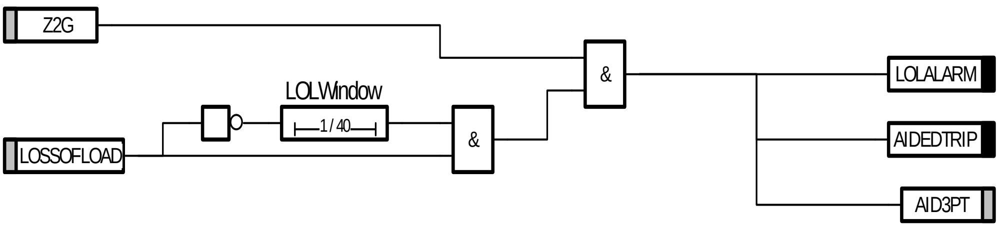
3.4 Protection Schemes

3.4.1 Loss Of Load

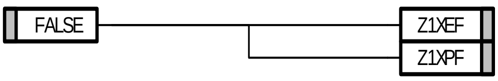
For a Loss Of Load trip to occur, we need to see the removal of current from one or two phases due to the remote end performing a three pole trip for a fault in its zone 1. This removes any load being supplied by us, and so we only see the fault current. If that fault was in our zone 1 then we would trip instantaneously. If it is in the end zone of the line (our Zone 2), then we accelerate the zone 2 operation. The load removal may be just that, ie disconnection of the load at a remote location, so we must see zone 2 pickup within a short time after operation of the LOL detector. Pole scatter at the remote end is catered for by a delay in the detector.

Note that loss of load cannot detect three phase conditions, and also requires a three pole trip at each end.

The Zone 2 protection must pickup within 40ms of the detector output



Clear the reach extension controls as that scheme is not in use.



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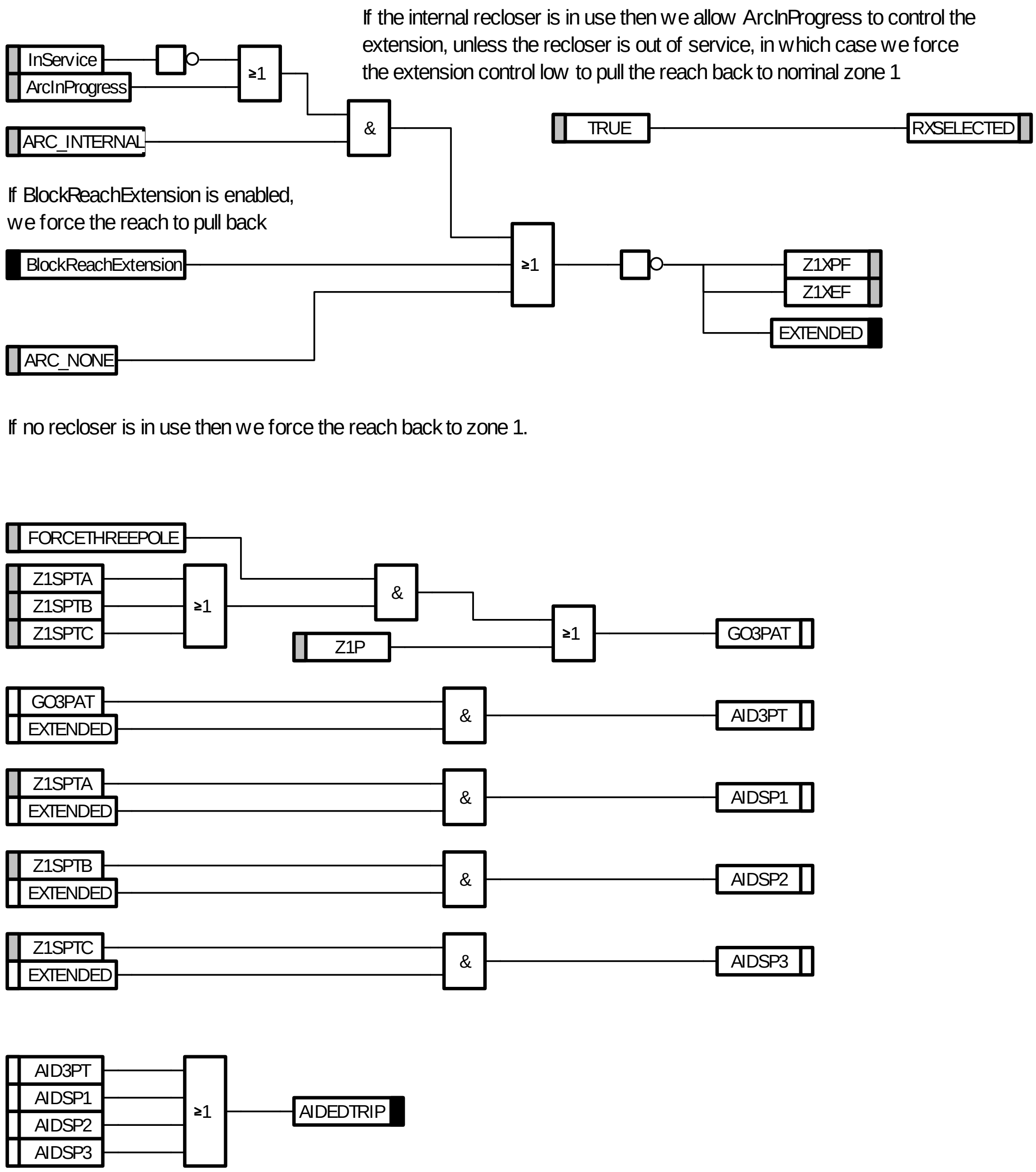
3.4.2 Reach Extension

This diagram performs the reach extension logic.

Basically, it directs the inverted ARC in Progress flag at the Z1X enable inputs, so that extension is enabled for first trip, then removed during the autoreclose sequence.

This is an enhanced version of the scheme which now incorporates checks to remove the overreach when the recloser is in local mode and out of service, or when no autorecloser is in use (though Reach Extension should not have been selected with no recloser).



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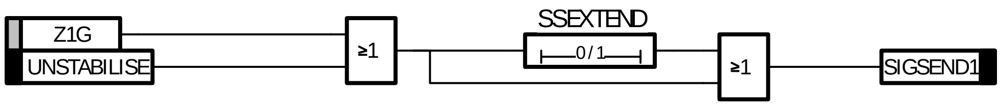
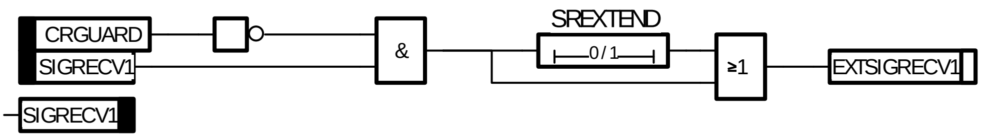
3.4.3 PUR

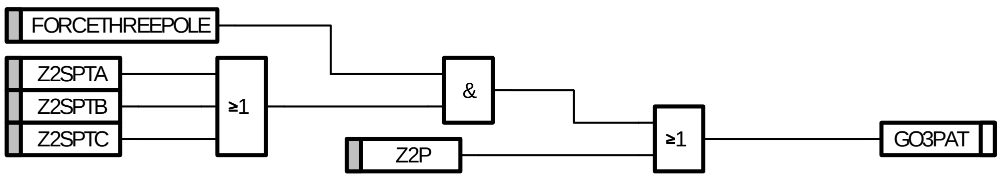
First, generate signal send from Zone 1 instantaneous, or the unstabilising input, which is either a manual operation, or comes from an external protection relay, giving us an intertrip

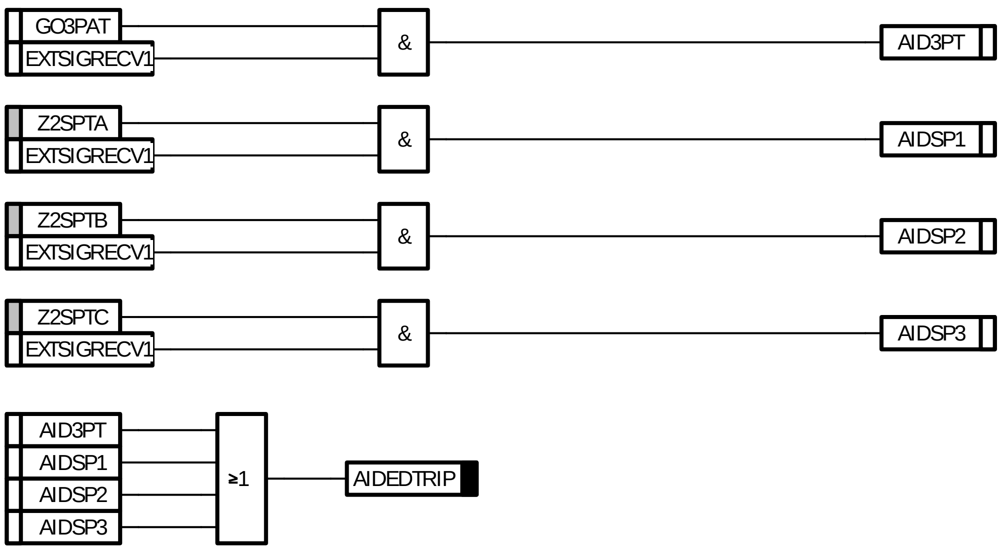


Next, we generate two forms of the aided trip signal; one from the zone 2 phase instantaneous output, and the other a phase segregated version for single pole tripping from the single pole trip logic.

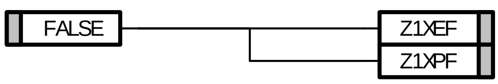
We also generate an output tag for the signal received input.







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



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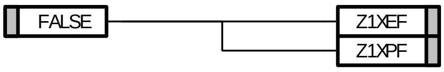
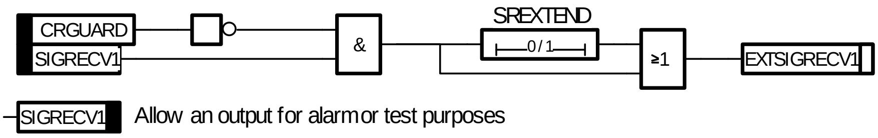
3.4.4 POR 1

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

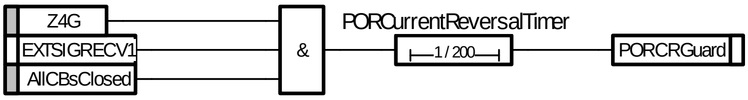


Process Signal Receive 1 first. Carrier receive guard signal from the comms equipment should be high when there is a problem with the carrier equipment. This would then block signal receive and prevent any nuisance operations due to communications channel or equipment failure.



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.



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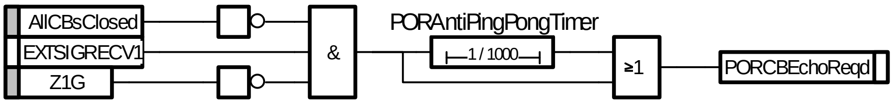
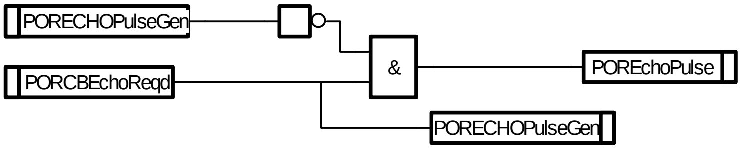
CB Echo

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.

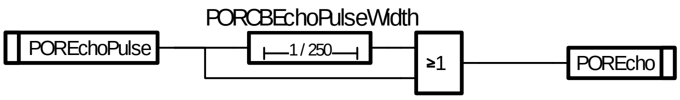
To avoid a lockup situation where the CB Echos at each end reinforce each other and prevent SigSend from dropping off we limit the duration of the CB Echo signal and keep the CB Echo Required signal asserted until the trigger condition has been absent for 1 second.



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).



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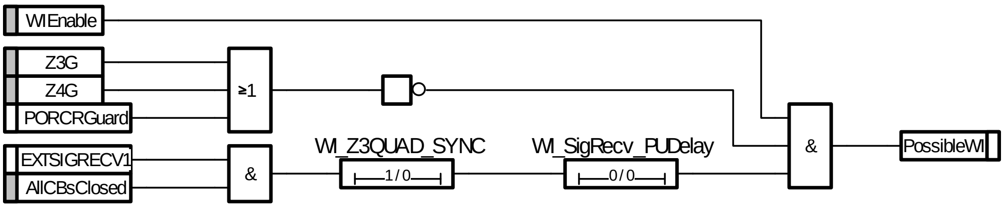
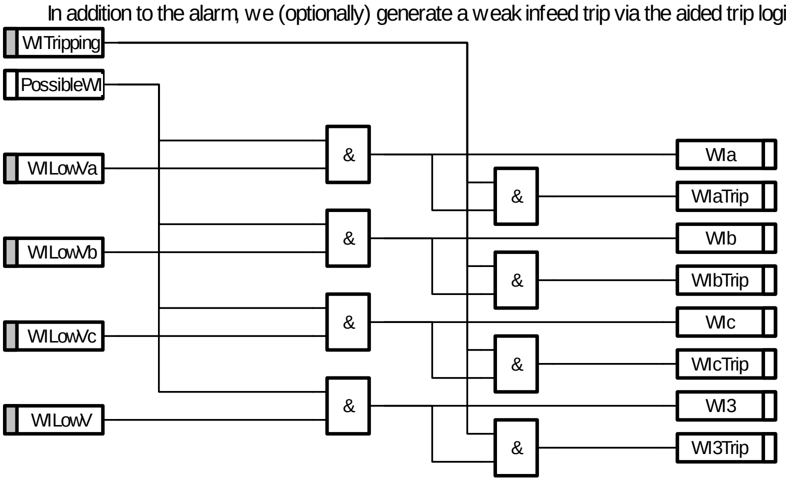
Weak Infeed Logic

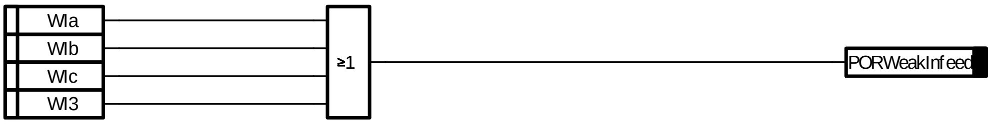
Under certain system conditions, such as on radial systems, or where the source capacity at one end of a line is reduced for some reason, then there may not be sufficient fault current flowing for the relay to determine the fault impedance. Under these circumstances we use weak infeed protection. This 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.



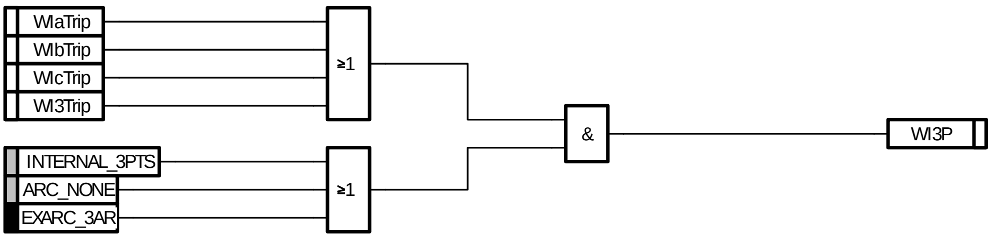
The possibility of a weak infeed condition is then confirmed by the use of phase undervoltage detectors. If there is a weak infeed condition, then we will see only the fault voltage (which will be very small), and so we can generate phase seqregated weak infeed booleans (WIx), and a general weak infeed 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.



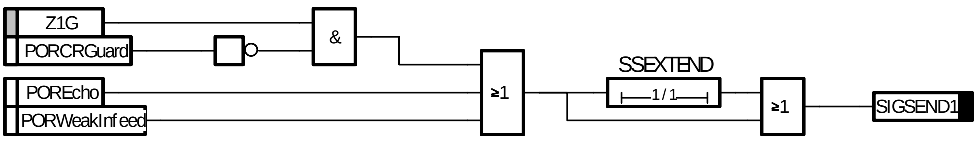
Combine the WIx booleans to give a general weak infeed alarm output.



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.



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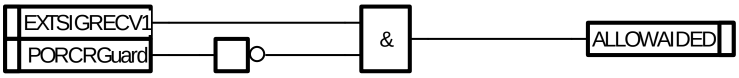
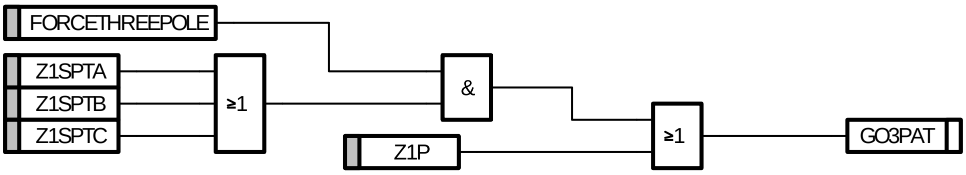
Aided Trip Logic

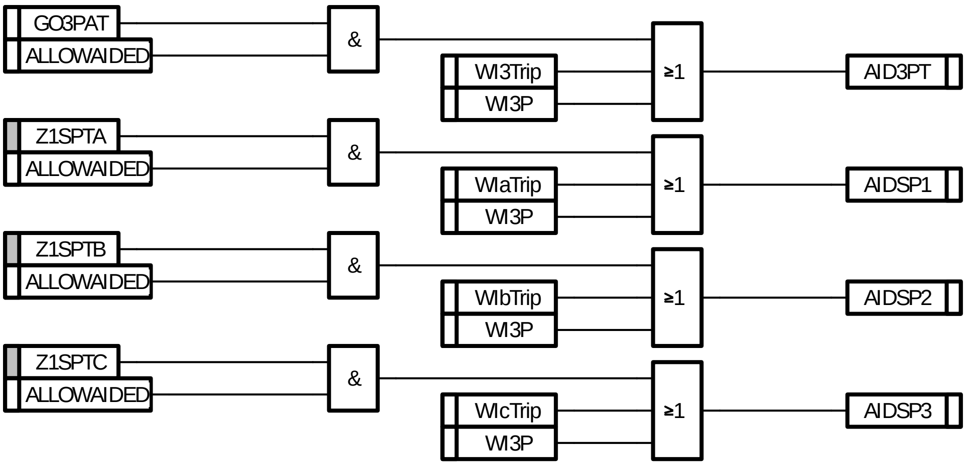
First we generate an enabling signal from SignalRx AND no Current Reversal Guard



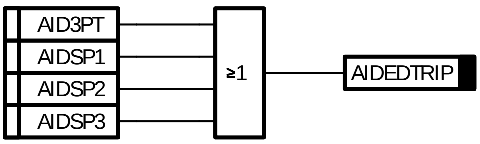
Three pole aided tripping is used for phase faults, or where 3P trips are forced.



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



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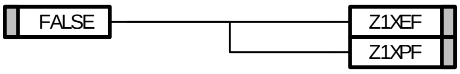
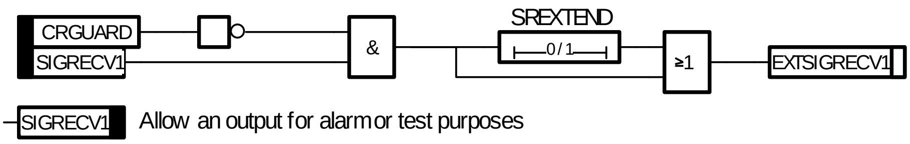
3.4.5 POR2

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

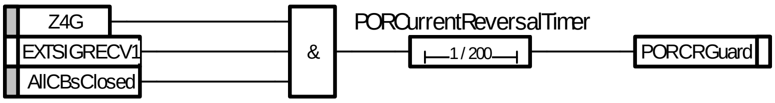


Process Signal Receive 1 first. Carrier receive guard signal from the comms equipment should be high when there is a problem with the carrier equipment. This would then block signal receive and prevent any nuisance operations due to communications channel or equipment failure.



Current Reversal Logic

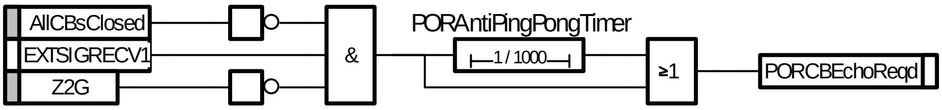
When the relay is applied to a feeder which has another in parallel, then if there is a fault on the adjacent feeder we may see it as a reverse fault. When the CB on the adjacent feeder at this end opens, then if the breaker at the other end operates more slowly, there is a chance that the fault current 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.



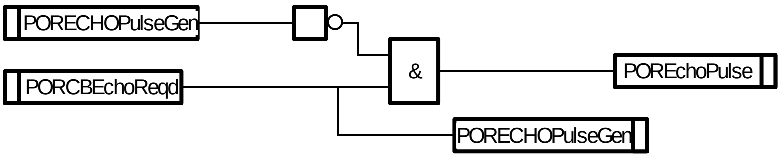
CB Echo

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.

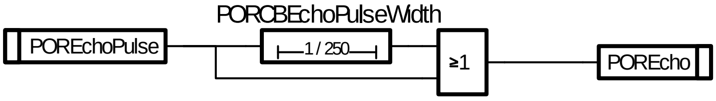
To avoid a lockup situation where the CB Echos at each end reinforce each other and prevent SigSend from dropping off we limit the duration of the CB Echo signal and keep the CB Echo Required signal asserted until the trigger condition has been absent for 1 second.



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).



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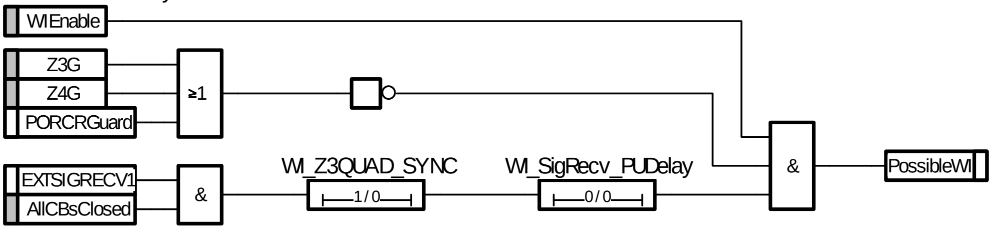
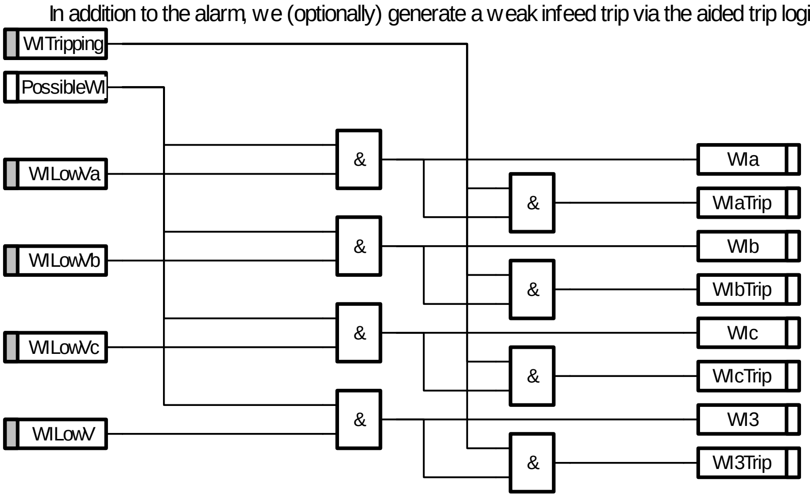
Weak Infeed Logic

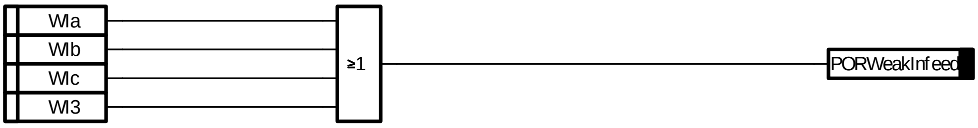
Under certain system conditions, such as on radial systems, or where the source capacity at one end of a line is reduced for some reason, then there may not be sufficient fault current flowing for the relay to determine the fault impedance. Under these circumstances we use weak infeed protection. This 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.



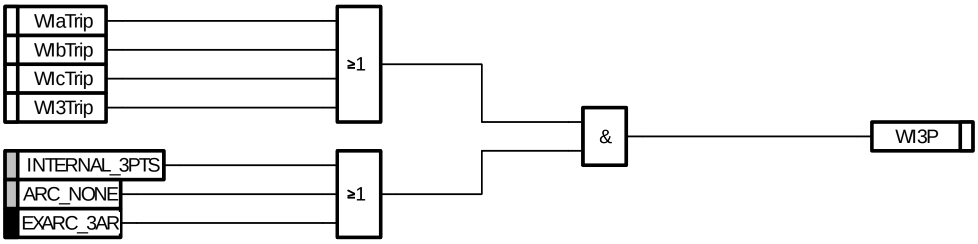
The possibility of a weak infeed condition is then confirmed by the use of phase undervoltage detectors. If there is a weak infeed condition, then we will see only the fault voltage (which will be very small), and so we can generate phase seqregated weak infeed booleans (WIx), and a general weak infeed 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.



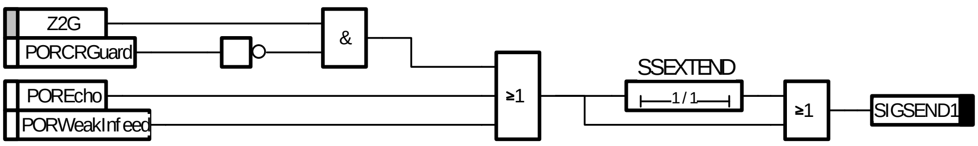
Combine the WIx booleans to give a general weak infeed alarm output.



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.



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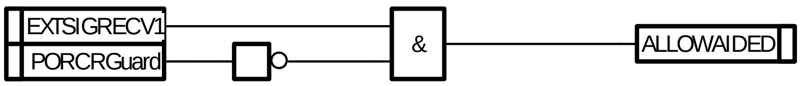
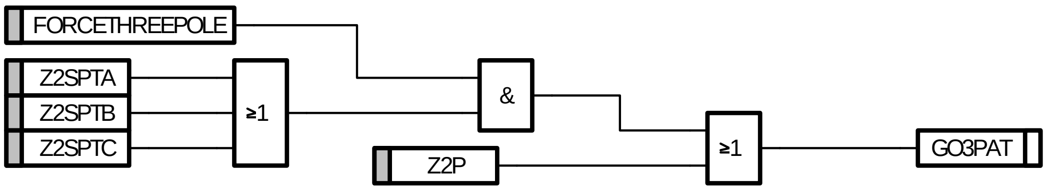
Aided Trip Logic

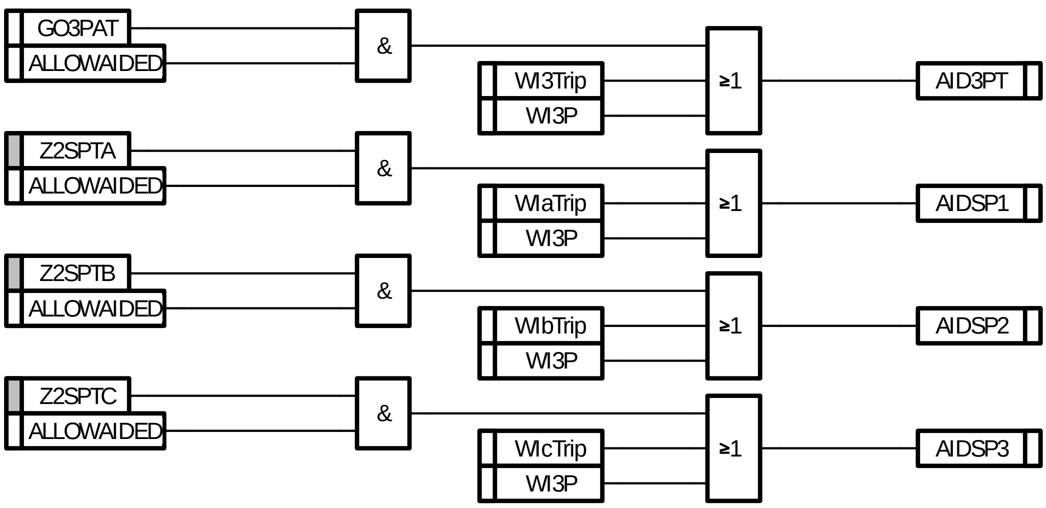
First we generate an enabling signal from SignalRx AND no Current Reversal Guard



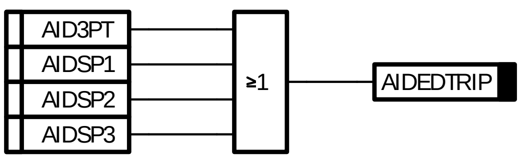
Three pole aided tripping is used for phase faults, or where 3P trips are forced.



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



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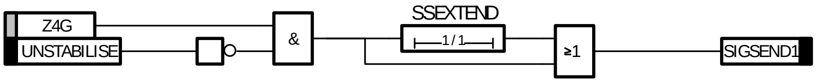
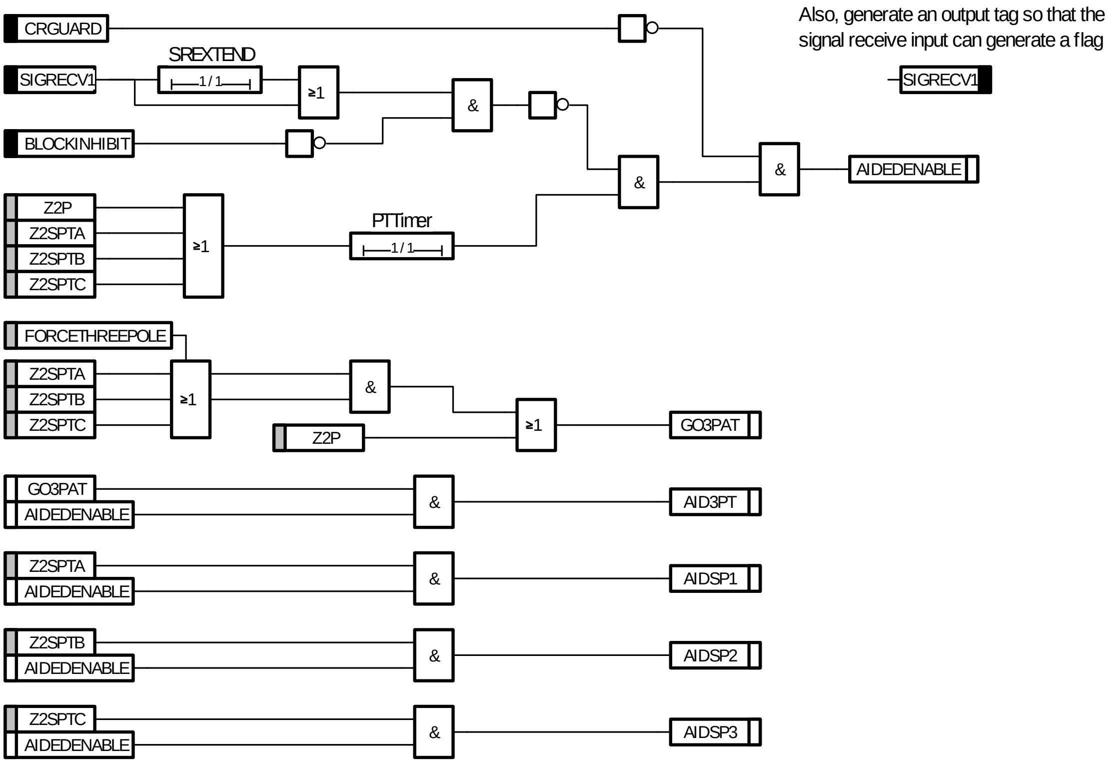
3.4.6 BOR

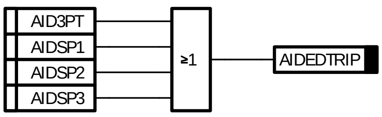
Blocking scheme using zone 4, intended for Ohmega 400 models with single pole tripping.

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.

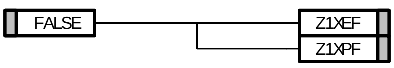


Now we generate the aided trip signal, which is delayed to allow time for blocking, and is blocked if signal receive is active.
Also, we need an inhibit signal (re NGC) to prevent blocking under certain circumstances. And the inclusion of the Carrier Receive Guard means that if the carrier fails we can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





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



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7SG164 Ohmega 400 Series

Distance Protection Relays

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

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Contents

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Reference Material

[1] - REYDISP EVOLUTION : is a PC based relay support package which allows local or remote access to relays for uploading settings, downloading event and disturbance records, reading real-time data and allowing control of plant. The package is available from Siemens and is compatible with all Argus and Modular II relays.

[2] - INFORMATIVE COMMUNICATIONS INTERFACE : a report detailing all aspects of the communications protocol used in the Argus and Modular II range of relays is available from Siemens. The report reference is 434TM05B.

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1 Introduction

1.1 General

This section details the description of the Single Pole / Three Pole Auto-reclose function
The Auto-reclose function consists of a Two-shot Single Pole / Three Pole Auto-reclose device with integral Check Synchronisation.

The relay contains scheme logic which allows input functions and output functions to be configured to meet the requirements of a particular customer's scheme. This is achieved by a number of pre-programmed customer options and features which enable various sequences to be selected together with appropriate timer mechanisms which allow effective control of the auto-reclose process. Auxiliary functions are provided which cover all aspects of the auto-reclose scheme i.e. Auto-reclosing, Manual Closing, Check Synchronisation.

The auto-reclose function has been designed to only allow reclosing if system conditions dictate. A number of features are included to prevent reclosing:
CB In Service, Inhibit Close, Block Reclose; the dead times are only started if certain criteria are met i.e. the trip has reset and the CB has opened and the line has gone dead;
The close pulse will only be issued if the system synchronisation conditions are met and the CB is open and there are no trips present. The relay errs on not closing. All of this logic is internal to the relay. Because of the complexity of auto-reclose schemes and the possibility of setting the relay incorrectly the user should be familiar with all aspects of the relay before energising any equipment.

Auto-reclose inputs are fully programmable via matrixes: Block Reclose, Reclose Lockout, Manual Close, A/R In, A/R Out, Reset Lockout etc.

Outputs are fully programmable to either LEDs or output contacts.

The relay has been designed for ease of setting, clear setting ranges indicate dead times, close pulse and reclaim time delay settings. Front panel instruments are provided that indicate the point which the Relay has reached during an Auto-reclose sequence, this greatly improves commissioning.

Suitable for single / double busbar substations where outgoing circuits are controlled by a single circuit breaker. Compatible to 'J' unit schemes.

The Auto-reclose control function is connected to the Circuit Breaker, and integral to the Protection relays. The interconnection of this equipment allows for the auto-reclose relay to issue a number of alarms indicating system conditions and possible problems:

- the state of the CB is monitored for CB Open, CB Closed and CB Indeterminate; per phase signals are provided.
- CB Single Pole Open and CB Three Pole Open outputs which can be used as inhibits i.e. Power Swing Blocking, Zone 1 Extension Inhibit.
- CB Pole Discrepancy protection.
- VT Alarms for Line and Bus side VTs.
- CB Counter Alarms.
- CB Failed To Close.
- CB Failed To Open.
- Close Onto Fault.
- Slow CB.
- Start Auto-reclose flexibility, either Trip, Trip and CB Open, or Trip Reset.
- 3PTS logic connection provided to instruct protection to issue trips as 3P.

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- CB In Service and CB Memory prevent unwanted auto-recloses if the CB is open or normally de-energised. Auto-reclose is only allowed to proceed if the CB was in a closed position.

- Flexible latched or self reset Lockout.

- Flexible connection of the CB Auxiliary switches, can be of type a, b or a&b.

- Switching A/R In/Out can be from switches, communications, keypad or telecontrol pulses.

- Close Mode Selection determining the auto-reclose sequence employed may be changed by a selector switch.

The relay will automatically determine circuit breaker reclosure conditions. These conditions are dead line close, dead bar close or check sync close. If one of these conditions exists and reclosure under this condition has been pre-selected by the user then reclosure will be initiated.

When the dead line or dead bar dead time has expired and dead line or dead bar conditions are met then the circuit breaker will be reclosed.

If the relay detects the presence of line and busbar volts and check sync reclosure has been pre-selected then the relay will generate a check sync request prior to any reclosure. If the required check sync conditions are met then the circuit breaker will be reclosed.

The relay can automatically select Check or System synchronise from measurements of the relative phase angles between line and bus voltages. The relay will prevent closure of the circuit breaker if either the phase angle, slip frequency or the voltage magnitude of the incoming or running voltages fall outside prescribed limits.

If the parameters are within the limits the relay will issue an output which can be used to close the circuit breaker. Both the check and system synchronise functions have independent settings. The relay includes split system detection which can be used for blocking purposes. Following a system split, closure of the circuit breaker can be performed by either system sync parameters (typically 10°), or by the Close On Zero function which takes account of the circuit breaker close time.

A serial communications interface provides control of the relay, access to information stored, and integration of the relay into a sub-station control or data acquisition system.

1.2 Auto-reclose

Auto-reclose is commonly applied to Transmission and Distribution systems. This relay has been designed for application to Transmission systems where single pole and three pole tripping is applied.

Statistically, the majority of system faults are of a transient nature so that once the fault has been cleared by the protection, the faulted circuit can be re-energised with a likelihood of minimal disturbance to the rest of the system. An important feature of overhead line faults is that since air is the main insulant a significant majority of flash-overs cause no permanent damage to the circuits and about 88% of fault clearances can be quickly followed by the circuits return to service by operation of automatic switching and reclosing facilities.

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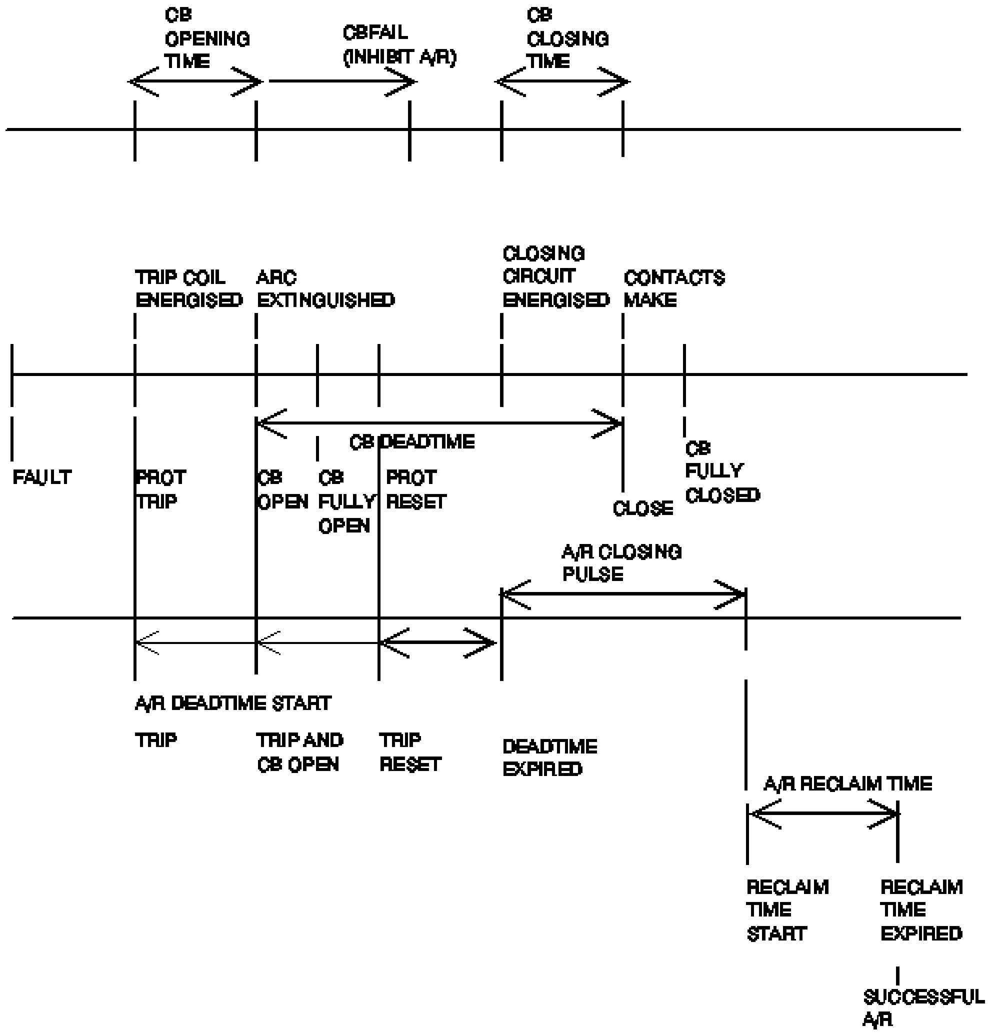

Figure 1 – Auto-reclose Sequence

1.3 Check Synchronisation

When two power systems are to be connected together it is essential that the systems either side of the breaker be reasonably in synchronism. Quantities such as the voltage magnitudes, the system frequencies and the relative phase angles of the two systems should be reasonably close before an attempt is made to connect. Closing the circuit breaker without due care and attention to some or all of these quantities can cause undue stresses to the system. The Check and System synchronising function measures single phase voltage quantities at each side of the CB and will only permit a CB close when the two systems fall within the relay setting parameters. Figure 2 shows the basic closing conditions for both the check and system synchronising functions.

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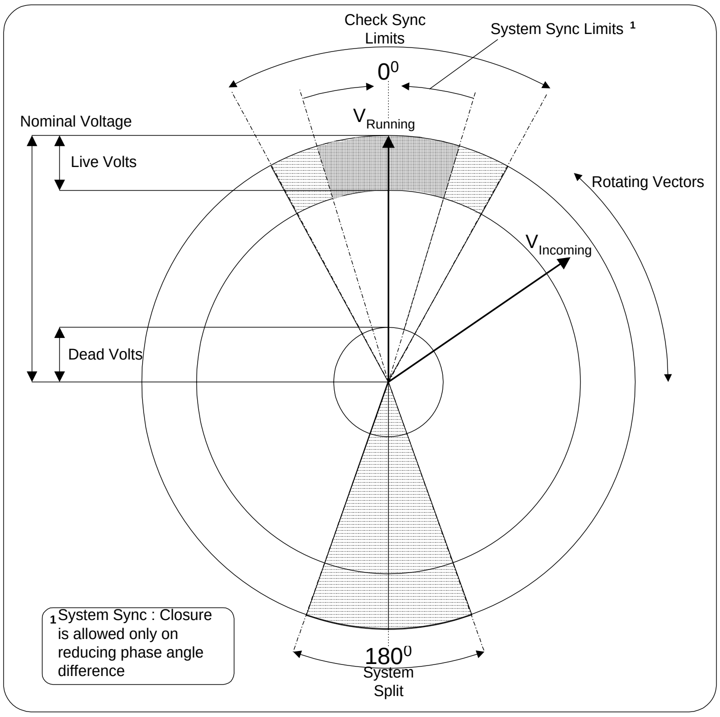

Figure 2 - Check and System Synchronising

The Check and System synchronising function is part of the comprehensive range of Modular II platform based numeric relays. These relays have extensive control functions, which are supplemented by advanced metering, data storage and fibre optic communications. Supervisory and self-monitoring features give added confidence to the user as well as reduced maintenance and down time. A menu-based interface gives user-friendly access to relay settings, meters and operational data.

2 Hardware Description

2.1 Analogue Inputs

The input stage of the relay measures two basic quantities, V_{Line} and V_{Bus}. The voltage transformer inputs are suitable for phase to neutral connections and the input stage overall measures in the range of 1 Vrms to 200 Vrms. It maintains accuracy within ±1% over the range 5 Vrms to 132 Vrms.

In order to ensure high accuracy true RMS measurements and accurate phase and slip frequency calculations, the voltage signals are sampled at a minimum of 8 samples per cycle for both 50Hz and 60Hz system frequencies. This sampling rate also provides high accuracy and quality waveform storage records.

2.2 Status Inputs

Each of the status inputs can be programmed to perform one or more of the following functions, (see settings sheet for complete list):

- Start Auto-reclose.
- CB Auxiliary contacts.
- Close the CB.
- Auto-reclose control functions.
- Bypass the sync function.
- Switch to an alternative settings group
- Trigger storage of a waveform record.
- Reset the Lockout condition.

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3 Auto-Reclose Control Functions

3.1 Auto-reclose

Auto-Reclose (A/R) is initiated by a valid trip relay operation while the associated circuit breaker is in service.

A circuit breaker's service status is determined by its position and (where Check Synchronisation is applied) its voltage references. The circuit breaker is defined as being in service when it is closed and its voltage references are live. The in service status has a drop-off delay of 2 sec, this delay is known as the circuit memory time. This functionality prevents auto-reclosing when the line is normally de-energised, or normally open.

The transition from 'A/R started' to 'initiate dead time' is programmable. It can take place when the trip signal is received; or when the trip signal is active and the CB has opened (the A/R dead time will then mimic the CB dead time); or when the trip has occurred and the CB has opened and then the trip has reset. If any of these do not occur within the Sequence Fail time the relay will Lockout. This is provided to prevent the A/R being primed indefinitely, or the Sequence Fail timer can be switched OFF.

Once an A/R sequence has been initiated, up to 2 unsuccessful recloses (where a closure is followed by a re-trip) may be performed before the A/R feature is locked-out. Each reclosure is preceded by a time delay (dead time) to give transient faults time to clear.
Once a CB has reclosed and remained closed for a specified time period (the Reclaim time), the A/R feature is re-initialised and a Successful Close output issued. A single, common Reclaim time is used.

A count is kept of how many recloses per phase have been performed.

Once lockout has occurred, an alarm is issued and all further External Close commands are inhibited for a specified time period (the Minimum Lockout time). A single, common lockout time is used. Lockout can be latched until reset.

There are separate dead-time settings for each of the recloses.

The relay will automatically determine circuit breaker reclosure conditions. These conditions are dead line close, dead bar close or check sync close. If one of these conditions exists and reclosure under this condition has been pre-selected by the user then reclosure will be initiated.
When the dead line or dead bar dead time has expired and dead line or dead bar conditions are met then the circuit breaker will be reclosed.

If the relay detects the presence of line and busbar volts and check sync reclosure has been pre-selected then the relay shall generate a check sync request prior to any reclosure. If the required check sync conditions are met then the circuit breaker will be reclosed.

A number of settings allow a very flexible application of the relay. The relay can be applied to any combination of CB auxiliary contacts depending upon how many contacts are available, these can be type 'a', 'b' or both 'a' and 'b'.

The Close Mode Selection setting can be selected by status inputs thereby allowing remote change to the type of allowable auto-reclose sequences. Either telecontrol, or panel mounted switches, or communications, or relay front panel keypad can be used to change this setting.

3.2 Protection Trips

The Protection function which trips the CB primes and starts the auto-reclose sequence. The relay internally determines what type of fault has occurred: Phase to earth, Phase to Phase, Three Phase.

3.3 Developing Faults

The relay automatically determines developing faults and whether these can initiate an auto-reclose sequence.

A setting is provided to inhibit the three pole dead time by faults involving all three poles, if required. The relay can be programmed to allow different types of fault to initiate different types of auto-reclose

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sequence. This can enhance the reliability of the reclose sequence. In systems where single pole tripping is employed the occurrence of a three phase fault can indicate severe problems and reclose can be disabled if required.

For example:

Single Pole Trips initiate 1P Auto-reclose.

Phase to Phase Faults initiate 3P Auto-reclose.

Three Pole Faults initiate either 3P Auto-reclose or Lockout.

A single pole trip which initiates a single pole dead time and then develops into a trip involving more phases or more than one CB opens will either initiate a three pole dead time if allowed or lockout.

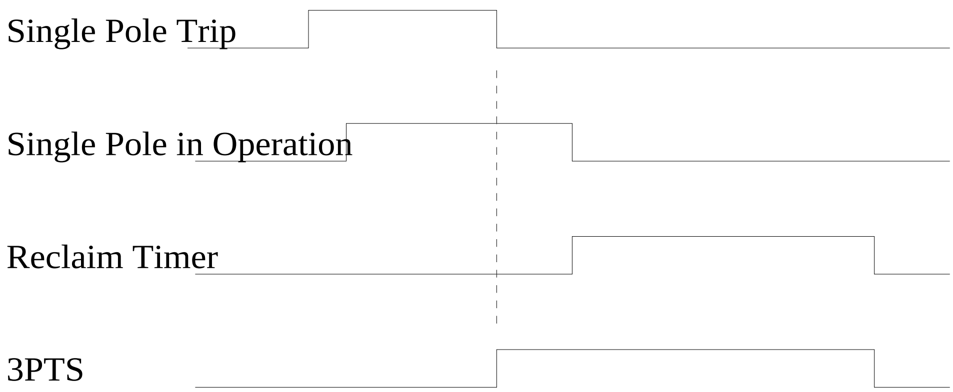
3.4 Three Pole Trip Select

The relay co-ordinates the action of the Protection with the state of the system. For conditions which dictate that a single pole reclose may be unsuccessful the auto-reclose relay instructs the protection to issue a three pole trip signal.

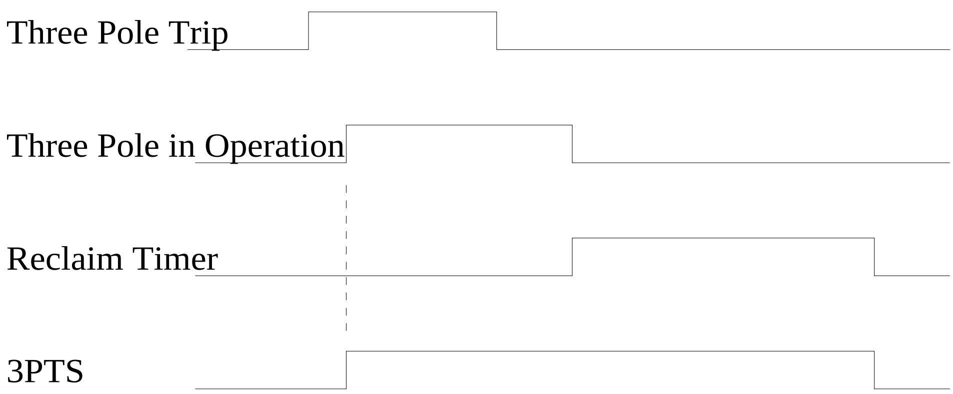
With Single pole reclosing sequences, following the first shot single pole trip and reclose subsequent tripping of the CB shall be 3 pole. An Alarm shall be issued to indicate three pole tripping is being commenced. A setting shall be provided to program an output relay to operate when the auto-reclose sequence goes to three pole either on selection or during a two shot scheme.

Definitions:

- Following a Single Pole auto-reclose sequence: All tripping after a single pole sequence will be 3 Pole. i.e. Prepare the main protection to go into 3 Pole mode.



- Three pole auto-reclose.



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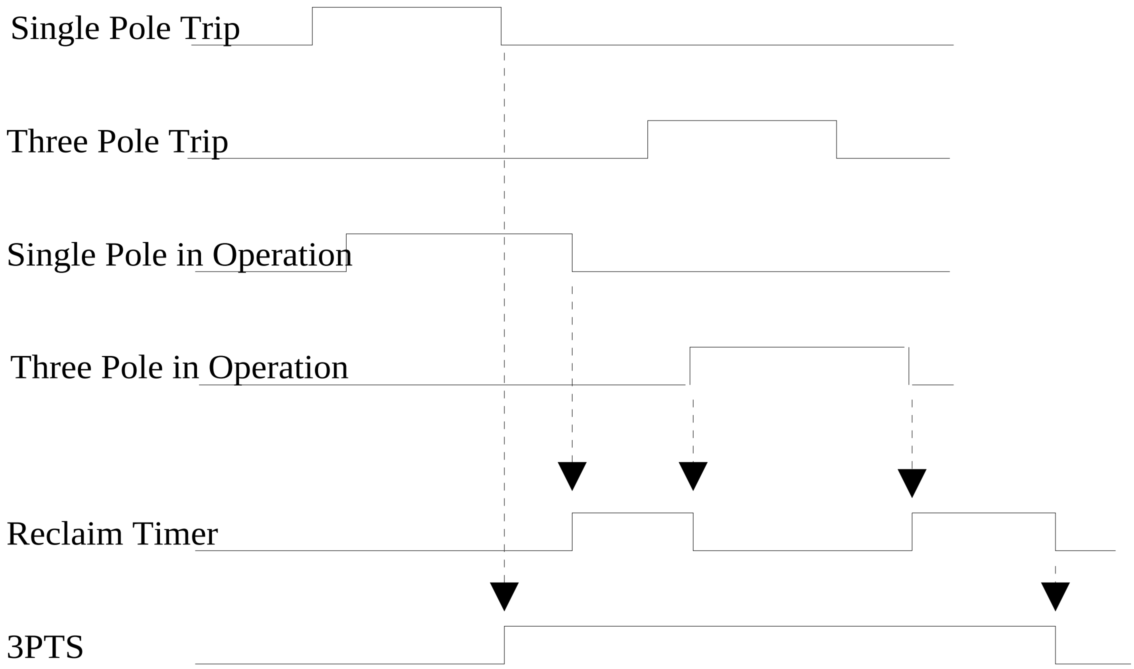
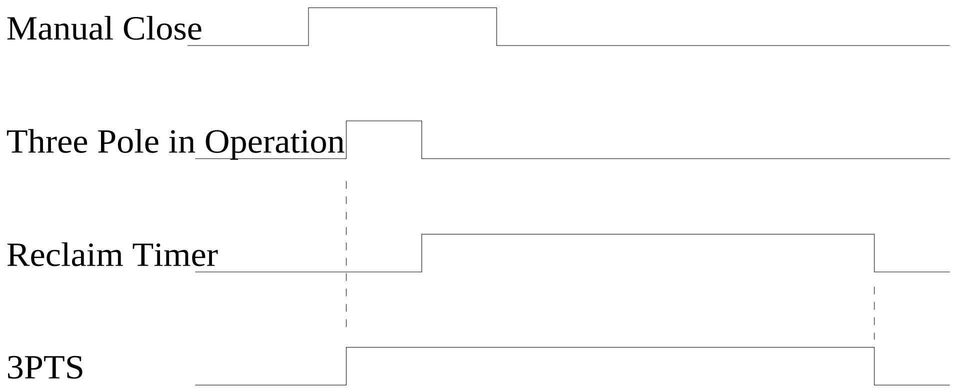
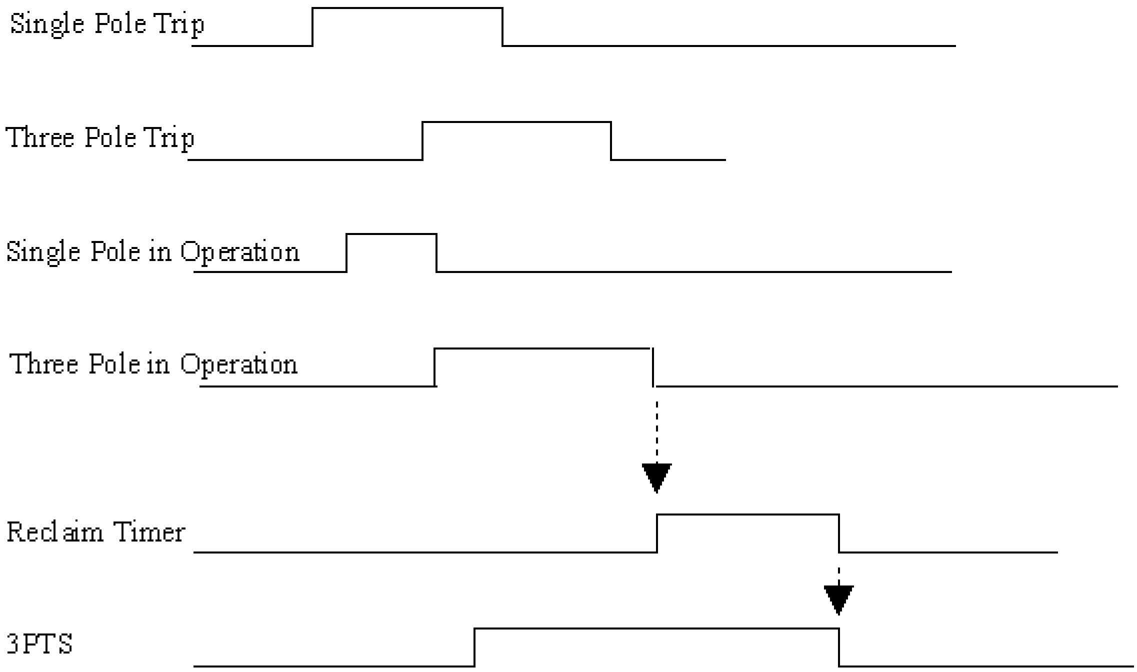
- For a sustained fault sequence (CMS set to 1P3P/3P): Subsequent tripping of the CB shall be 3 pole. An alarm will be issued to indicate 3 pole closing. We remain with 3PTS if fault in reclaim time. The Protection relay has tripped single phase and then reset, the recloser will complete the single phase reclosing sequence, a second trip within the reclaim time must be three pole, to force this second trip to be three pole the 3PTS output is given after the single pole trip has cleared.



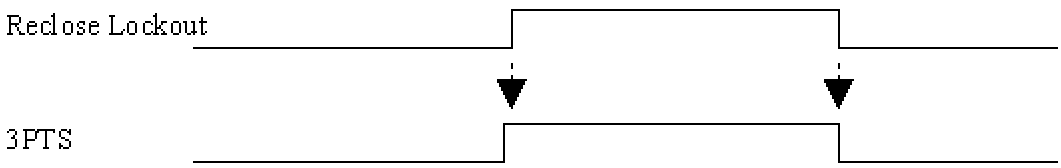
- Following the Manual Close Command: 3 pole trip select (3PTS) is initiated following a manual close command. Any subsequent faults shall initiate a 3PT.



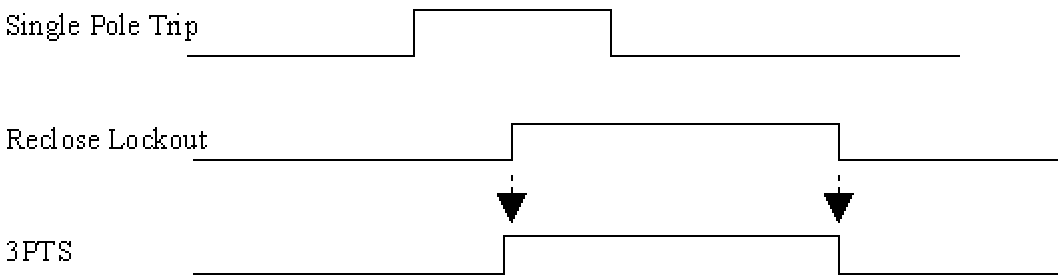
- Evolving Fault: Should the relay change to a 3 pole trip sequence during a single pole reclosure sequence, the 1PARC sequence will reset and a three pole closing alarm will be issued.



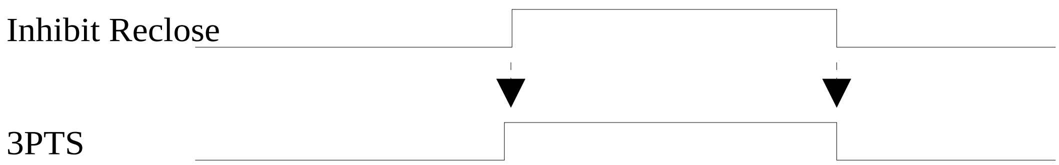
- During a Reclose Lockout signal: If a Reclose Lockout signal becomes active during a 1P auto-reclose sequence the relay will select 3PT. Reclose Lockout will initiate 3PTS.



- If Reclose Lockout during Single Pole Trip: Go to Lockout, Trip 3P straight away.



- During Block Reclose or Inhibit Close:



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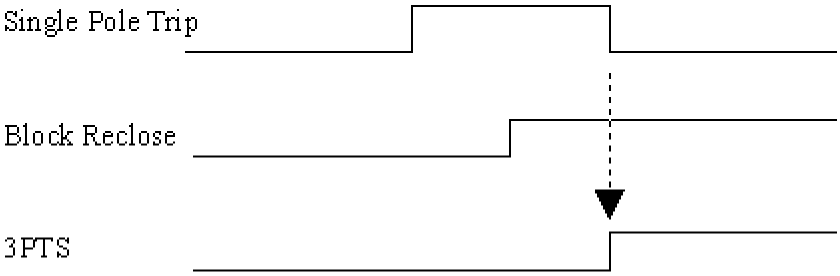
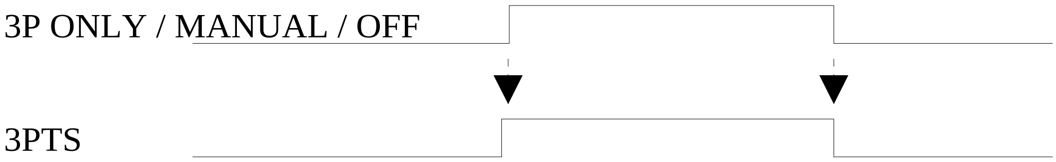
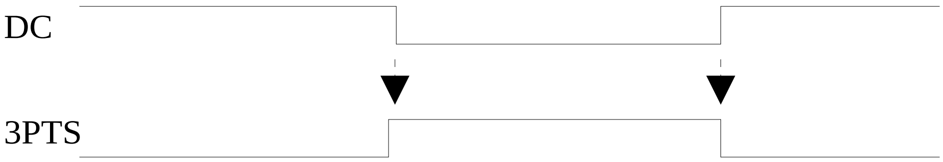
- If Block Reclose during a 1P auto-reclose sequence: Should a Block Reclose signal become present during a 1PARC sequence, 3PTS shall initiate upon resetting of the current 1PARC initiate signal. i.e. give the 1P shot a chance, the Block may be transient.



- As a result of selected CMS:



- For loss of DC: Should the DC supply be lost 3PT shall be selected.



This requires that a normally energised N/C contact is used as the output for 3PTS. A separate flag 3PTS Flag is provided for use as the LED indication.

3.5 Manual Close

An External Close Command can be received via a status input or communications. This would normally be initiated manually. It causes an instantaneous closure, over-riding any A/R sequence then in operation. Manual Close resets Lockout.

An External Close will initiate Line Check. If a fault appears on the line during the Close Pulse or the Reclaim Time with Line Check set, the Protection relay will initiate a Trip and the A/R relay will Lockout. This prevents a CB being repeatedly closed onto a faulted line.

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

There is a separate input Inhibit Close which prevents the close pulse being issued from a Manual Close. If the Inhibit Close signal has not been removed before the end of a defined time, the Permissive Close Delay, the A/R feature is locked-out. The input Block Reclose does not prevent Manual Closing. Block Reclose only prevents auto-reclosing. Both Inhibit Close and Block Reclose utilise the Permissive Close Delay timer.

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3.6 In/Out Switching

The A/R feature may be switched out by changing the A/R In Service setting by a number of methods. These are either a keypad change from the front panel, or via a communication, or by an A/R OUT status input. A/R OUT status input has priority over A/R IN. If both are raised the relay will be in Out Of Service. Once the relay has been switched Out Of Service the reverse action A/R IN is required before the relay will go back In Service. A/R In Status Input is positive edge triggered.

3.7 Overall Control

The A/R feature may be disabled by a Lockout command (Reclose Lockout) or by an external signal applied to a status input (A/R OUT).

If the Lockout command or A/R OUT are received while an A/R operation is in progress, the feature is immediately locked-out. An External A/R IN command can be received via a status input. This will re-enable the module.

The A/R feature may be paused by an external Block Reclose or Inhibit Close signal applied to a status input. This causes the feature to temporarily halt before it issues the next CB close command and can be used, for example, to delay CB closure until the CB pressure has reached an acceptable level. If the Block Reclose signal has not been removed before the end of a defined time, the Permissive Close Delay, the A/R feature is locked-out. A Block Reclose active within the dead time resets the dead time timer.

3.8 CB Close Command pulse

The duration of the CB Close Command pulse will be settable to allow a range of CBs to be used. The Close pulse will be terminated if any protection trips occur. This is to prevent Close and Trip Command pulses existing simultaneously. A Close Onto Fault Output is given if a trip picks-up in the Close Pulse. This can be independently wired to Lockout.

3.9 CB Failed To Open and CB Failed to Close

CB Failed To Open and CB Failed to Close features are used to confirm that a CB has not responded correctly to each Trip and Close Command. If a CB fails to operate, the A/R feature can be set to lockout.

CB Failed To Open utilises the CB Closed status input and trip signal. If the CB remains closed after a trip signal has been received for longer than the CB Fail To Open time delay setting then an alarm is issued. This alarm could be used to lockout the auto-reclose sequence; or could indicate a slow CB opening.

CB Failed To Close results in lockout if the CB is still open at the end of the Close Pulse time delay setting.

3.10 CB Closed by Another Device

If, during a dead time period, the Relay detects that the CB has closed (due to an external source) it increments its Reclose count and advances to the next part of the Reclose sequence (begin Reclaim time).

3.11 Indications

The relay has a fully programmable output to either output contacts or LEDs.

The following are included:

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1. A/R In Service
2. A/R Out of Service
3. A/R In Progress
4. Successful A/R
5. Lockout
6. 3PTS and 3PTS Flag

see Output Relay Menu and LED Menu for complete list.

3.12 CB Close Counters

Additional A/R features are provided as an aid to maintenance.

Two counters ‘Total CB Close Count’ and ‘Delta CB Close Count’ are provided. Each counter has a User settable Alarm count. These counters can be used for Maintenance Alarms. These figures are re-settable and have a maximum alarm number of 999.

3.13 Metering

All Counters and the Status of the A/R sequence are displayed in Meters under the Instruments Menu.

3.14 Dead-time and Reclaim Timing

The Dead time will start if a Trip has occurred and the CB is Open and the Trip has then reset and the line has gone dead. Once a trip has occurred if the CB does not open or the Trip does not reset then the A/R will Lockout. This could be due to either a CB Fail condition, which would independently notify Lockout, or the Trip relay contact failing to reset. If the line does not go dead this may signify that the remote end has failed to clear the fault, and the auto-reclose will go to Lockout.

The Reclaim time will start once the Close Pulse has timed out and the CB has closed. Lockout is alarmed if the CB is open at the end of the reclaim time. If the CB remains closed for the Reclaim time, the relay will reset and be ready for further operation.

3.15 Lockout

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

- At the end of the Reclaim time if the CB is in the open position.

- A protection operates during the final Reclaim time.

- If a Close Pulse is given and the CB fails to close.

- The Reclose Lockout status input is active.

- At the end of the Permissive Close Delay due to a persistent Block Reclose or Inhibit Close.

- At the end of the Sync Close Delay due to Synchronism not being achieved.

- At the end of the Sequence Fail time.

- At the end of the Overall Sequence time.

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

- By a Manual Close command.

- By a Reset Lockout signal, provided there is no signal present which will cause Lockout.

- At the end of the Minimum Lockout time if Reset Lockout is selected to be reset by a timer, provided there is no signal present which will cause Lockout.

- If Lockout was entered by an A/R Out signal during an Auto-reclose sequence then an A/R In signal must be received before Lockout can reset.

- By the CB Closed, provided there is no signal present which will cause Lockout.

The Lockout condition has a delayed drop-off of 2s.

The Lockout condition will initiate the Lockout indication and alarm contact.

Lockout does not issue a trip signal.

Lockout indicates an abnormal system occurrence, an event that needs to be investigated. When a CB is normally open the A/R relay does not go to Lockout, but A/R sequences are prevented by using a combination of Trip and CB In Service to start the sequence.

3.16 Intertrip Initiated Auto-reclose

Auto-reclose can be initiated by an Intertrip Receive signal. A Persistent Intertrip timer is provided. If the Persistent Intertrip timer times-out before the Intertrip Receive signal has reset then the relay will go to Lockout. Only a one shot auto-reclose sequence is allowed by intertripping, any other intertrips cause the relay to go to Lockout. Intertrip dead time initiate must correspond to Trip Reset.

3.17 Sequential Isolation

Some utilities apply an arrangement when a CB is opened to automatically open the isolator. This is called Sequential Isolation. This needs to be inhibited if the CB is to be automatically reclosed. Facilities to inhibit sequential isolation are provided to enable the A/R system to stop sequential isolation if an associated A/R sequence has started. The Inhibit Sequential Isolation output is set when an A/R sequence is started and is reset at the start of the close pulse or at lockout.

3.18 CB Single Pole In Op / CB Three Pole In Op

Two outputs are provided which indicate whether all CB’s are open (Three Pole In Op) or a single pole CB is open (Single Pole In Op). These outputs can be used for inhibit purposes i.e. Power Swing Blocking, Zone 1 Extension Inhibit.

3.19 VT Alarms

The relay detects if a VT Fail has occurred. This could be a Line VT Fail or a Bus VT Fail. If the CB is closed and the Line is Live and the Bus is Dead for greater than 2 seconds a Bus VT Alarm is issued. If the CB is closed and the Line is Dead and the Bus is Live for greater than 2 seconds a Line VT Alarm is issued. The relay cannot distinguish between the system VT and the measuring VT within the relay, the VT Fail could be either.

3.20 Close Onto Fault

This output provides flexibility to be able to distinguish faults occurring during the close pulse. Any Trip occurring within the close pulse is designated as a Close Onto Fault. This can be used to stop the auto-

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reclose sequence if required, wired to Lockout. There can now be a difference between trips in the close pulse and trips in the reclaim time. A trip in the reclaim time can be designated as a separate fault. This can be enhanced further by extending the close pulse time setting to longer than usual, say 5 seconds, effectively creating two reclaim times.

3.21 CB Pole Discrepancy

Systems using single pole tripping or CB's with separate phase operation govern the time which a single CB may be open by CB Pole Discrepancy Protection. If the single pole is open greater than the Pole Discrepancy time, typically 1.6 seconds, the auto-reclose process is normally Locked out. This is also applied to three pole tripping schemes.

3.22 Close Mode Selection (CMS)

Close Mode Selection (CMS) refers to the auto-reclose sequence selected. The setting can be changed by the front panel keypad; or status inputs wired to panel switches or telecontrol; or communications.

The table below illustrates the available auto-reclose schemes i.e. 1st Action = 1P refers to first reclose attempt is allowed to be a Single Pole Reclose; 1st Action = 1P/3P refers to first reclose attempt can be either Single Pole OR Three Pole; 2nd Action = 3P refers to second reclose attempt can only be Three Pole Reclose; 2nd Action = LO refers that no reclose will be allowed and that for any further reclose initiations (protection trips), the relay will go to Lockout.

1st Action	2nd Action	3rd Action	CMS Setting from keypad/ comm's.
F-LO			Off
1PF-1PR	F-LO		1P
F-3PR	F-LO		3P
1PF-1PR 3PF-3PR	F-LO		1P/3P
1PF-1PR 3PF-3PR	3PR 2*3PF-LO	F-LO	1P3P/3P
F-3PR	F-3PR	F-LO	3P3P
1PF-1PR 3PF-LO	1PF-1PR 3PF-LO	F-LO	1P1P
1PF-1PR 3PF-3PR	1PF-1PR 3PF-3PR	F-LO	1P1P/3P3P

The Close Mode Selection defines the allowable number and type of reclose shots allowed during the sequence.

KEY:
- 1PF Single Pole Fault
- 1PT Single Pole Trip
- 1PR Single Pole Reclose
- LO Lockout
- 3PF Three Pole Fault
- 3PR Three Pole Reclose
- F Any Fault

SINGLE SHOT SEQUENCE

The following tables attempt to define the auto-reclose sequence for that selected Close Mode setting. For example

1st Action

1PF - 1PR

A Single Pole Fault which results in a Single Pole Protection trip will initiate a Single Pole Reclose.

1st Action

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3PF - LO
If the first protection trip is multi-phase then no reclose attempt will be allowed and the reclose relay will proceed directly to Lockout.

2nd Action

F - LO

Any fault occurring in the Reclaim time will result in the reclose relay proceeding directly to Lockout.

CMS set to 1P, Single Phase Operating Sequence - 1 POLE

1st Action	2nd Action
1PF - 1PR 3PF - LO	F - LO

Single Pole Operation

The CMS setting provides for a one shot Single Pole auto-reclose sequence.

The Auto-reclose sequence will be started by a single pole reclose initiation provided only a single pole of the CB pole has opened, there is no Reclose Lockout signal present and the selection of the Close Mode Selection (CMS) function permits single pole reclosing.

If the single pole trip evolves into a multiple phase trip the single pole reclosing sequence is disabled.

The single pole initialisation signal will be maintained until it is reset by the closing of the open pole of the CB.

If no Lockout condition exists after the single phase reclosing sequence has elapsed the open pole is closed directly by issuing a Close Pulse to the breaker close coils.

The Reclaim time timer will be started by the Close command to the CB.

All subsequent tripping within the Reclaim time following an auto-reclose can be set to be three pole.

CMS set to 3P, Three Phase Operating Sequence - 3 POLE

1st Action	2nd Action
1PF - 3PT - 3PR 3PF - 3PR	F - LO F - LO

The CMS setting provides for a one shot Three Pole auto-reclose sequence.

The 3 phase Dead time timer will be started by a three pole reclose initiation provided all poles of the CB have opened, there is no Reclose Lockout signal present, the selection of the CMS function permits 3 pole reclosing.

If 3 pole closing only is selected, the recloser will issue a three pole trip select.

The initiation command will be maintained until it is reset by the closing of the open breaker.

For a 3 pole reclose, if the line and/or busbar are 'dead', and if no lockout condition exists, it will be possible to issue a close pulse directly to the CB. However should both the line and busbar be 'live', a 3 pole reclose of the open breaker is only possible following a successful Check Synchronism, whereupon a closing pulse will be issued to the CB.

Following a decision to close, a timer will ensure that the Close Pulse is maintained long enough to allow for the spring rewind time if a single pole trip and reclose preceded the 3 pole trip.

The Reclaim time timer will be started by the close command to the CB.

All subsequent tripping within the Reclaim time following an auto-reclose can be set to be three pole.

CMS set to 1P/3P, Single or Three Pole Operation - 1P/3P

1st Action	2nd Action
1PF - 1PR 3PF - 3PR	F - LO F - LO

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Single or Three Pole Operation

The CMS setting provides for a single shot Single or Three Pole auto-reclose sequence.

If the single pole trip evolves into a multiple phase trip the single pole reclosing sequence will be disabled and the sequence will proceed with a three phase reclose after the appropriate three phase dead time provided all three poles of the CB have opened.

If a single pole trip causes all poles of the CB to open then a three pole reclose will be allowed after the appropriate three pole dead time.

TWO SHOT SEQUENCES

CMS set to 1P3P/3P, Two Shot Reclosing Sequence - IP3P/3P

1st Action	2nd Action	3rd Action
1PF - 1PR	1PF - 3PT - 3PR 3PF - 3PR	F – LO
3PF - 3PR	F – LO	

Single Pole then Three Pole Operation OR Three Pole

The CMS setting provides for a two shot auto-reclose sequence if the first shot has been a Single Pole reclose. This option is commonly applied to Transmission systems and succeeds because the opening of all three poles of the CB after a failed single pole reclose can remove the mechanism of induced voltage across the phases which caused the reclose to fail.

If the CB re-trips for a recurring fault within the Reclaim time following a single pole auto-reclose, a 3 pole auto-reclose can be initiated if a second reclose attempt is permitted.
A second reclose is permitted if the CMS function is selected to 1P3P and the Block Second Shot input has not been initiated.

When the Block Second Shot input is initiated, a second reclose attempt is not permitted.

When a second reclose is permitted, the Reclaim time is reset by the renewed reclose initiation signal and commences again with the close command to the CB.

For a 3 pole reclose, if the line and/or busbar are 'dead', and if no lockout condition exists, it will be possible to issue a close pulse directly to the CB. However should both the line and busbar be 'live', a 3 pole reclose of the open breaker will only be possible following a successful synchronism check, whereupon a close pulse is issued to the CB.

Following a decision to reclose, a timer ensures that the close pulse is maintained long enough to allow for the spring rewind time if a single pole trip and reclose preceded the 3 pole trip.

The 3 phase Dead time timer is started by a 3 pole reclose initiation for a recurring fault within the Reclaim time following a single pole trip and auto-reclose.

If the breaker re-trips within the Reclaim time following a 3 pole second reclose, the Lockout condition will be established immediately to ensure no further 3 pole recloses are attempted.

All subsequent tripping within the Reclaim time following an auto-reclose can be set to be three pole.

CMS set to 3P3P, Two Shot Reclosing Sequence - 3P3P

1st Action	2nd Action	3rd Action
1PF - 3PT - 3PR 3PF - 3PR	1PF - 3PT - 3PR 3PF - 3PR	F - LO F - LO

3P3P

The CMS setting provides for a two shot Three Pole auto-reclose sequence.

CMS set to 1P1P/3P3P, Two Shot Reclosing Sequence - 1P1P/3P3P

1st Action	2nd Action	3rd Action
1PF - 3PT - 3PR 3PF - 3PR	1PF - 3PT - 3PR 3PF - 3PR	F - LO F - LO

1P1P/3P3P

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The CMS setting provides for a two shot, Single or Three Pole auto-reclose sequence.

CMS set to 1P1P, Two Shot Reclosing Sequence - 1P1P

1st Action	2nd Action	3rd Action
1PF - 1PR	1PF - 3PT - 3PR	F - LO
3PF - LO	F – LO	

1P1P

The CMS setting provides for a two shot Single Pole auto-reclose sequence.

CMS Change Selection

The method of changing the Close Mode Selection by a connection of status inputs wired to a switch or telecontrol is outlined below:

CMS Change One	CMS Change Two	CMS Change Three	CMS Scheme Selected
0	0	0	No Change
0	0	1	1P
0	1	0	3P
0	1	1	1P/3P
1	0	0	1P3P/3P
1	0	1	3P3P
1	1	0	1P1P
1	1	1	1P1P/3P3P

A change to the CMS scheme is implemented if the switch position remains at the new setting for greater than 2 seconds. To allow for connection to tele-control pulses, no change is implemented when all inputs are not energised. The switch should either stay at its selection or return to its ‘no change’ position after the change has completed.

Note: It is not possible to select Close Mode Selection to OFF by the CMS Change Status Inputs. A/R Out Status Input can be used for this purpose.

3.23 Voltage monitoring elements

3.23.1 Undervoltage detectors

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

3.23.2 Differential voltage detectors

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

3.23.3 Voltage detectors

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

If a voltage is in the dead band range then it will be classed as dead until it has reached the live band area. Similarly, if a voltage is live, it continues to be live until it has reached the dead band area. This effectively allows for variable amounts of hysteresis to be set. Figure 3 illustrates the voltage detector operation.

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

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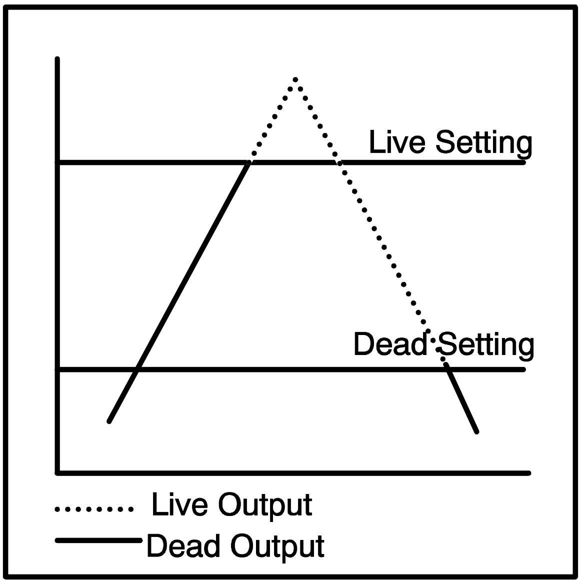
Although a wide range is provided for live and dead voltage detector levels, these must not overlap. The relay software acts to prevent this from happening and this is to stop unusual alarm outputs and conflicts with internal logic elements. If the user attempts to increment the dead voltage level to the live voltage level, the relay will not accept the setting. Similarly, if the live level is decremented to the dead level, the setting will not be allowed. The two voltages are displayed simultaneously on the LCD so that this operation is clear to the user.

Figure 3 - Voltage Detector Operation



3.23.4 Sync Override Logic

For certain switching operations, a means of bypassing the Check Synchronisation function is provided. This is provided with a separate Sync Override and a separate Manual Sync Override.

3.24 Check Synchronising Mode

<u>For the relay to issue a CheckSync Close the following conditions have to be met :</u>

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

CS SLIP FREQUENCY, [If ENABLED] – the frequency difference between line and bus has to be less than the slip frequency setting value.

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

LINE U/V DETECTOR, [If ENABLED] – the line voltage has to be above the line undervoltage setting value for an output to be given.

BUS U/V DETECTOR, [If ENABLED] – the bus voltage has to be above the bus undervoltage setting value for an output to be given.

DIFFERENTIAL VOLTAGE DETECTOR, [If ENABLED] – the difference between the line and bus voltages has to be less than the ΔV detector setting value for an output to be given.

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The relay is always started in Check Synchronising mode of operation. To proceed to System Synchronisation a system split must occur.

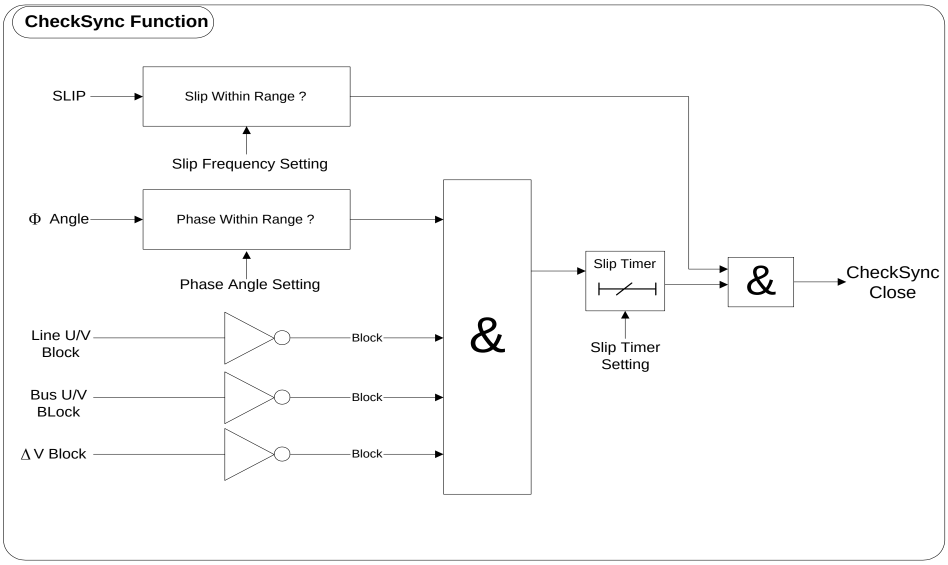

Figure 4 - Check Sync Function

3.25 Manual Sync Override Feature

If manual closes are required to be carried out via an operator, these will be performed with Check Synchronisation unless the Manual Sync Override input is energised.

3.26 System Split Detector

A system split occurs where there is a loosely tied or non-parallel circuits on a power system. Under these conditions the frequencies of the voltages either side of the breaker are asynchronous and therefore high phase angle differences can occur as the frequencies slip past each other. The system split detector operates when the phase angle difference exceeds a pre-set value. The setting range for a system split is from 90°-175° step 1°.

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

If a system split occurs during a CheckSync operation the following events occur :

- The CheckSync function is inhibited.
- The SystemSync function is started if the setting has been set to A/R Split Action SYSTEM SYNC. If the A/R Split Action has been set to LOCKOUT, then, a system split LED indication is given. The relay will stay in this lockout mode until one of the following methods of resetting it is performed:
  1) The relay is reset from Lockout.
  2) A status input command is received.
  3) An appropriate IEC870 comms. Command is received.
  4)
- An event is recorded.
- The split flag can be mapped to an output relay for alarm indication.
- The system split LED will stay on for a minimum time, or can be latched using non self reset LEDs.

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3.27 System Synchronising Mode

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

SS PHASE ANGLE – the phase difference between the line and bus voltages has to be less than the phase angle setting value and the phase angle has to be decreasing before the element will issue a valid close signal.

SS SLIP FREQUENCY, [If ENABLED] – the frequency difference between line and bus has to be less than the slip frequency setting value.

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

LINE U/V DETECTOR, [If ENABLED] – the line voltage has to be above the line undervoltage setting value for an output to be given.

BUS U/V DETECTOR, [If ENABLED] – the bus voltage has to be above the line undervoltage setting value for an output to be given.

DIFFERENTIAL VOLTAGE DETECTOR, [If ENABLED] – the difference between the line and bus voltages has to be less than the ∆V detector setting value for an output to be given.
The System Synchronising operation of the relay can be started in two different ways. It is set by the ‘A/R Split Action’ setting which has three parameters :LOCKOUT , SYSTEM SYNC, CLOSE ON ZERO; or ‘MC Split Action’ setting which also has three parameters : CLOSE ON ZERO, CHECK SYNC, SYSTEM SYNC.

If the ‘A/R Split Action’ setting is set to :

LOCKOUT : after a split has occurred the relay will go into lockout mode

SYSTEM SYNC: the relay will only start system synchronising after a split condition has occurred. It will issue a System Sync Close automatically if the relevant parameters are met.

CLOSE ON ZERO : the relay will only start system synchronising after a split condition has occurred. The relay will issue a close command determined by the CB close time and synchronisation parameters.

I f the ‘MC Split Action’ setting is set to :

CLOSE ON ZERO : the relay will only start system synchronising after a split condition has occurred. The relay will issue a close command determined by the CB close time and synchronisation parameters.

CHECK SYNC: the relay will only start system synchronising after a split condition has occurred.

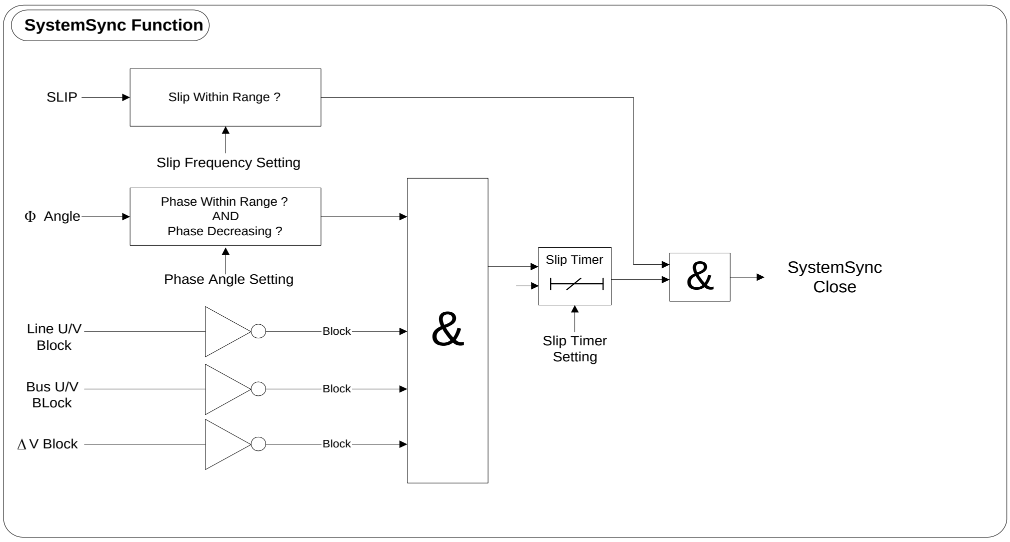

Figure 5 - System Sync Function

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It will issue a Check Sync Close automatically if the relevant parameters are met.

SYSTEM SYNC: the relay will only start system synchronising after a split condition has occurred. It will issue a System Sync Close automatically if the relevant parameters are met.

4 Other Features

4.1 Metering

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

- Phase difference between Line and Bus
- Frequency of both Line and Bus
- Frequency slip between Line and Bus
- RMS volts for both Line and Bus
- Voltage Differential between line and Bus
- Total Number of CB Closes per phase
- Delta Number of CB Closes per phase
- A/R State
- Digital input status
- Output relay status
- Date - displayed in DD/MM/YY format
- Time - displayed in HH:MM:SS format
-

Note : while the instrument displays are updated as often as the software routines can service them, some have their response time deliberately slowed down to enable them to be read.

Figure 6 shows the display menu structure from where the available instruments can be accessed.

4.2 Data Storage

Data records are available in two forms, namely Waveform records and Event records. All records are time and date stamped with a real time clock which maintains the 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 Config menu or via the communications interface. In the latter case, relays connected in a network can be synchronised by a global time sync command.
Alternatively, synchronising pulses can be received via a special input.

4.2.1 Waveform Records.

The waveform record feature stores analogue and digital information for the voltage inputs, status inputs and output relays. A single phase waveform record for both the line and bus voltages can be stored and this shows the voltages at either side of the breaker at the moment of closing of the switch. The waveform record is 1 second wide with a sampling resolution of 8 samples per cycle. The recorder feature has the ability to store records for the previous ten close operations of the relay. These are labelled 1-10 with 1 being the most recent record.

<u>The waveform recorder is triggered in the following ways ;</u>

- Via the waveform trigger status input signal.
- by the Close Pulse.

4.2.2 Event Records

The event recorder feature allows the time tagging of any change of state (Event) of the relay. As an event occurs the actual event condition is logged as a record along with a time and date stamp to a resolution of 5msec. There is capacity for a maximum of 500 event records to be

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stored in the relay and when the event buffer is full any new record will over-write the oldest. The following events are logged :

- Change of setting (though not the actual setting change). 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 of the control functions of the relay.
- Change of state of any of the voltage elements.
-

For a full list of all the events available see Table 1.

4.3 Communications

The following additional information is available via the communications:

- Close Data Records
- Instrument and meters
- Control Functions

5 Menu Settings

5.1 A/R Menu

A/R In Service – this setting switches the Auto-reclose in or out.

Close Mode Selection – this setting selects the appropriate auto-reclose sequence.

Gn Dead Bar Close – this setting determines the closing action.

Gn Dead Line Close – this setting determines the closing action.

Gn Check Sync Close – this setting determines the closing action.

Gn First 1P Dead time – this setting sets the first shot Single pole dead time time delay.

Gn Second 1P Dead time – this setting sets the second shot Single pole dead time time delay

Gn First 3P Dead time – this setting sets the first shot Three pole dead time time delay.

Gn Second 3P Dead time – this setting sets the second shot Three pole dead time time delay.

Gn Start Dead time – this setting selects how to initiate the dead time.

Gn 3P Dead time Initiate – this setting sets whether the dead time can be initiated from three phase faults.

Gn CB Aux Switches – this setting sets the type of connection to the CB Auxiliary contacts.

Gn CB Close Pulse – this setting sets the close pulse duration.

Gn Reclaim Time – this setting sets the reclaim time.

Gn Sync Close Delay – this setting sets the allowable time the Auto-reclose sequence will wait for an In Sync signal before the sequence is locked out.

Gn Permissive Close Delay – this setting sets the allowable time a Block Reclose or Inhibit Close may be active before the Auto-reclose sequence is locked out.

Gn Overall Sequence Timer – this setting sets the time to lockout to complete the auto-reclose sequence.

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Gn Sequence Fail Timer – this setting sets the time to lockout if all the A/R start signals are not received. These are Trip Reset, CB Open and Dead Line.

Gn Persistent Intertrip – this setting sets the time to lockout if the Intertrip Receive input does not reset.

Gn CB Fail To Open Delay – this setting sets the CB Fail to Open time delay.

Gn Minimum LO Timer – this setting sets the minimum Lockout timer.

Gn Reset LO By Timer – this setting determines whether Lockout can be reset by the time delay setting, or by some other means i.e. a Reset LO status input.

Gn CB Indeterminate – this setting sets the time which indicates that CB Open and CB Closed are in an Indeterminate position.

Gn CB Memory Timer – this setting sets the drop-off time which indicates that the CB was In Service.

Gn Set Type – Where dual auto-reclose relays are applied this setting sets which is the master and which the slave.

Gn Total CB Close Counter – this setting sets the count at which an alarm will be given if that number of closes occur.

Gn Delta CB Close Counter – this setting sets the count at which an alarm will be given if that number of closes occur.

Gn Reset Total CB Count – this setting resets the count and alarm.

Gn Reset Delta CB Count – this setting resets the count and alarm.

5.2 CB Pole Discrepancy Menu

Gn Pole Discrepancy Time – this setting sets the time delay before Pole Discrepancy is issued.

5.3 Sync Menu

Gn Live Bus/Dead Bus – this setting sets the voltage levels for Live and Dead Bus.

Gn Live Line/Dead Line – this setting sets the voltage levels for Live and Dead Line.

Gn Bus Undervolts – this setting sets the Bus undervoltage detector.

Gn Line Undervolts – this setting sets the Line undervoltage detector.

Gn Voltage Differential – this setting sets the differential voltage allowed between Bus and Line.

Gn Split Angle – this setting sets the angle at which a system split will occur.

Gn MC Split Action – this setting sets the action which will occur if a Manual Close is given after a system split.

Gn A/R Split Action – this setting sets the action which will occur if a system split occurs during an auto-reclose sequence.

Gn Check Sync Angle – this setting sets the phase angle limits for the Check Sync element.

Gn Check Sync Slip – this setting sets the Check Sync Slip frequency.

Gn Check Sync Timer – this setting sets the Check Sync time delay.

Gn System Sync Angle – this setting sets the phase angle limits for the System Sync element.

Gn SS and COZ Slip Frequency – this setting sets the slip frequency for the System Sync and Close On Zero functions

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Gn System Sync Timer – this setting sets the System Sync time delay.

Gn CB Close Time – this setting sets the CB Close time required for the Close On Zero function.

5.4 Status Input Menu

Manual Close - this setting sets the status input(s) which, when energised, starts the Manual Close operation of the relay.

A/R Out - this setting sets the status input(s) which, when energised, switches the Auto-reclose Out. This input has priority over A/R In.

A/R In - this setting sets the status input(s) which, when energised, switches the Auto-reclose In, unless the A/R Out is raised.

Inhibit Close - this setting sets the status input(s) which, when energised, inhibits the Close pulse for either Manual or auto-reclose sequences.

Block Reclose - this setting sets the status input(s) which, when energised, Blocks Reclose during the auto-reclose sequence. An associated time delay is provided Permissive Close Delay which if not expired allows the Block Reclose input to be used as a temporary block.

Reclose Lockout - this setting sets the status input(s) which, when energised, causes the relay to go to Lockout.

Block Second Shot - this setting sets the status input(s) which, when energised, stops the second auto-reclose sequence.

A Trip - this setting sets the status input(s) which, when energised, starts the auto-reclose cycle. It is required in conjunction with the state of the Circuit Breaker and Line.

B Trip - this setting sets the status input(s) which, when energised, starts the auto-reclose cycle. It is required in conjunction with the state of the Circuit Breaker and Line.

C Trip - this setting sets the status input(s) which, when energised, starts the auto-reclose cycle. It is required in conjunction with the state of the Circuit Breaker and Line.

3 Trip - this setting sets the status input(s) which, when energised, starts the auto-reclose cycle. It is required in conjunction with the state of the Circuit Breaker and Line.

Intertrip Receive - this setting sets the status input(s) which, when energised, starts the auto-reclose cycle. The Intertrip Receive is required to reset within the Persistent Intertrip time. Only a one shot Intertrip initiated auto-reclose sequence is allowed.

CB A Aux One - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

CB B Aux One - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

CB C Aux One - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

CB A Aux Two - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

CB B Aux Two - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

CB C Aux Two - this setting sets the status input(s) which, when energised, indicates the condition of the CB Auxiliary contacts.

Sync Override - this setting sets the status input(s) which, when energised, will allow a Close Pulse to be issued when it has been initiated by auto-reclosing, irrelevant of the condition of the Check Sync function.

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Manual Sync Override - this setting sets the status input(s) which, when energised, will allow a Close Pulse to be issued when it has been initiated by Manual Closing, irrelevant of the condition of the Check Sync function.

Reset Lockout - this setting sets the status input(s) which, when energised, will reset a latched lockout condition if there is no signal still present to cause the relay to be still in Lockout.

CMS Change One - this setting sets the status input(s) which, when energised, indicate which Auto-reclose Sequence is selected. If not required no connection should be made.

CMS Change Two - this setting sets the status input(s) which, when energised, indicate which Auto-reclose Sequence is selected. If not required no connection should be made.

CMS Change Three - this setting sets the status input(s) which, when energised, indicate which Auto-reclose Sequence is selected. If not required no connection should be made.

Master Slave - this setting sets the status input(s) which, when energised, provide a means of selecting which auto-reclose relay has priority over another.

Switch Groups - this setting sets the status input(s) which, when energised, switches the active Group to the number programmed in Switched Group in the SYSTEM CONFIG MENU.

Trigger Storage - this setting sets the status input(s) which, when energised, triggers the data storage.

5.5 Reylogic Control Menu

General Logic – this setting allows any Reylogic to be enabled/disabled.

5.6 Reylogic Elements Menu

Gn ManualCloseTimer PU – this setting sets the pick up time delay associated with that input.

Gn ManualCloseTimer DO – this setting sets the drop off time delay associated with that input.

Gn InhibitCloseTimer PU – this setting sets the pick up time delay associated with that input.

Gn InhibitCloseTimer DO – this setting sets the drop off time delay associated with that input.

Gn AROutTimer PU – this setting sets the pick up time delay associated with that input.

Gn AROutTimer DO – this setting sets the drop off time delay associated with that input.

Gn ARInTimer PU – this setting sets the pick up time delay associated with that input.

Gn ARInTimer DO – this setting sets the drop off time delay associated with that input.

Gn TripATimer PU – this setting sets the pick up time delay associated with that input.

Gn TripATimer DO – this setting sets the drop off time delay associated with that input.

Gn TripBTimer PU – this setting sets the pick up time delay associated with that input.

Gn TripBTimer DO – this setting sets the drop off time delay associated with that input.

Gn TripCTimer PU – this setting sets the pick up time delay associated with that input.

Gn TripCTimer DO – this setting sets the drop off time delay associated with that input.

Gn Trip3Timer PU – this setting sets the pick up time delay associated with that input.

Gn Trip3Timer DO – this setting sets the drop off time delay associated with that input.

Gn RecloseLockoutTimer PU – this setting sets the pick up time delay associated with that input.

Gn RecloseLockoutTimer DO – this setting sets the drop off time delay associated with that input.

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Gn ResetLockoutTimer PU – this setting sets the pick up time delay associated with that input.

Gn ResetlockoutTimer DO – this setting sets the drop off time delay associated with that input.

Gn IntertripReceiveTimer PU – this setting sets the pick up time delay associated with that input.

Gn IntertripReceiveTimer DO – this setting sets the drop off time delay associated with that input.

Gn BlockSecondShotTimer PU – this setting sets the pick up time delay associated with that input.

Gn BlockSecondShotTimer DO – this setting sets the drop off time delay associated with that input.

Gn BlockRecloseTimer PU – this setting sets the pick up time delay associated with that input.

Gn BlockRecloseTimer DO – this setting sets the drop off time delay associated with that input.

5.7 Output Relay Menu

Close Pulse – this setting sets the output relay(s) which is operated when a Close Pulse is given.

Lockout – this setting sets the output relay(s) which is operated when Lockout is given.

A/R Out Of Service – this setting sets the output relay(s) which is operated when A/R Out of Service is given.

A/R In Service – this setting sets the output relay(s) which is operated when A/R In Service is given.

A/R In Progress – this setting sets the output relay(s) which is operated when A/R In Progress is given.

Successful Close – this setting sets the output relay(s) which is operated when the auto-reclose sequence has successfully completed.

3PTS – this setting sets the output relay(s) which is operated when the auto-reclose sequence indicates 3PTS is active. Use 3PTS for the output contact and 3PTS Flag as the LED indication.

CB Failed To Close – this setting sets the output relay(s) which is operated when the CB Fails To Close within the close pulse time.

Manual Close Fail – this setting sets the output relay(s) which is operated when the CB Fails To Close during a Manual Close sequence.

Close Onto Fault – this setting sets the output relay(s) which is operated when a trip has occurred during the close pulse.

Check Sync Start – this setting sets the output relay(s) which is operated when the required Check Sync relay is requested to start.

Three Pole In Op – this setting sets the output relay(s) which is operated when all three poles of the CB are open.

Single Pole In Op – this setting sets the output relay(s) which is operated when a single pole CB is open.

CB A Open – this setting sets the output relay(s) which is operated when a CB A Open is detected.

CB B Open – this setting sets the output relay(s) which is operated when a CB B Open is detected.

CB C Open – this setting sets the output relay(s) which is operated when a CB C Open is detected.

CB A Closed – this setting sets the output relay(s) which is operated when a CB A Closed is detected.

CB B Closed – this setting sets the output relay(s) which is operated when a CB B Closed is detected.

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CB C Closed – this setting sets the output relay(s) which is operated when a CB C Closed is detected.

CB A Indeterminate – this setting sets the output relay(s) which is operated when a CB A Indeterminate is detected.

CB B Indeterminate – this setting sets the output relay(s) which is operated when a CB B Indeterminate is detected.

CB C Indeterminate – this setting sets the output relay(s) which is operated when a CB C Indeterminate is detected.

Total CB Count Alarm – this setting sets the output relay(s) which is operated when the count exceeds it’s setting.

Delta CB Count Alarm – this setting sets the output relay(s) which is operated when the count exceeds it’s setting.

CB In Service Alarm – this setting sets the output relay(s) which is operated when the CB is in service.

CB Not In Service Alarm – this setting sets the output relay(s) which is operated when the CB is not in service.

CB Memory – this setting sets the output relay(s) which is operated when the CB is closed and the Line is live with a 2 sec delayed drop-off.

Persistent Intertrip – this setting sets the output relay(s) which is operated when a Persistent Intertrip is given.

Manual Close – this setting sets the output relay(s) which is operated when a Manual Close is given.

Line VT Failure – this setting sets the output relay(s) which is operated when the Line VT has failed.

Bus VT Failure – this setting sets the output relay(s) which is operated when the Bus VT has failed.

VT Failure – this setting sets the output relay(s) which is operated when either the line or bus VT has failed.

Reclose Lockout – this setting sets the output relay(s) which is operated when the Reclose Lockout is active.

Block Reclose Alarm – this setting sets the output relay(s) which is operated when a Block Reclose input is active.

Inhibit Close Alarm – this setting sets the output relay(s) which is operated when a Inhibit Close input is active.

Live Line – this setting sets the output relay(s) which is operated when a Live Line is detected.

Live Bus – this setting sets the output relay(s) which is operated when a Live Bus is detected.

In Sync – this setting sets the output relay(s) which is operated when an In Sync is given.

System Split – this setting sets the output relay(s) which is operated when a System Split occurs.

3PTS Flag – this setting sets the output relay(s) which is operated when a 3PTS is not set. It is a negated 3PTS signal intended to be used as the LED indication for the 3PTS signal. 3PTS is a normally energised N/C contact like Protection Healthy i.e. it gives a 3PTS signal if the auto-reclose relay loses its power supply.

PCD Timeout – this setting sets the output relay(s) which is operated when the end of the Permissive Close Delay is reached.

A/R Not Allowed – this setting sets the output relay(s) which is operated to indicate an alarm condition that a trip has tried to initiate an auto-reclose sequence but the CB was not in service.

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CMS Change Allowed – this setting sets the output relay(s) which is operated to indicate that a change to the Close Mode Selection setting is allowed.

Sync In Progress Flag – this setting sets the output relay(s) which is operated when the relay is waiting for In Sync.

Dead Line Close Flag – this setting sets the output relay(s) which is operated when the relay has closed due to Dead Line closing.

Dead Bus Close Flag – this setting sets the output relay(s) which is operated when the relay has closed due to Dead Bus closing.

1Pole Close Flag – this setting sets the output relay(s) which is operated when the relay has closed due to a Single Pole reclose.

Inhibit Seq Isolation – this setting sets the output relay(s) which is operated to stop sequential isolation – Normally Set.

A Trip – this setting sets the output relay(s) which is operated to indicate an A Phase trip has been received.

B Trip – this setting sets the output relay(s) which is operated to indicate an B Phase trip has been received.

B Trip – this setting sets the output relay(s) which is operated to indicate an C Phase trip has been received.

Three Trip – this setting sets the output relay(s) which is operated to indicate an Three Phase trip has been received.

CB Failed To Open – this setting sets the output relay(s) which is operated when the CB has failed to open within the allocated time.

CB Pole Discrepancy – this setting sets the output relay(s) which is operated when a CB Pole Discrepancy condition exists.

Inhibit Seq Isolation OP – this setting sets the output relay(s) which is operated to stop sequential isolation. A normally energised N/C contact is usually used – Normally Reset.

New Data Stored – this setting sets the output relay(s) which is operated when new data has been stored.

ExtGroupSwitched – this setting sets the output relay(s) which is operated when the Setting Group has changed.

Hand Reset Outputs – this setting sets the output relay(s) which are required to be latched until reset.

Protection Healthy – this setting sets the output relay(s) which is operated when Protection Healthy is given. This acts as a normally energised C/O contact.

5.8 LED Menu

The LED menu is a duplication of the output relay menu, allowing all outputs to be steered to an LED.

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6 Event List

Event Table

Event Description	Event Code	GI	Frame Type
Data lost	0	6	1
Reset FCB	2	6	5
Reset CU	3	6	5
Start/Restart	4	6	5
Power On	5	6	5
AR in progress	16	6	1
Teleprotection Active	17	6	1
Protection Active	18		
LEDs reset	19	6	1
Monitor Direction Reset	20		
Trip Test	21		
Settings Changed	22	4	1
Setting G1 selected	23	4	1
Setting G2 selected	24	4	1
Setting G3 selected	25	4	1
Setting G4 selected	26	4	1
Input 1	27	4	1
Input 2	28	4	1
Input 3	29	4	1
Input 4	30	4	1
CB on by AR	128	6	1
CB “on” by long time AR	129	6	1
Reclose blocked	130	6	1
Lockout	131	6	1
CBFailToClose	132	6	1
CBFailToOpen	133	6	1
CloseOntoFault	134	6	1
VTFailAlarm	135	6	1
CBCloseCounterAlarm	136	6	1
SyncInProgress	137	6	1
SyncOverride	138	6	1
DeadLineClose	139	6	1
DeadBusClose	140	6	1
SystemSplit	141	6	1
CheckSyncStart	142	6	1
Input 5	165	4	1
Input 6	166	4	1
Input 7	167	4	1
Input 8	168	4	1
Input 9	169	4	1
Input 10	170	4	1
Input 11	171	4	1

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Input 12	172	4	1
Input 13	173	4	1
Input 14	174	4	1
Input 15	175	4	1
Input 16	176	4	1
Input 17	177	4	1
Input 18	178	4	1
Input 19	179	4	1
Input 20	180	4	1
Input 21	181	4	1
Input 22	182	4	1
Input 23	183	4	1
Input 24	184	4	1
Input 25	185	4	1
Input 26	186	4	1
Input 27	187	4	1
Input 28	188	4	1
Input 29	189	4	1
Input 30	190	4	1
Input 31	191	4	1
Input 32	192	4	1
Output 1	193	4	1
Output 2	194	4	1
Output 3	195	4	1
Output 4	196	4	1
Output 5	197	4	1
Output 6	198	4	1
Output 7	199	4	1
Output 8	200	4	1
Output 9	201	4	1
Output 10	202	4	1
Output 11	203	4	1
Output 12	204	4	1
Output 13	205	4	1
Output 14	206	4	1
Output 15	207	4	1
Output 16	208	4	1
Output 17	209	4	1
Output 18	210	4	1
Output 19	211	4	1
Output 20	212	4	1
Output 21	213	4	1
Output 22	214	4	1
Output 23	215	4	1
Output 24	216	4	1
Output 25	217	4	1
Output 26	218	4	1
Output 27	219	4	1
Output 28	220	4	1
Output 29	221	4	1
Output 30	222	4	1
Output 31	223	4	1
Output 32	224	4	1

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Successful Close	225	6	1
External AR Start	226	6	1
Manual Close	227	6	1
Reset lockout	228	6	1
AR Out	229	6	1
AR In	230	6	1
In Sync	231	4	1
Live Bus	232	4	1
Live Line	233	4	1
Trip	234	6	1
Starter	235	6	1
Reclose Lockout	236	6	1
Trip And Reclose Input	237	6	1
CB PoleDiscrepancy	238	6	1
Reclaim	239	6	1
Ext Group Change	240	6	1
Ext Group Back	241	6	1
Manual Sync Override	242	6	1
Intertrip Receive	243	6	1
AutoIsolation Complete I/P	244	6	1
Inhibit Seq Isolation	245	6	1
Persistent Intertrip	246	6	1
AutoIsolation Fail	247	6	1
AutoIsolation Completed	248	6	1
AutoIsolation Initiate	249	6	1

Table 1 - Event Codes

KEY :

Event Code – is the allocated number given to a particular event.

GI – If the relay is interrogated for its events using the general interrogation (GI) command then only those indicated with the 4 will respond.

Frame Type – a ‘1’ indicates that the event is time tagged. A ‘5’ indicates an event which is generated only on power-on or reset of the relay.

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7 Setting Ranges

DAR Settings

A/R In Service	In/Out
Close Mode Selection	OFF,1P,3P,1P/3P,1P3P/3P,1P1P,3P3P,1P1P/3P3P
Dead Bar Close	Enabled/Disabled
Dead Line Close	Enabled/Disabled
Check Sync Close	Enabled/Disabled
First 1P Dead time	0.05 – 100sec in 0.05sec steps
Second 1P Dead time	0.05 – 100sec in 0.05sec steps
First 3P Dead time	0.1 – 900sec in 0.1sec steps
Second 3P Dead time	0.1 – 900sec in 0.1sec steps
Start Dead time	Trip Make, Trip & CB Open, Trip Reset
3P Dead time Initiate	1P/2P,1P/2P/3P
CB Aux Switches	Type a, Type b, Type a&b
Close Pulse	0.1 – 20sec in 0.1sec steps
Reclaim Time	OFF - 1 – 600sec in 1sec steps
Sync Close Delay	1 – 60sec in 1sec steps
Permissive Close Delay	OFF -1 – 600sec in 1sec steps
Overall Sequence Timer	OFF – 1 – 3000sec in 1 sec steps
Sequence Fail Delay	OFF - 1 – 200sec in 1sec steps
Persistent Intertrip	1 – 180sec in 1sec steps
CB Fail To Open Delay	0.1 – 2000msec in 10msec steps
Minimum LO Time	0 – 60sec in 1sec steps
Reset LO By Timer	Enabled/Disabled
CB Indeterminate	50 –200ms in 10ms steps
CB Memory Timer	0 – 5sec in 1 sec steps
Set Type	Master / Slave
Total Close Count Alarm	1..999
Delta Close Count Alarm	1.999

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Check Synchronising Settings

Dead Bus	5 – 150%
Live Bus	10 – 155%
Dead Line	5 – 150%
Live Line	10 – 155%
Bus Undervolts	OFF – 150%
Line Undervolts	OFF – 150%
Voltage Differential	OFF – 100%
Split Angle	OFF – 175°
Manual Close Split Action	COZ/SS/CS
Auto-reclose Split Action	Lockout/COZ/SS
Check Sync Angle	5 - 90°
Check Sync Slip	OFF – 2000mHz
Check Sync Timer	OFF – 100s
System Sync Angle	5 - 90°
SS and COZ Slip Frequency	OFF – 2000mHz
System Sync Timer	OFF – 100s
CB Close Time	5 – 200ms

8 Accuracy

General	IEC255
Auxiliary Supply	Nominal
Rating	63.5 Vrms
Frequency	50 or 60Hz
Ambient Temperature	20°C

CS and SS Phase Angle measurement	
Operate	Setting -3° + 0°
Reset	operate value -0° + 3°
CS and SS Slip Frequency	
Operate	Setting -15mHz + 0mHz
Reset	operate value -0mHz + 15mHz
Split Detector measurement	
Operate	setting ±1.5°
Reset	detector is latched
Line and Bus Voltage Detector Elements	
Live Operate	setting ±1%
Live Reset	dead operate setting ±1%
Dead Operate	setting ±1%
Dead Reset	live operate setting ±1%
Line and Bus U/V Detector Elements	
Operate	Setting ±1%
Reset	< 104% of operate value
∆V Detector Element	

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Operate	Setting ±2% or 0.5V whichever is greater
Reset	Typically > 90% (and always within 2V) of operate value
All Timers	
Timing Accuracy	±1% or 10ms

Measuring Accuracy

Voltage	± 1% (for range 7V-132Vrms)
Frequency	Typically ± 10mHz
Phase	Typically ± 1°

Frequency

Range	47Hz to 51Hz 57Hz to 61Hz
Setting variation	≤ 1%
Phase Angle Measurement	≤ 1%
Operating time variation	≤ 1%

Continuous Overload

AC Voltage	250Vrms

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9 Auto-Reclose Menu Settings

9.1 DAR Menu

SETTING	RANGE	DEFAULT
A/R In Service	IN/OUT	OUT
Close Mode Selection	OFF,1P,3P,1P/3P,1P3P/3P,1P1P,3P3P,1P1P/3P3P	3P
Dead Bar Close	Enabled/Disabled	Disabled
Dead Line Close	Enabled/Disabled	Disabled
Check Sync Close	Enabled/Disabled	Enabled
First 1P Dead time	0.05-100s step 0.05s	1.0s
Second 1P Dead time	0.05-100s step 0.05s	1.0s
First 3P Dead time	0.1-900s step 0.1s	5.0s
Second 3P Dead time	0.1-900s step 0.1s	5.0s
Start Dead time	Trip & CB Open, Trip Make, Trip reset	Trip & CB Open
3P Dead time Initiate	1P/2P/3P, 1P/2P	1P/2P/3P
CB Aux Switches	Type a, Type b, Type a&b	Type a
CB Close Pulse	0.2-20s step 0.1s	2.0s
Reclaim Time	OFF - 1-600s step 1s	5s
Sync Close Delay	0-60s step 1s	30s
Permissive Close Delay	OFF - 0-600s step 1s	60s
Overall Sequence Timer	OFF – 1 – 3000s step 1s	OFF
Sequence Fail Timer	OFF-1-200s step 1s	OFF
Persistent Intertrip	1-180s step 1s	60s
CB Fail To Open Delay	50-2000ms step 10ms	100ms
Minimum LO Timer	0-60s step 1s	2s
Reset LO By Timer	Enabled/Disabled	Disabled
CB Indeterminate	50 – 200ms step 10ms	80ms
CB Memory Timer	0 – 5s step 1s	2s
Set Type	Master / Slave	Master
Total CB Close Counter	1-999 step1	100
Delta CB Close Counter	1-999 step1	20
Reset Total CB Count	YES/NO	NO
Reset Delta CB Count	YES/NO	NO

9.2 Pole Discrepancy Menu

SETTING	RANGE	DEFAULT
Pole Discrepancy Time	OFF-0.1-20.0s step 0.1s	1.6s

9.3 Sync Menu

SETTING	RANGE	DEFAULT
Gn Bus Dead : Live	5-150% step1% 10-155% step 1%	20% 90%
Gn Line Dead : Live	5-150% step1% 10-155% step 1%	20% 90%
Gn Bus U/V Detector	OFF, 5-150% step 1%	90%
Gn Line U/V Detector	OFF, 5-150% step 1%	90%
Gn Voltage Differential	OFF-1-100% step 1%	10%
Gn Split Angle	OFF-95°-175° step1°	175°
Gn MC Split Action	Close On Zero/Check Sync/System Sync	Close On Zero

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SETTING	RANGE	DEFAULT
Gn A/R Split Action	Lockout/System Sync/Close On Zero	Lockout
Gn Check Sync Angle	5° - 90° step 1°	20°
Gn Check Sync Slip	OFF, 0.020 - 2.000Hz step 0.005Hz	0.050Hz
Gn Check Sync Timer	OFF, 0.1 - 100sec step 0.1sec	OFF
Gn System Sync Angle	5° - 90° step 1°	10°
Gn SS and COZ Slip Frequency	OFF, 0.010 - 2.000Hz step 0.005Hz	0.125Hz
Gn System Sync Timer	OFF, 0 – 100sec step 0.1sec	OFF
Gn CB Close Time	5-200ms step 5ms	60ms

9.4 Status Config Menu

SETTING	RANGE	DEFAULT
Manual Close	S1..S13	None
A/R Out	S1..S13	None
A/R In	S1..S13	None
Inhibit Close	S1..S13	None
Block Reclose	S1..S13	None
Reclose Lockout	S1..S13	None
Block Second Shot	S1..S13	None
A Trip	S1..S13	None
B Trip	S1..S13	None
C Trip	S1..S13	None
3 Trip	S1..S13	None
Intertrip Receive	S1..S13	None
CB A Aux One	S1..S13	None
CB B Aux One	S1..S13	None
CB C Aux One	S1..S13	None
CB A Aux Two	S1..S13	None
CB B Aux Two	S1..S13	None
CB C Aux Two	S1..S13	None
Sync Override	S1..S13	None
Manual Sync Override	S1..S13	None
Reset lockout	S1..S13	None
CMS Change One	S1..S13	None
CMS Change Two	S1..S13	None
CMS Change Three	S1..S13	None
Master Slave	S1..S13	None
Switch Groups	S1..S13	None
Trigger Storage	S1..S13	None

9.5 Reylogic Control Menu

SETTING	RANGE	DEFAULT
General Logic	Enable/Disable	Enable

9.6 Reylogic Elements Menu

SETTING	RANGE	DEFAULT
ManualCloseTimer PU	0-60000ms step 1ms	15
ManualCloseTimer DO	0-60000ms step 1ms	0
InhibitCloseTimer PU	0-60000ms step 1ms	15
InhibitCloseTimer DO	0-60000ms step 1ms	0

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SETTING	RANGE	DEFAULT
AROutTimer PU	0-60000ms step 1ms	15
AROutTimer DO	0-60000ms step 1ms	0
ARInTimer PU	0-60000ms step 1ms	15
ARInTimer DO	0-60000ms step 1ms	0
TripATimer PU	0-60000ms step 1ms	15
TripATimer DO	0-60000ms step 1ms	0
TripBTimer PU	0-60000ms step 1ms	15
TripBTimer DO	0-60000ms step 1ms	0
TripCTimer PU	0-60000ms step 1ms	15
TripCTimer DO	0-60000ms step 1ms	0
Trip3Timer PU	0-60000ms step 1ms	15
Trip3Timer DO	0-60000ms step 1ms	0
RecloseLoTimer PU	0-60000ms step 1ms	15
RecloseLoTimer DO	0-60000ms step 1ms	0
ResetLOTimer PU	0-60000ms step 1ms	15
ResetLOTimer DO	0-60000ms step 1ms	0
ITReceiveTimer PU	0-60000ms step 1ms	15
ITReceiveTimer DO	0-60000ms step 1ms	0
Block2ShotTimer PU	0-60000ms step 1ms	15
Block2ShotTimer DO	0-60000ms step 1ms	0
BlockARTimer PU	0-60000ms step 1ms	15
BlockARTimer DO	0-60000ms step 1ms	0

9.7 Output Relay Menu

SETTING	RANGE	DEFAULT
Close Pulse	RL1..RL13	None
Lockout	RL1..RL13	None
A/R Out Of Service	RL1..RL13	None
A/R In Service	RL1..RL13	None
A/R In Progress	RL1..RL13	None
Successful Close	RL1..RL13	None
3PTS	RL1..RL13	None
CB Failed To Close	RL1..RL13	None
Manual Close Fail	RL1..RL13	None
Close Onto Fault	RL1..RL13	None
Check Sync Start	RL1..RL13	None
Three Pole In Op	RL1..RL13	None
Single Pole In Op	RL1..RL13	None
CB A Open	RL1..RL13	None
CB B Open	RL1..RL13	None
CB C Open	RL1..RL13	None
CB A Closed	RL1..RL13	None
CB B Closed	RL1..RL13	None
CB C Closed	RL1..RL13	None
CB A Indeterminate	RL1..RL13	None
CB B Indeterminate	RL1..RL13	None
CB C Indeterminate	RL1..RL13	None
Total CB Count Alarm	RL1..RL13	None
Delta CB Count Alarm	RL1..RL13	None
CB In Service	RL1..RL13	None
CB Not In Ser Alarm	RL1..RL13	None
CB Memory	RL1..RL13	None
Persistent Intertrip	RL1..RL13	None
Manual Close	RL1..RL13	None
Line VT Failure	RL1..RL13	None

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SETTING	RANGE	DEFAULT
Bus VT Failure	RL1..RL13	None
VT Failure	RL1..RL13	None
Reclose Lockout	RL1..RL13	None
Block Reclose Alarm	RL1..RL13	None
Inhibit Close	RL1..RL13	None
Live Line	RL1..RL13	None
Live Bus	RL1..RL13	None
In Sync	RL1..RL13	None
System Split	RL1..RL13	None
3PTS Flag	RL1..RL13	None
PCD Timeout	RL1..RL13	None
A/R Not Allowed	RL1..RL13	None
CMS Change Allowed	RL1..RL13	None
Sync In Prog Flag	RL1..RL13	None
Dead Line Close Flag	RL1..RL13	None
Dead Bus Close Flag	RL1..RL13	None
1P Close Flag	RL1..RL13	None
Inhibit SeqIsolation	RL1..RL13	None
A Trip	RL1..RL13	None
B Trip	RL1..RL13	None
C Trip	RL1..RL13	None
Three Trip	RL1..RL13	None
CB Failed to Open	RL1..RL13	None
CB Pole Discrepancy	RL1..RL13	None
Inhibit SeqIsolation OP	RL1..RL13	None
New Data Stored	RL1..RL13	None
ExtGroupSwitched	RL1..RL13	None
Hand Reset Outputs	RL1..RL13	None
Protection Healthy	RL1..RL13	1

9.8 LED Menu

SETTING	RANGE	DEFAULT
Close Pulse	L1..L16/32	
Lockout	L1..L16/32	
A/R Out Of Service	L1..L16/32	
A/R In Service	L1..L16/32	
A/R In Progress	L1..L16/32	
Successful Close	L1..L16/32	
3PTS	L1..L16/32	
CB Failed To Close	L1..L16/32	
Manual Close Fail	L1..L16/32	
Close Onto Fault	L1..L16/32	
Check Sync Start	L1..L16/32	
Three Pole In Op	L1..L16/32	
Single Pole In Op	L1..L16/32	
CB A Open	L1..L16/32	
CB B Open	L1..L16/32	
CB C Open	L1..L16/32	
CB A Closed	L1..L16/32	
CB B Closed	L1..L16/32	
CB C Closed	L1..L16/32	
CB A Indeterminate	L1..L16/32	
CB B Indeterminate	L1..L16/32	
CB C Indeterminate	L1..L16/32	
Total CB Count Alarm	L1..L16/32	

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SETTING	RANGE	DEFAULT
Delta CB Count Alarm	L1..L16/32	
CB In Service	L1..L16/32	
CB Not In Ser Alarm	L1..L16/32	
CB Memory	L1..L16/32	
Persistent Intertrip	L1..L16/32	
Manual Close	L1..L16/32	
Line VT Failure	L1..L16/32	
Bus VT Failure	L1..L16/32	
VT Failure	L1..L16/32	
Reclose Lockout	L1..L16/32	
Block Reclose Alarm	L1..L16/32	
Inhibit Close	L1..L16/32	
Live Line	L1..L16/32	
Live Bus	L1..L16/32	
In Sync	L1..L16/32	
System Split	L1..L16/32	
3PTS Flag	L1..L16/32	
PCD Timeout	L1..L16/32	
A/R Not Allowed	L1..L16/32	
CMS Change Allowed	L1..L16/32	
Sync In Prog Flag	L1..L16/32	
Dead Line Close Flag	L1..L16/32	
Dead Bus Close Flag	L1..L16/32	
1P Close Flag	L1..L16/32	
Inhibit SeqIsolation	L1..L16/32	
A Trip	L1..L16/32	
B Trip	L1..L16/32	
C Trip	L1..L16/32	
Three Trip	L1..L16/32	
CB Failed to Open	L1..L16/32	
CB Pole Discrepancy	L1..L16/32	
Inhibit SeqIsolation OP	L1..L16/32	
New Data Stored	L1..L16/32	
ExtGroupSwitched	L1..L16/32	
Hand Reset Outputs	L1..L16/32	
Protection Healthy	L1..L16/32	

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10 Applications

10.1 Introduction

The relays provide a full closing system: Auto-reclose, Manual Closing and Check Synchronisation. The input/output is fully programmable to matrixes from the status inputs to the output contacts or/and LEDs.

The combined check and system synchronising function can automatically select check or system synchronise from measurements of the relative phase angles between the line and bus voltages. The relay will prevent closure of the circuit breaker if the phase angle, slip frequency or the voltage magnitude of the incoming and running voltages fall outside prescribed limits.

If the parameters are within the limits the relay will issue an output which can be used to close the circuit breaker directly. Both the check and system synchronise functions have independent settings and blocking features. The relay also includes split system detection, which can be used for blocking purposes within the auto-reclose scheme.

The auto-reclose function requires the correct application, setting and commissioning to verify operation. Because of the complexity of auto-reclose schemes and the possibility of setting the relay incorrectly the user should be familiar with all aspects of the relay before energising any equipment.

10.2 General Information

The relay can directly replace older Auto-reclose relays. The relay contains the equivalent UK specification Auto-reclose logic (‘J’ unit, or ‘C’ unit), Indication (‘F’ unit) and In/Out Switching (‘H’ unit) all within the relay.

On initial switch on of AC volts to the relay, the Check Sync function will wait for 2 seconds before any output can be given. This is to allow time for the frequency and phase measuring elements to settle and establish healthy outputs and also allow for any transient conditions on voltage switch on.

It also allows busbar connection of multiple incoming volts to use a common check sync relay.

10.3 Auto-reclose

The Auto-reclose function provides the flexibility to be applied to a number of different Auto-reclose schemes. This is achieved by a number of settings which provide choices as to connections and time delays. The relay can be easily connected as a basic scheme with minimal input and output or more of the functions can be set to provide extra alarms and control.

Settings:

In/Out Switching can be connected directly to the relay’s status inputs, additional control auxiliary relays are not required because the relay has separately grounded inputs.
The reclosure options are circuit breaker specific.

Reclosure Options	Option Range
Dead Bar Close	Enabled/Disabled
Dead Line Close	Enabled/Disabled
Check Sync Close	Enabled/Disabled

Dead time:

There are four dead time settings:

First Single Pole Dead time, Second Single Pole Dead time, First Three Pole Dead time, Second Three Pole Dead time.

The Dead time is the time taken from the circuit breaker tripping and the trip reset to a reclose signal being issued.

The dead time can be started in three ways:

1. When the Protection Trip is received. Set Start Dead time setting to Trip Make.

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2. When the Protection Trip is received AND the CB has opened AND the line has gone dead. Set Start Dead time setting to Trip & CB Open.

3. When the Protection Trip is received AND the CB has opened AND the line has gone dead AND the Protection Trip resets. Set Start Dead time setting to Trip Reset.

The different methods are provided to take account of different utilities preferences.
Some utilities use a trip reset interlock to facilitate isolation. This may hold the trip active until any post-fault isolation has completed. Should use Trip Reset setting.

A method is provided to prevent three pole auto-reclosing if the fault involves all three phases but to proceed if the fault involves one or two phases.

To allow three pole auto-reclosing for faults involving all phases set the 3P Dead time Initiate setting to 1P\2P\3P.

To prevent three pole auto-reclosing for faults involving all three phases set the 3P Dead time Initiate setting to 1P\2P.

Sequence Fail timer:

To prevent the auto-reclose sequence being primed indefinitely a Sequence Fail time delay should be set greater than any trip reset time delays. If the Sequence Fail timer expires because either the trip fails to reset, or the CB does not open, or the line does not go dead then the auto-reclose sequence will lockout. If the timer is not required then it can be set to OFF.

Permissive Close Delay:

The Permissive Close Delay works in conjunction with the Block Reclose and Inhibit Close inputs. Block Reclose stops the auto-reclose sequence, Inhibit Close stops the auto-reclose sequence and the Manual Close sequence. If the Permissive Close Delay expires the relay will lockout. CB conditions such as Low Pressure should be connected to the Inhibit Close input. At the end of the Dead time if there is a Block Reclose or Inhibit Close present the relay will wait for as long as the Permissive Close Delay. If the Block Reclose or Inhibit Close input resets before the end of the Permissive Close Delay then reclosure will be permitted.

Sync Close Delay:

This timer limits how long the relay will wait for the In Sync signal. If Check Sync Close is allowed but the Sync Check function is returning Not In Sync the relay will wait. If the Sync Close Delay expires the relay will lockout. This setting needs to be set to accommodate the closing operation programmed.

For a reclosure scheme with Dead Line Charge at the remote end and Check Sync Close at this end it is likely that a Sync Close Delay of 5sec would suffice. This is dependent upon whether the system will island. If it is not possible for the system to split and Check Sync is being used (i.e. there will be a constant phase angle, say 6°), then the setting of the Sync Close Delay should be set to 5sec.

For a reclosure scheme which may split and the reclosure is programmed for Check or System Sync at tighter angles or Close On Zero after system split, it may take a considerable time for the two systems to come into synchronism. This will be dependent upon the slip frequency.

The Sync Close Delay needs to be set longer than the possible delay the two systems take to get back in Sync, otherwise the relay will lockout before a reclosure can be attempted.

For a slip frequency of 50mHz it takes 20 seconds for a complete rotation. If the dead time is set to 5sec it would be necessary to set the Sync Close Delay to approximately 20 seconds. It is recommended to set the Sync Close Delay to the minimum slip frequency rotation time.

For worst case, where the dead time was set longer than the slip frequency rotation time the close may be required just at the point where the vector has left the setting range, in which case a full rotation would be required to get back into the limits. Allow enough time or it may lockout while trying to come into synch.

Persistent Intertrip:

The reclosure can be started by an Intertrip Receive.

Intertrips are generally connected to some form of inter-tripping communication channel. To prevent problems with these channels if the intertrip is present for longer than the Persistent Intertrip time the reclosure will not be initiated and the relay will lockout.

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The dead time is started when the Intertrip resets provided the CB has opened, there are no other trips or starter active, the line has gone dead, and the Persistent Intertrip timer has not timed out. Only a one shot intertrip initiated scheme is allowed, any intertrips occurring in the close pulse or reclaim cause lockout, even if set to more than one shot.

The Persistent Intertrip time is only associated with the Intertrip Receive status input.
If multi-shot reclosing is required by intertripping then the Intertrip Receive should be connected to the External A/R Start (3 Trip) input rather than the Intertrip Receive input. The Persistent Intertrip setting in the relay would not be used

Overall Sequence Time:

The Overall Sequence time is provided to govern the maximum time which the complete auto-reclose sequence can take. It would generally be set greater than all the constituent times. If the Overall Sequence Timer expires the relay will go to Lockout. This timer is provided as a back-up to prevent the auto-reclose being primed indefinitely and giving a close pulse when not expected. However the correct setting of the Sequence Fail timer and Permissive Close Delay mean the Overall Sequence timer is not required. It has been left in the relay to satisfy existing customers who require it.

CB Close Pulse:

The CB Close Pulse should be set to a value to ensure that the CB is closed, typically 2sec. To take account of slow spring rewind times the close pulse setting range has deliberately been extended up to 20 seconds.

Reclaim Time:

The reclaim time would be set to a value which represents a correct reconnection. If the CB remains closed for the Reclaim time following an auto-reclose, the relay will reset and be ready for further operations. At the end of the reclaim time a fleeting contact ‘Successful A/R’ will be issued, for 2 seconds. A trip within the reclaim time would initiate another reclose if the next shot is allowed, otherwise the auto-reclose sequence will be locked out.

Minimum Lockout Timer:

Once the relay enters the lockout state this may be latched until reset or reset automatically provided there is no mechanism to keep the relay in lockout. However a minimum lockout time can be set. Recommended setting 2 seconds.

Reset LO By Timer:

If Reset LO By Timer is set to Yes the relay will automatically reset from lockout provided there is no mechanism to cause lockout. This will be set depending upon how lockout is dealt with by individual utilities. Some utilities investigate every lockout occurrence (in which case this setting should be set to Disabled) whilst others accept lockout as normal operation.

CB Fail To Open:

A combination of a Protection Trip and the CB auxiliary contacts indicating CB Closed after a settable time delay results in the alarm CB Fail To Open. This would be useful in auto-reclose applications where conventional CB Fail protection was not fitted. The CB Fail To Open output would be independently wired to Lockout and stop the auto-reclose sequence. Alternatively a time delay setting could be set which indicates CB Slow, and give an alarm if the CB is still closed after this setting, typically 100ms.

CB Indeterminate:

The connection of the CB auxiliary contacts can include one contact indicating Open and another contact indicating Closed. If the CB Auxiliary contacts were to indicate either both open or both closed for greater than the CB Indeterminate time, (typically set to 80ms) then a CB Indeterminate Alarm is issued. Separate phase outputs are provided. These could all be mapped to the same output contact to provide a common alarm.

CB Memory Time:

A setting is provided which indicates when the CB has been In Service. This is defined as being when the CB is Closed and the Line is Live and has a delayed drop-off, the CB Memory time. It is expected that this would be set to 2 seconds.

Set Type:

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Where two auto-reclose relays are applied for one CB the relay which is designated Master can be set to override the Slave. This requires that the Master's output A/R In Progress is wired to the Master Slave input of the Slave. When the Master Slave input of the Slave is active it will cancel any auto-reclose sequence, reset and wait in its ready state until the A/R In Progress of the Master is released.

Application to Transmission Feeder:

Where applied to a feeder with A/R at each end, different dead times would be applied, example: 5sec and Dead Line Charge at local end (small generation); and 10sec and Check Sync and Dead Line Charge at remote end (large generation). Choosing to Dead Line Charge from the small source would ensure that closing onto a fault causes the least shock to the system. The Transmission line is reclosed even if the remote or local CB cannot close. Closure is only permitted if the line has gone dead which indicates that both local and remote CBs have opened.

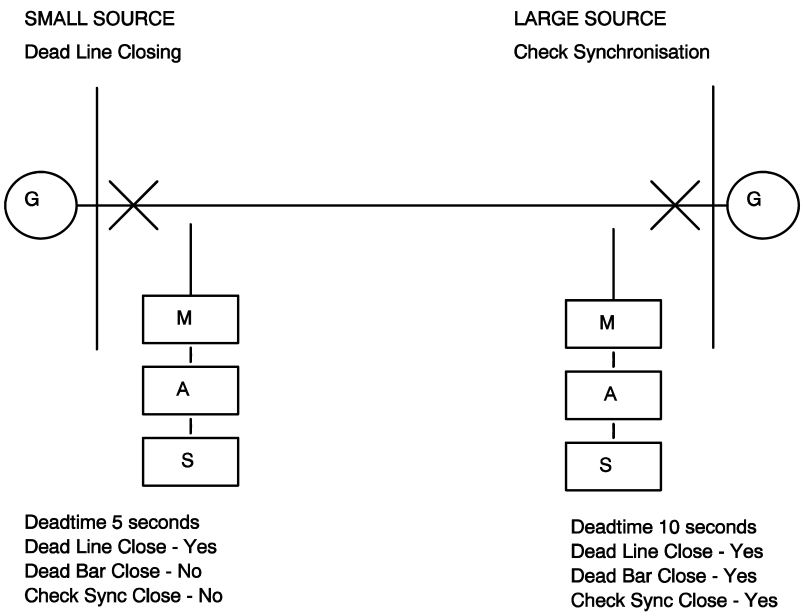

Figure 1 Typical Feeder Diagram

Application to T'd Feeder or Mesh Corner:
Two auto-reclose relays would need to be specified for a double CB situation such as Teed feeders or Mesh Corner. One auto-reclose relay per CB. Each relay could be set to the same dead time i.e. 5 seconds, and priority of closing would be X1 then X2. X1's A/R In Progress output would be connected to X2's Block Reclose input which would reset the dead time of X2.

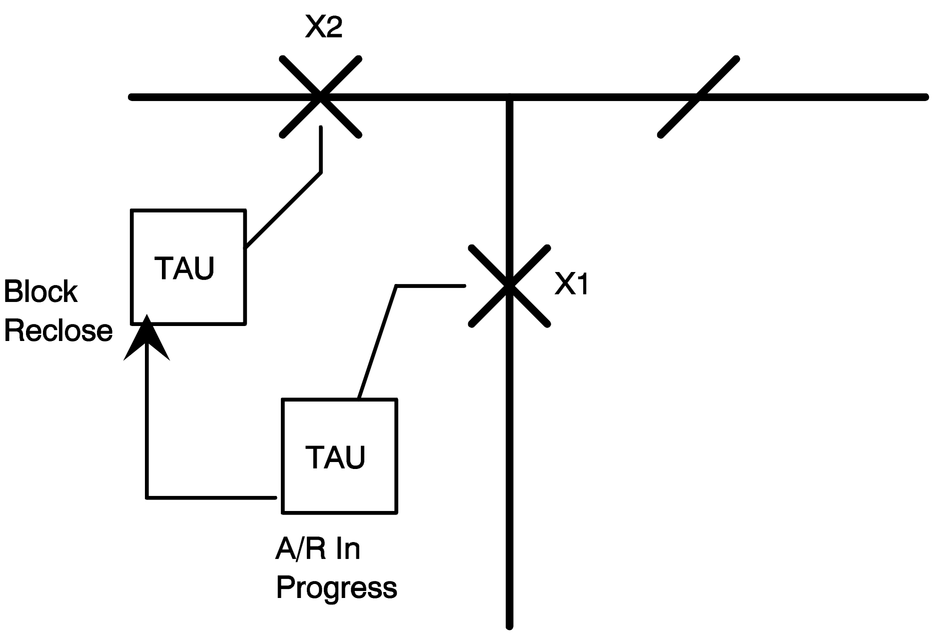

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Figure 2 Mesh or T'd Feeder Connection Diagram

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CB Status:
The status of the CB can be determined by a combination of connections. Either a full connection of CB Phase A Open, CB Phase B Open, CB Phase C Open and CB Phase A Closed, CB Phase B Closed, CB Phase C Closed. Or a simpler connection of only CB And Isolator Open, and CB And Isolator Closed, in this case the matrix has to account for phase A,B,C connected to the same input.

The CB Status module takes account of separate phase CB's (A, B and C). Due to differing applications of auto-reclose schemes and availability or non-availability of CB auxiliary contacts this module has been designed to return the state of each CB from a number of possible arrangements of contacts. To allow this flexibility there are a number of settings provided. The relay can determine CB open or closed from a combination of 'a' or 'b' or 'a' and 'b' contacts.
This means that the status input is processed to return the definitive CB condition.

Auxiliary type contacts 'a' - CLOSES WHEN CB CLOSES.

Auxiliary type contacts 'b' - CLOSES WHEN CB OPENS.

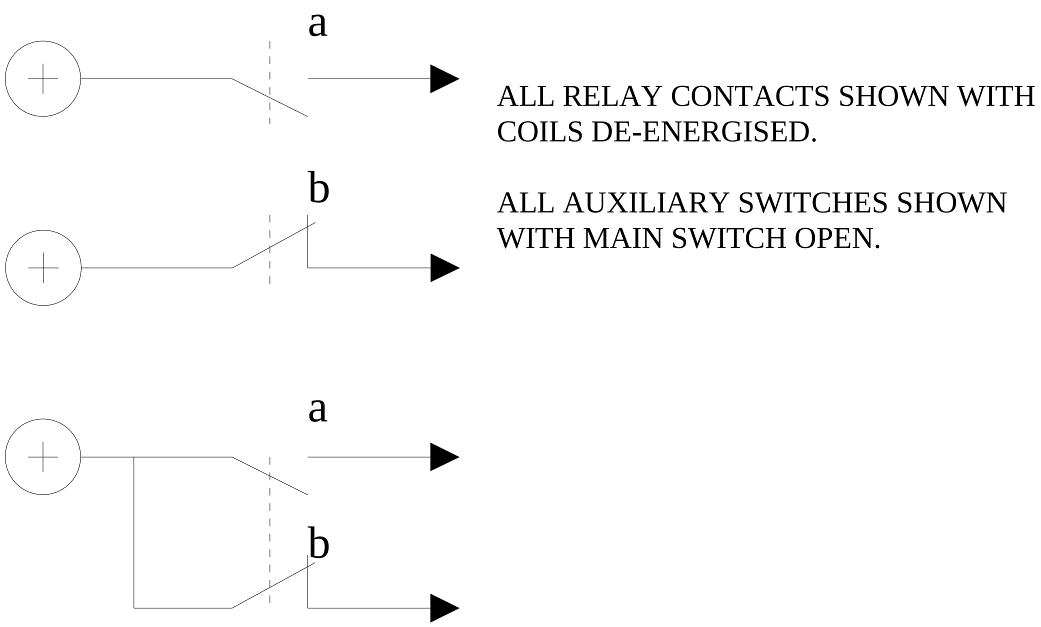

Fig 3. Primary Plant Auxiliary Switches

The relay provides a CB Auxiliary Switch setting which allows either 'a' type contacts only, or 'b' type contacts only, or both 'a' and 'b' contacts.

Using 'a' type contacts only: input is Auxiliary One Status Input
Open when CB open therefore input is low when CB is open.
Closed when CB closed therefore input is high when CB closed.

Using 'b' type contacts only: input is Auxiliary One Status Input
Open when CB closed therefore input is low when CB is closed.
Closed when CB open therefore input is high when CB open.

Using both 'a' and 'b' type contacts:
'a' contacts: input is Auxiliary One Status Input
Open when CB open therefore input is low when CB is open.
Closed when CB closed therefore input is high when CB closed.

'b' contacts: input is Auxiliary Two Status Input
Open when CB closed therefore input is low when CB is closed.
Closed when CB open therefore input is high when CB open.

When both 'a' and 'b' type contacts are used there are now 4 possible positions:

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Auxiliary One Status Input	**Auxiliary Two Status Input**	**CB Position**
FALSE	FALSE	Don't Believe It (DBI)
FALSE	TRUE	CB OPEN
TRUE	FALSE	CB CLOSED
TRUE	TRUE	INDETERMINATE

Table 1. CB Position using a + b Primary Plant Auxiliary Switches

When 'a' and 'b' contacts are used CB Open and CB Closed are determined from the following logic:
CBOpen = NOT Aux One AND Aux Two
CBClosed = Aux One AND NOT Aux Two

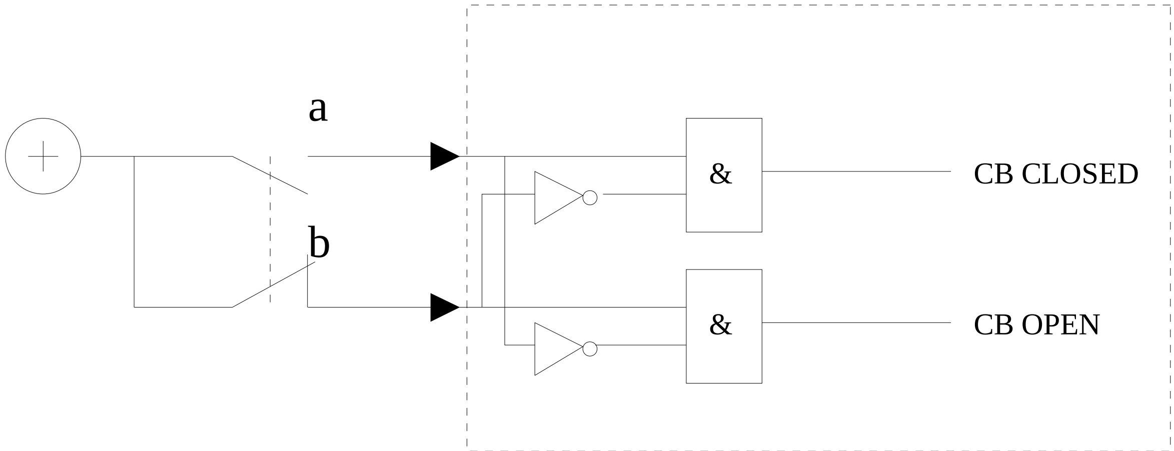

Fig 4. Processing of CB Closed and CB Open when using a + b Primary Plant Auxiliary Switches

It is intended that for application to Transmission systems separate phase CB Auxiliary contacts will be wired to the status inputs. This is essential for systems using Single Pole Reclose. However for systems which only apply Three Pole Reclose it is possible to gang the switches externally and wire to one status input only. To achieve this the following Trip Matrix settings need to be applied.

Status Input	S1	S2	S3	..	Sn
CB A Aux One	1	0	0	0	0
CB B Aux One	0	1	0	0	0
CB C Aux One	0	0	1	0	0

Table 2. Using separate phase CB Auxiliary contacts with Single Pole reclose, 3 inputs to the relay

Status Input	S1	S2	S3	..	Sn
CB A Aux One	1	0	0	0	0
CB B Aux One	1	0	0	0	0
CB C Aux One	1	0	0	0	0

Table 3. Using externally ganged separate phase CB Auxiliary contacts with Three Pole reclose, 1 input to the relay

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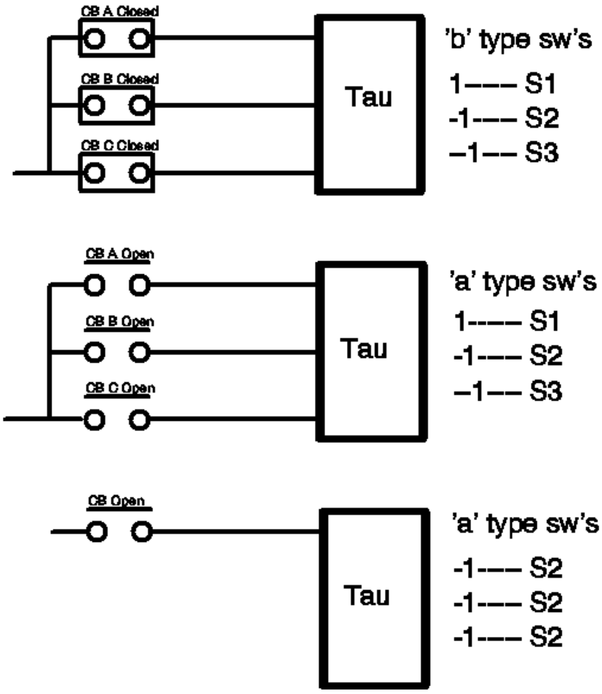

Figure 5 Possible CB Auxiliary Contact Connections

Output Alarms:
Various outputs are given during the auto-reclose sequence, these can be used for alarm purposes or to Lockout the sequence; or could be further divided into System Alarm/CB Alarm indication, or not used. If they are not used the output setting would be left blank.

Close Onto fault Inhibit: A trip or starter has picked-up within the close pulse. A trip within the close pulse is recognised and a Close Onto Fault output issued. This can be used to prevent auto-reclosing, i.e. independently wired to Lockout.

CB Counter: CB Maintenance is required, the number of CB Close counts since last maintenance has exceeded its alarm setting.

A/R Not Allowed: A trip has occurred but the CB is not in service. This indicates an alarm condition – auto-reclose is not allowed for a normally open or de-energised line.

CB Fail To Open: A combination of a Protection Trip and the CB auxiliary contacts indicating CB Closed after a settable time delay results in the alarm CB Fail To Open. This would be useful in auto-reclose applications where conventional CB Fail protection was not fitted. The CB Fail To Open output would be independently wired to Lockout and stop the auto-reclose sequence. Alternatively a time delay setting could be set which indicates CB Slow, and give an alarm if the CB is still closed after this setting.

Pole Discrepancy: A mismatch of CB positions across the three phases might indicate CB problems. Generally if one or two of the phases is indicating closed whilst the others are open, and vice versa, for longer than a time delay setting then an alarm will be issued.

This alarm can be used to Lockout the auto-reclose sequence. This is applied as a separate protection to single pole reclose schemes, and is sometimes quoted as requiring a separate supply to the main protection. Three Pole tripping schemes also use Pole Discrepancy. The function is easily integrated into the Auto-reclose relay and provides the same functionality. A requirement for Pole Discrepancy would be to connect all phases of CB Open or/and CB Closed to the relay.

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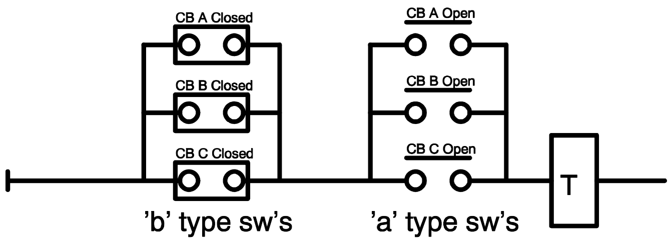

Figure 6 Standard Connection of Pole Discrepancy Protection

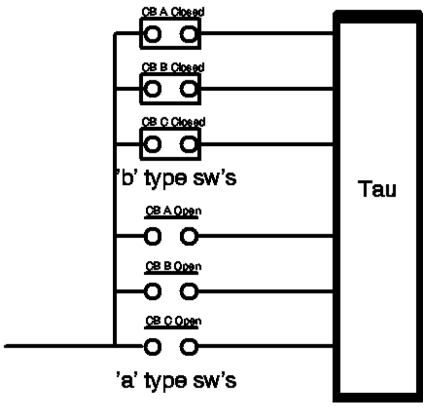

Figure 7 Connection of Pole Discrepancy

CB Fail To Close: At the end of the close pulse if the CB is open then the CB Fail To Close output is issued. Lockout will be established.

VT Alarm: An alarm indicates that there is a VT Failure. The Bus VT Fail alarm is generated when the relay detects a live line and CB Closed and dead bus for greater than 2 seconds. The Line VT alarm is generated when the relay detects a live bar and CB Closed and dead line for greater than 2 seconds. The relay cannot distinguish between a VT Fail on the system and the VT Fail in the relay, the VT Fail indication may mean either.

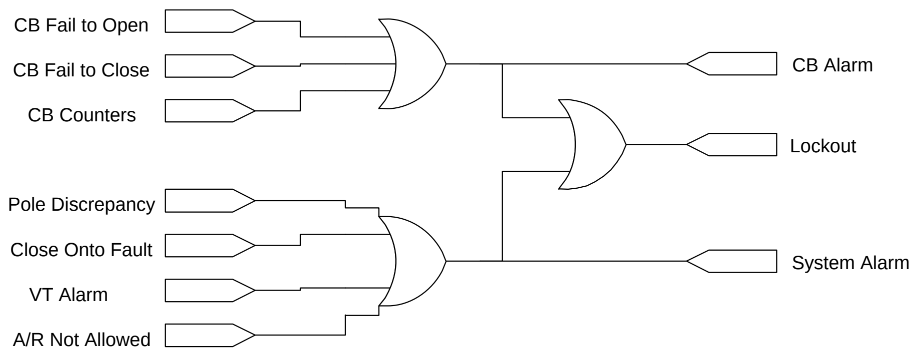

Figure 8 Possible A/R Alarms

10.4 Synchronising Modes

The relay operates in Check Sync (CS) mode until a system split occurs. After a system split the relay can be programmed to perform a number of actions. These can be Lockout, or set to close via Check Sync, System Sync (SS) or Close On Zero (COZ). The close can be automatic or via Manual Closing.

The check sync (CS) and system sync (SS) functions each have independent settings. If the requirement is for the relay to be set up as a check synchronising relay, then there are a number of ways of implementing this using the settings.

1. Set CS Phase, CS Slip Frequency and CS Timer to required settings.
   Set System Split Detector to OFF.
   Set A/R Split Action to Lockout. Or A/R Split Action to System Sync and set the System Sync setting to be identical to the Check Sync settings.

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Setting the split detector to off will ensure that the relay never goes into system synchronising mode even if a split in the power system occurs. The relay will continue to attempt a check sync close if the power system conditions fall within the relay setting parameters.

2. Set System Split Detector to a suitable angle e.g. 170°
   Set A/R Split Action to LOCKOUT

This will ensure that if the power system splits the relay will not go into system synchronising mode but revert to lockout mode.

3. Set A/R Split Action to LOCKOUT
   Set MC Split Action to System Sync

Lockout will be exited by a Manual Close at tighter angles.

Note : the relay settings groups could be used to switch between the different modes of the relay. The relay could be set up to be a check synchroniser in settings group 1 and a check and system synchronising relay in settings group 2. The group selection and thus the actual relay mode of operation could then be changed remotely using a status input signal or a communications command from a control system.

10.5 Manual Closing

Manual Closing can occur at any point. The decision to close the CB lies with the operator. Manual Closing overrides a Locked out auto-reclose sequence. The close decision is dependent upon the active CB condition: Dead Line, Dead Bus or Check Synchronisation.

The relay automatically closes dependent upon these conditions. The relay will not wait indefinitely for the system to come into sync. A Synch Close Delay is provided which governs the available time the relay will wait for an In Synch signal to appear. If the In Synch signal does not appear before the end of the Synch Close Delay timer the relay will Lockout.

A separate Manual Sync Override is provided.

10.6 Typical Voltage Settings

The relay can be connected to either single phase or 3 phase V.T's. It is usual, particularly in transmission networks, to use the output of the B (centre) phase V.T's for the reference line and bus voltages and thus the nominal voltage is 63.5 Vrms.

Note : the input measuring range actually measures upto 200 Vrms.

The relay undervoltage blocking elements, if enabled, can be used to block the close operation if either the incoming (line) or running (bus) volts fall below a certain percentage of rated voltage.

Typically, the undervoltage elements are set somewhere between 80% and 90% of rating.

Note : when using the undervoltage elements care should be taken to ensure that the reset of the element occurs at below the expected minimum operating voltage of the system. The undervoltage elements reset at <104% of the operate level. If the system is expected to run at less than the rated voltage the undervoltage element reset level must be set to operate at a value below this plus some margin for error.

e.g.

- for a phase to neutral connection nominally at 63.5 Vrms but which can run as low as 59 Vrms,

the undervoltage setting should be set no higher than 59 V – 1 V (error margin) = 58V x 96% = 55.68V (the actual setting would have to be 55.5V). This is equivalent to approximately 87% of rated voltage. If the setting is set higher than this then the element may never reset and will continuously block.

A differential voltage detector is incorporated and this, if enabled, blocks the synchronising function if the difference between the measured voltages is greater than the setting. This is used to prevent closing of the circuit breaker with a large voltage differential between the incoming (line) and running (bus) voltages, which could overstress the electrical systems. Typically, the differential voltage elements are set below 10% of rated voltage.

The relay Dead and Live voltage monitors are used along with corresponding internal logic to bypass the synchronising operation of the relay. Typically, anywhere above 80% to 90% of rating can be classed as a live line or live bus. The dead voltage monitors should be set to somewhere above the expected level of induced voltages on the line or bus. It should be noted that a dead line or bus can have a considerable potential induced

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onto it from a parallel line or capacitance across open breaker contacts. This potential can be as high as 30% of rated voltage.

10.7 Synchronising Override Logic

The synchronising override logic is provided to close immediately and not wait for the relay's synchronisation. Settings provide options for Dead Line and Live Bus closing, Live Line and Dead Bus closing. All of the possible combinations are shown below.

Check Sync Close Enabled/Disabled
Dead Line Close Enabled/Disabled
Dead Bar Close Enabled/Disabled
Sync Override
Manual Sync Override

10.8 Slip and Phase Angle Relationship

Slip frequency is defined as the difference between two frequencies. As two different frequencies 'slip' past each other large phase angle differences can ensue. Another way to calculate slip is to measure the phase difference between two waveforms and check that the phase angle change in a defined time period is less than a predetermined value. If F1 and F2 represent the frequencies of two systems then it can be shown that for check synchronising operation,

$$\Delta F = F1 - F2 = \frac{1}{Td} \times \frac{\theta}{180°}$$

where Td = time delay setting and θ = phase angle setting.
For system synchronising operation the following formula is used because in this mode the relay will only issue a close signal if the phase angle is decreasing in value. It will not issue a close if the phase angle is increasing in value.

$$\Delta F = F1 - F2 = \frac{1}{Td} \times \frac{\theta}{360°}$$

where Td = time delay setting and θ = phase angle setting.
The relay has both a frequency measuring element and phase detector and so can be set up to measure slip either directly or by the phase detector plus timer method. Use of either method is perfectly valid, as is use of both at the same time.

Note : if using both the slip frequency detector and the phase angle plus slip timer for a particular scheme then care has to be taken in setting selection. It is possible to set the relay up with an incorrect slip timer setting which will prevent the relay from issuing a valid close signal. For example if there is a high rate of slip on a system and the time delay setting has been set too long the incoming vector could pass through the valid close window too quickly and not allow the time delay to time out and give a valid output.

10.9 Check Synchronising Settings

The check synchronising operation of the relay is used mainly in switching operations which link two parts of a system which are weakly tied via other paths elsewhere in the system. In this synchronous system there should be no frequency difference across the breaker but large differences in phase angle and voltage magnitude may exist due to the line characteristics such as its length and type of loading.

For check synchronising the relay should be set to the maximum phase angle and maximum voltage differences which still permit the circuit breaker to close without causing large disturbances to the system. For most systems the phase angle should be set between 20° and 30°. There should not be any slip frequency but a setting of 50mHz is typically applied as a check against loss of synchronism.

Table 1 shows some possible check synchronising settings when using the phase detector plus time delay method.

Phase Angle Setting (θ)	Ideal Time Delay	Actual Timer Setting (Td)	Actual Slip Frequency (mHz)
10	1.11	1.1	50.505
15	1.67	1.7	49.020
20	2.22	2.2	50.505
25	2.78	2.8	49.603
30	3.33	3.3	50.505
35	3.89	3.9	49.858

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40	4.44	4.4	50.505
45	5.00	5.0	50.000

Table 4 - Typical Check Synchronising Settings

Alternatively, if the slip frequency detector is used and the slip timer turned OFF, a setting of 50mHz could be applied to the slip frequency detector directly to achieve the same ends.
Note : in check synchronising mode the valid phase window for closing is actually twice the phase angle setting value because the valid close can be given when the phase angle is either decreasing or increasing.

10.10 System Synchronising Settings

The system synchronising operation of the relay can automatically start if the two systems become asynchronous i.e. there are no ties between the two systems and one system is effectively ‘islanded’. If this situation occurs the frequencies will slip past each other and may cause the phase angle to come into the system split limits. The system split detector can be set anywhere from 90° to 175° and is typically set to 170°. This will start system synchronising automatically.

When there are high rates of slip between the two systems greater care is needed when closing the breaker and for this reason the system synchronising mode has independent settings from the check synchronising mode. The allowable phase angle close window is usually set much narrower than for check synchronising operation. Also the close decision from the relay is only given in the case of the phase angle decreasing. It will not issue a close if the phase angle is increasing in value. Typically the slip frequency will be set to a limit of 250mHz or less and the phase angle to 10° or 15°. Table 2 shows some possible system synchronising settings for limits of 100mHz and 250mHz respectively.

Phase Angle Setting (θ)	Ideal Time Delay	Actual Timer Setting (Td)	Actual Slip Frequency (mHz)
10	0.56	0.5	111.111
15	0.83	0.8	104.167
10	0.11	0.1	277.778
15	0.33	0.3	277.778

Table 5 - Typical System Synchronising Settings

Alternatively, if the slip frequency detector is used and the slip timer turned OFF, settings of 100mHz and 250mHz could be applied to the slip frequency detector directly to achieve the same ends.

10.11 Example Setting Calculations For Slip Timer

For check synchronising the relay can issue a valid close signal at any time while the incoming vector is within the phase angle setting range. If it gives the close signal at the boundary of the setting then the breaker will close with the phase angle outside of the setting limits. This is due to delays with the software timing loop issuing the close command, the output relay picking up and the actual breaker closing time delays. To reduce the risk of a late closure it is common practice to set the time delay setting (Td) to typically 10x the circuit breaker closing time. This will ensure that the breaker will close no later than 1.2x the actual phase angle setting of the relay.

Proof :

The change in phase angle between two waveforms is directly related to the frequency difference, or slip, between them. The change in phase angle $\Delta\theta$ for a system with 1Hz slip is 360° in 1 second. Thus,

Change in phase angle $\Delta\theta$ = (Slip x 360°) / sec.
The amount the phasor can travel during the breaker close time can therefore be given by,
$\Delta\theta$ = Slip x 360° x tc - where tc is the breaker close time.

Using the equation given in section 2.7 for check synchronising,

$$\text{Slip} = \frac{1}{\text{Td}} \times \frac{\theta}{180^\circ}$$ and substituting this into $\Delta\theta$ = Slip x 360° x tc gives the following,

$$\Delta\theta = \frac{1}{\text{Td}} \times \frac{\theta}{180^\circ} \times 360^\circ \times \text{tc};$$

It was stated that the slip timer setting Td should be set to 10x the breaker closing time tc.
Substituting for this in the above equation gives,

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$\Delta\theta = (2 \times \theta) / 10$ or $\Delta\theta = 0.2 \times \theta$

Thus for a time delay (Td) of 10x breaker closing time (tc) the actual change in phase angle will be 20% of the phase angle setting. The maximum closing angle will be 120% of phase angle setting.

In practice the relay operating times need to be taken into consideration. A typical example now follows :

- Maximum allowed phase angle for closure = 30°.

- Circuit breaker closure time = 150ms.

- Maximum relay delays – S/W loop + Output relay delays = 5ms + 7ms = 12ms.

Therefore slip timer time delay should be set to 10x (150ms + 12ms) = 1.62sec.
The phase angle setting should be set to 80% of the maximum allowable closing angle which is 24°.

If the relay was to issue a close right on the boundary of 24° then the breaker will definitely not close outside of 30°.

With an angle of 24° and Td of 1.62sec, using the equation from section 2.7, the slip is therefore
24 / (1.62 x 180) = 82mHz. If the relay were to close on the boundary the phase angle traversed in the 162ms total delay time is given by,

$\Delta\theta$ = Slip x 360° x (tc + trelay) = 0.082 x 360 x 0.162 = 4.78°.

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11 Commissioning

11.1 Required Test Equipment

The following additional equipment will be required to commission the auto-reclose and check synch functions on the relay.

- Two variable A.C. voltage sources with a means of varying the phase relationship between them e.g. phase shifting transformer. Ideally, a portable relay test set e.g. Doble, Omicron etc.
- Time interval meter.
- 2 A.C. Voltmeters.
- Phase angle meter.

11.2 Inspection

Check that the relay has not been damaged in any way since being installed into the panel. Check that the serial numbers of the relay, the case and the relay cover are all identical. Check also that the relay is the correct model and that the rating is correct.
Ensure that all connections are tight and in accordance with the relay wiring diagram or the scheme diagram. Check that all the modules are fully connected and inserted. Ensure that the relay case is solidly bonded to a local earth point by checking the earthing connection to the case.

11.3 Applying Settings

Before applying settings to the relay the engineers should take time out to familiarise themselves with the relay's menu system. Section 1 and section 3 of this manual are helpful in this respect. 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.

Settings can be entered into the relay using the keypad on the front of the relay or they can be sent to the relay, from a file, using a portable PC and Reydisp Evolution software package.

In applications where more than one setting group is to be used then it may be necessary to test the relay in more than one configuration.

Note : when using setting 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 setting group" on which the relay operates and an "edit/view setting group" which allows the settings in one group to be viewed and altered while protection continues to operate on a different unaffected group. The "active setting group" and the "edit setting group" are selected in the "System Configuration Menu".

11.4 Precautions

Before testing commences the relay should be isolated from the voltage transformers in line with the local site procedures. The closing and alarm circuits should also be isolated where practical. Ensure that the correct d.c. auxiliary voltage is applied to the circuit. See the relevant scheme diagrams for the relay connections.

12 Tests

12.1 Commissioning Tests

Select the required relay configuration and settings for the application.

12.1.1 Measurement Tests

Apply A.C. volts to both of the voltage input circuits of the relay using the A.C. variable voltage sources or portable relay test set. The relay should display the correct value of voltage $\pm$ 5% which is the tolerance of the measurement display meters. The instruments mode 'Line RMS' and 'Bus RMS' meters display the secondary voltage levels.

The applied A.C. volts can be in the range of 5 – 200Vrms. Nominal volts of 63.5V.

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12.1.2 Scheme Tests

It is not necessary to perform tests on all internal elements of the relay. If the settings have been checked, the external wiring checked, the status inputs and output relays verified and the relay measures satisfactorily then the relay can be deemed to be working to its design requirements. It will operate correctly, to the performance claims, and its operation under all service conditions is guaranteed.

However, if added confidence is required, then the following elements can be checked. Note that the relay should be commissioned with the actual settings calculated for the particular scheme.
Auto-reclose schemes vary between different utilities. Some of the functions such as Block Reclose are used differently. Therefore it is important that tests are carried out with relevance to the engineered scheme.

The purpose of these tests is to confirm the correct operation of the status and control inputs. Some of the tests will require the application of voltage.

In order to ensure that all operations proceed correctly, the following should be observed:

- A working circuit breaker, complete with auxiliary supplies, should be connected to the relay, if possible; if not, then an electronic circuit simulating the circuit breaker operation may be used instead. See Appendix 2. If this is not available a switch may suffice, care will be required with settings. Or alternatively the test equipment may provide a CB control circuit.

- Throughout the tests, a close pulse length should be selected which is suitable for the circuit breaker or simulation circuit, given that the CB closing operation must be complete, before the close pulse is removed by the relay.

-

To facilitate ease of commissioning a meter is included in the instruments which shows what state the auto-reclose sequence has reached. The states are as follows:

StartUpLockout: Temporarily displayed after power on.

AROutOfService: When the relay is switched Out Of Service either at start up or from the idle state.

InServiceLockout: When switching IN from Out Of Service there is a temporary switch in lockout.

Idle: quiescent state, waiting for an auto-reclose sequence to begin.

Lockout: Lockout state. No Auto-reclosing allowed.

The Auto-reclose sequence is performed with the following states:
SequenceInProgress: AR Start. A trip has occurred and the CB was in service whilst in idle. Will wait for AR Primed conditions: CB Open AND Trip reset AND Dead Line.

SecDead timeInitiate: A trip within the first close pulse or first reclaim and a second reclose is allowed. Will wait for AR Primed conditions: CB Open AND Trip reset AND Dead Line.

SingleFirstDead time, ThreeFirstDead time, SingleSecDead time, ThreeSecondDead time: The auto-reclose dead time.

FirstCloseInhibit, SecondCloseInhibit: At the end of the dead time if waiting for synchronisation or Block Reclose to reset then will be in this state.

FirstClosePulse, SecondClosePulse: The Close Pulse is being issued.

FirstReclaim, SecondReclaim: checking for correct reclose.

The Manual Closing sequence is performed with the following states:

ManualClose: Wait for correct close conditions, i.e. synchronisation.

ManualClosePulse: The Close Pulse is being issued.

ManualReclaim: checking for correct close.

After receiving the relay the default position is Out Of Service, therefore at power up the meter will display StartUpLockout to AROutOfService.

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With the state displaying AROutOfService an A/R IN signal is required to switch in the relay. The meter will then display InServiceLockout to Idle. There should be a 4 second delay while the relay is temporarily in Lockout.

Idle is the quiescent state when waiting for an auto-reclose sequence to begin. This should be the initial displayed state when performing the majority of the tests.

12.1.3 Phase Angle Tests

The CS Phase Angle detector and the SS Phase Angle detector can be tested in the following way:

Apply nominal volts to both the line and bus input terminals of the relay. On initial turn on, the relay will start in check synchronising mode. If the voltage vectors are displaced by an amount greater than the CS Phase Angle setting but not as much as the System Split Detector angle then the relay will stay in check synchronising mode. Using the instruments display, locate the Phase Angle instrument as shown below:

Phase Angle 0.0°

Check the Check Sync Angle setting in the SYNC MENU. Assign an unused LED to indicate In Sync i.e. L = 16. At switch on, the relay has a 2sec. delay before In Sync is issued, but if voltages are continuously applied and only the phase angle changed the In Sync LED can then be used to check pick-up and drop-off of the Check Sync function.

Apply voltage, after 2 sec the LED will come on, Slowly increase the phase angle past the setting so that the LED goes out. Slowly bring in the phase angle and check the pick up. Then slowly increase the phase angle and check the drop off.

The pick up and drop off values should fall within the performance claims.

Repeat for opposite angles.

Note : the phase angle should be adjusted slowly so that the LCD has time to update. The instrument has a delay on updating.

This test should be repeated for the system synchronising settings. This is best carried out by increasing the phase angle until a split occurs and then bringing the angles in. The split will cause the relay to go into system synchronising mode.

The results can be put into Table 1 at the back of this section.

12.1.4 Slip Frequency Tests

The CS Slip Frequency detector and SS Slip Frequency detector elements are more difficult to test and require variable frequency sources. A portable relay test set is ideal for this.
Depending on the relay scheme settings it may be difficult to test the CS and SS slip frequency elements independently without adjusting the settings.

To test the CS Slip Frequency element turn the Split Angle to OFF. This will ensure that a split does not happen and the relay is in check sync mode. Increase the frequency slip to a value outside of the slip frequency limits and then slowly reduce it until the element picks up. This will be indicated on the same LED as above. Gradually increase the slip until the element drops off as indicated. Record the results in Table 2.

To test the SS Slip Frequency element turn the Split Angle back to the value required for the scheme. System Sync only occurs after a system split. Turn CS Slip Frequency element to OFF. Increase the phase angle until a split occurs and then repeat the above tests. Record the results in Table 2.

Note : remember to return all settings back to the original scheme settings if they have had to be changed.

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12.1.5 Timer Tests

The Check Sync Timer and System Sync Timer can be tested by setting the angle between the two voltages to a value outside of the phase angle settings. Reduce the phase angle to zero and the output should not close until after the timer has timed out.

In practice however, the timers are difficult to test without specialist test equipment and test software. There are three recommended methods:

1. Apply in phase nominal volts to the relay. The relay will issue a close only after the timer has timed out. Note, however, that the relay has a start-up timer of 2sec. which is the minimum time before an output is given. This start-up timer effectively runs in parallel with the timer. If for example a Check Sync Time of 2.0sec has been selected then the time for close will be 2.0sec. If however, 0.5sec has been selected then the time for close will be 2.0sec.

2. Apply in phase volts to the relay at a level below the undervoltage blocking element level. The relay will time through the start-up timer. If the volts are then increased to nominal then the relay will close after the set slip time. If 0.5sec has been selected then the relay will close after 0.5sec.
   All results should fall within the performance claims given in Section 2 - Performance Specification.

3. Using Reydisp Evolution software the event records will give accurate times for all of the timing events within the relay. The following events were extracted from a relay which had the Check Sync Timer set to 1.0 sec. When the phase angle moved inside the close window the actual close output was given after a time of 1.005 seconds.

09:08:43.020 , 21/02/00 Rey Raised In Sync
09:08:44.025 , 21/02/00 IEC Raised CB 'on' by AR

12.1.6 Voltage Detectors

Check the pick up and drop off levels for the voltage detector elements. Individually ramp up and down the line and bus volts and examine a Live Line / Live Bus LED indication to see where the elements actually operate. Record the results in Table 4.

12.1.7 Undervoltage Elements

Check the pick up and drop off levels for both the line undervoltage and bus undervoltage blocking elements. The In Sync indication is derived from In Phase AND No Slip AND No Differential AND Not Undervolts. Apply voltage from the same source to the Line and Bus inputs, decrease the voltage until the In Sync LED goes out, then increase the voltage until the LED comes back on. It is better to set the Check Sync timer to zero for this test. Separate results for the Line and Bus can be recorded by varying the Undervolts settings. Record the results in Table 4.

12.1.8 Differential Voltage Elements

Check the pick up and drop off levels for the differential voltage blocking element. Apply different voltages to the Line and Bus. Keep the voltages in phase and no slip and above the undervoltage levels. The In Sync LED will go out when the Voltage Differential setting goes above the setting. Record the results in Table 4.
All results should fall within the performance claims given in the Performance Specification.

12.1.9 A/R In/Out Switching

The relay can be switched out at any point. The commissioning to confirm the action of the In/Out switching mechanism requires a full understanding of how this function works. A/R Out has priority over A/R In. This function can be used as an Auto-reclose Inhibit.

Energise A/R Out and check for A/R Out of Service indication. Check in the instruments mode that Auto-reclose State displays AROutOfService.

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Energise A/R In and not A/R Out, the relay should then go back to indicate A/R In Service. Whilst performing the test check in the instruments mode that the Auto-reclose State progresses from displaying AROutOfService to InServiceLockout to Idle.

With both A/R In and A/R Out energised the relay should indicate A/R Out of Service.
There is a temporary 4 second Lockout whilst the relay is switched back into service.
During an auto-reclose sequence if A/R Out is asserted the relay will go to Lockout. Whilst in Lockout an A/R In is required before Lockout can be exited.

12.1.10 CB Status

The CB Status should be checked before any other input as correct operation of the auto-reclose sequence relies upon the state of the circuit breaker being received correctly from the auxiliary contact circuit. Various connections can be used, as described in the Applications Guide.
There are separate signals provided for each phase:

CB A Open, CB B Open, CB C Open.

CB A Closed, CB B Closed, CB C Closed.

CB A indeterminate, CB B Indeterminate, CB C Indeterminate.

Ensure that with the circuit breaker in the open position, the CB Open (appropriate CB Aux input) status input is enabled. Check that with the CB in the open position, the CB Open LED is lit.
Ensure that with the circuit breaker in the closed position, the CB Closed (appropriate CB Aux input) status input is enabled. Check that with the CB in the closed position, the CB Closed LED is lit. Operate the CB manually, and ensure that it is in the closed position. Check that the CB Closed LED is lit.

The indication if the CB is Open and Closed, or not Open and not Closed is a separate CB Indeterminate LED and output for this.

12.1.11 CB In Service

With the CB Status correctly commissioned the CB In Service is not required to be checked. However the test is explained below:

To prevent unwanted auto-recloses a CB In Service feature is provided which only allows auto-reclosing to start provided the CB was in the closed position prior to a trip input being received. For the relay with Check Synchronisation the CB in Service feature includes CB Closed and Live Line. This is classified as the CB Memory and has a 2 second delayed drop off.
To facilitate commissioning the logic outputs from this function are mapped to the LED menu: CB Not In Service Alarm (which is at the end of the 2 sec delayed drop-off) and CB Memory.

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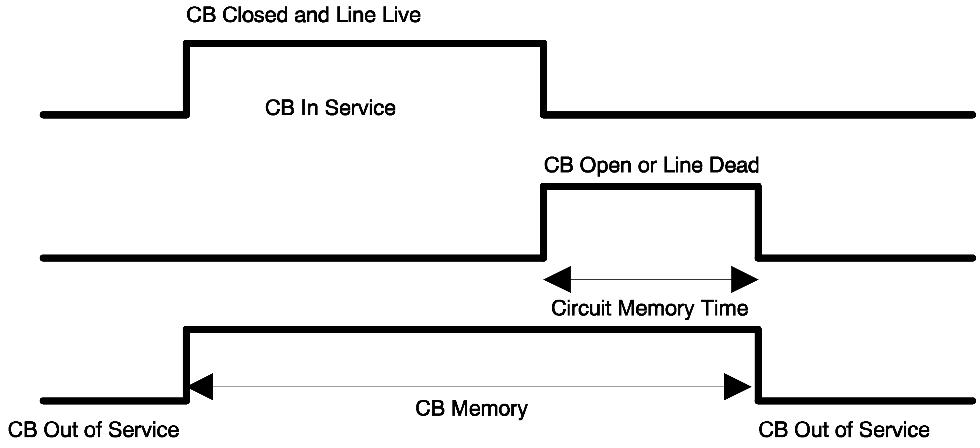

Figure 1 CB In Service

Map the CB Memory and CB Not In Service Alarm to LEDs. Manually close the CB and energise the line voltage, CB Memory should be lit. De-energise either the line or open the CB (manually open the CB), the CB Memory should reset after a 2 second delay and the CB Not In Service Alarm should be lit.

12.1.12 Trip and Auto-reclose

Ensure that the CB is closed, and voltage is applied to both the line and bus VTs. Operate the trip status input whilst CB Memory is lit, A/R In Progress should light.

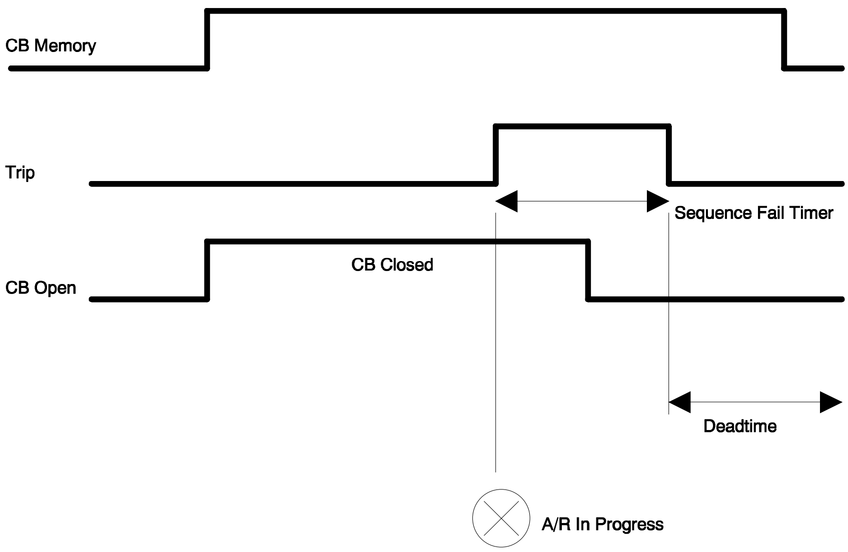

Figure 2 Trip And Auto-reclose

If a trip input occurs and CB Memory is not lit then an A/R Not Allowed indication is raised. This may be connected to cause the relay to go to Lockout, check scheme details to determine whether this needs testing. The dead time is started when the CB opens and the trip resets. There is a timer Sequence Fail Timer provided which can be set to go to Lockout if either the CB does not open or the trip fails to reset within the set time. This is provided to prevent the auto-reclose sequence being primed indefinitely; or the Sequence Fail timer can be set to OFF.

Assuming the trip operation to be successful, the close pulse will be issued after the first dead time setting – close the CB during the close pulse, followed by a reclaim period, before the relay returns to an idle condition, and indicates Successful Close.

If the CB is not closed during the close pulse the relay will indicate Lockout and CB Failed To Close.

12.1.13 Measurement of Auto-reclose Time Delays

All of the time delays are proven by software testing. The auto-reclose time delays may be measured to give added confidence. The measurements may be recorded using Reydisp.

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Measure the Sequence Fail Timer (if applied) – Set the Sequence Fail timer to greater than the trip reset time, say 60 seconds. With CB Memory lit, energise a trip signal (start the timer), stop the timer when lockout is issued.

Measure the Dead time time delay – To measure the dead time the correct sequence of events must occur: Set Start Dead time to Trip Reset. With CB Memory lit, energise a trip signal, then open the CB, de-energise the line, remove the trip signal (start the timer). Stop the timer when the Close Pulse is issued. The Close Pulse will be issued if the line is de-energised and the setting Dead Line Close is selected to Enabled.

Measure the Close Pulse – measure the duration of the close pulse which should correspond to the setting.

Measure the Reclaim time - Start at the end of the close pulse, stop when Successful Close is issued, provided the CB has closed.

Measure the Sync Close Delay (if applied) – apply Dead Line Close = Disabled, Dead Bar Close = Disabled, Check Sync Close = Enabled. Start the dead time but do not reapply voltage, the system will wait for as long as the dead time + Sync Close Delay before going to Lockout.
Measure the Persistent Intertrip Timer (if applied) – Energise the Intertrip Receive status input (start timer). Keep energised until Lockout is issued (stop timer).

The time delays for the Start Up Lockout Timer, In Service Lockout Timer, Minimum Lockout Timer and Lockout Delayed Drop Off Timer are set within the relay and are not adjustable, they are therefore not required to be tested.

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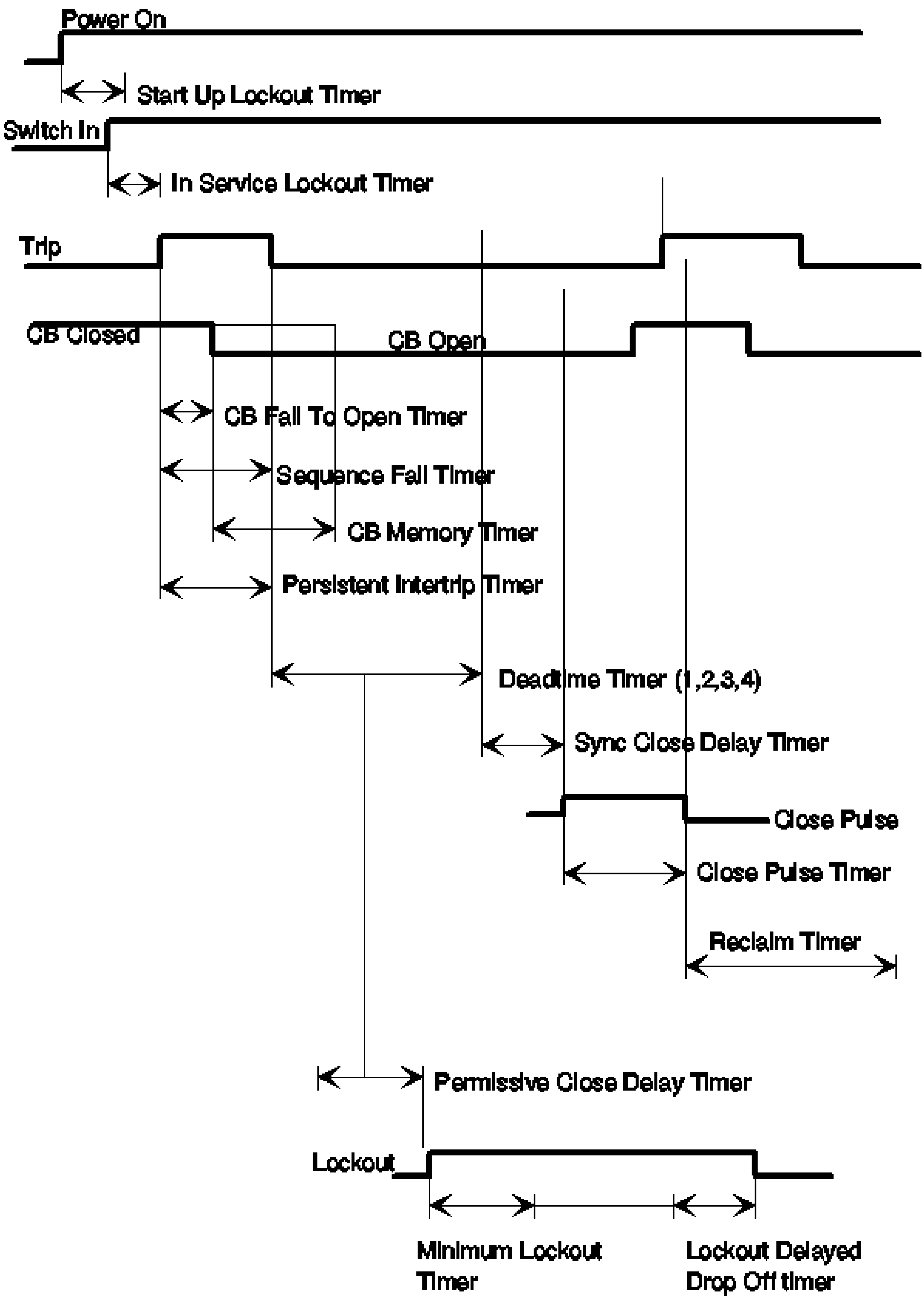

Figure 3 Auto-reclose Timers

12.1.14 Reclose Lockout

The auto-reclose sequence can be locked out at any point in the sequence provided that the A/R is In Service. Ensure that the relay is In Service, energise the Reclose Lockout status input, confirm that the relay indicates Lockout.

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12.1.15 Manual Close

Manual Closing can occur at any point. This mimics a hard-wired close command to the circuit breaker.
With the circuit breaker closed. Operate the Manual Close input and ensure that no close pulse is issued.
Manually trip the circuit breaker. Operate the Manual Close input, and ensure that a close pulse of the programmed time is issued.

12.1.16 System Closing Conditions

The test for Dead Line Closing, Dead Bar Closing or Check Sync Closing is different dependent upon whether it is a Manual Close or Auto-reclose.
There are three settings associated with the circuit breaker's three pole closing conditions:

Dead Line Close Enabled/Disabled.

Dead Bar Close Enabled/Disabled.

Check Sync Close Enabled/Disabled.

The order at which these are checked is Dead Line then Dead Bar then Check Sync. However Check Synch has priority.

These settings are only relevant to Three Pole auto-reclosing. Single Pole Auto-reclosing does not check these settings. Also, when a Manual Close is issued the relay does not check these settings, the relay just checks the state of the system.
To test for the Manual Close conditions:

Manually open the circuit breakers. Apply voltage to indicate Live Bar and issue a Manual Close. The relay should issue a close pulse and a Dead Line Close Flag.
Manually open the circuit breakers. Apply voltage to indicate Live Line and issue a Manual Close. The relay should issue a close pulse and a Dead Bus Close Flag.

Manually open the circuit breakers. Apply voltage to indicate Live Line and Live Bar and issue a Manual Close. The relay should issue a close pulse and a Sync In Progress Flag.

To test for the three pole auto-reclosing conditions:
Dead Line Closing - Ensure that the circuit breaker is closed. Select Dead Line Close = Enabled in the A/R MENU. For an auto-reclosing sequence to start, the CB must be closed and the line live. Issue a 3P trip input and then open all the circuit breakers, switch off the line voltage. Keep the line voltage off to simulate a dead line close. After the first dead time the close pulse should be issued together with a Dead Line Close Flag.

Dead Bar Closing - Ensure that the circuit breaker is closed. Select Dead Bar Close = Enabled and Dead Line Close = Disabled in the A/R MENU. For an auto-reclosing sequence to start, the CB must be closed and the line live. Issue a 3P trip input and then open all the circuit breakers, switch off the line voltage. Keep the line voltage and bar voltage off to simulate a dead bar close. After the first dead time the close pulse should be issued together with a Dead Bus Close Flag.

There are two instances where closing can be performed by Sync Check. These are either at the end of the dead time when the system will wait for as long as the Sync Close Delay; Or during the dead time when the system comes into synchronisation and Check Sync Close is allowed. For the latter the dead time will be bypassed and the close pulse issued directly. To test for both of these:
Check Sync Closing at end of dead time - Ensure that the circuit breaker is closed. Select Dead Bar Close = Disabled and Dead Line Close = Disabled and Check Sync Close = Enabled in the A/R MENU.

For an auto-reclosing sequence to start, the CB must be closed and the line live. Issue a 3P trip input and then open all the circuit breakers, switch off the line voltage. Keep the bar voltage live. At the end of the dead time switch on the line voltage and bring the line and bar volts into synchronism. The close pulse should be issued together with a Sync In Progress Flag.

Check Sync Closing during the dead time - Ensure that the circuit breaker is closed. Select Dead Bar Close = Disabled and Dead Line Close = Disabled and Check Sync Close = Enabled in the A/R MENU. For an auto-reclosing sequence to start, the CB must be closed and the line live. Issue a 3P trip input and then open all the circuit breakers, switch off the line voltage. Keep the bar voltage live. During the dead time switch on the line voltage and bring the line and bar volts into synchronism. A suitably long dead time should be set. The close pulse should be issued together with a Sync In Progress Flag.

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To test for single pole auto-reclosing:

Ensure that the circuit breaker is closed. Select Close Mode Selection = 1P/3P in the A/R MENU. For an auto-reclosing sequence to start, the CB must be closed and the line live. Issue an A Phase trip input and then open the A Phase circuit breaker. Keep the line voltage on to simulate a single pole open. After the first 1P dead time the close pulse should be issued together with a 1Pole Close Flag. Repeat for other phases.

12.1.17 Multi-shot Auto-reclose sequence

The relay can be programmed to perform a number of auto-reclose shots.
The setting Close Mode Selection controls the number of closes.

13 Putting Into Service

After tests have been performed satisfactorily the relay should be put back into service as follows:

- Remove all test connections
- Where possible, the relay settings should be downloaded to a computer and a printout of the settings obtained. This should then be compared against the required settings. It is important that the correct settings group is active, if more than one group has been programmed.
- Replace all fuses and links.

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14 APPENDIX 1 – Test Tables

Table 1 – Phase Angle Tests

		Positive angle		Negative angle	
Phase Element	Phase Setting (Degrees)	Pick Up (Degrees)	Drop Off (Degrees)	Pick Up (Degrees)	Drop Off (Degrees)
CS Phase Angle					
SS Phase Angle					

Table 2 – Slip Frequency Tests

		Positive Slip		Negative Slip	
Slip Element	Slip Setting (Hz)	Pick Up (Hz)	Drop Off (Hz)	Pick Up (Hz)	Drop Off (Hz)
CS Slip Freq.					
SS Slip Freq.					

Table 3 – Timer Tests

Timer Type	Timer Setting (sec)	Actual Time (sec)
CS Timer		
SS Timer		

Table 4 – Voltage Element Tests

	Live Level			Dead Level		
Voltage Detector	Setting (V)	Pick Up (V)	Drop Off (V)	Setting (V)	Pick Up (V)	Drop Off (V)
Line						
Bus						

Voltage Element	Setting (V)	Pick Up (V)	Drop Off (V)
Line Undervoltage			
Bus Undervoltage			
Differential Element			

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15 APPENDIX 2 - Circuit Breaker Simulation Circuit

This appendix describes the circuit used to simulate circuit breaker operation during the development of the relay, enabling the relay to be tested in isolation from a full working circuit breaker.

The circuit consisted of a two coil, magnetic latching bi-stable relay, which operated form trip and close signals. The latching relay was used to drive a 5 volt, 8mm relay, with double pole, changeover contacts. These contacts were then used as follows:

a) One pair of normally closed contacts was used to drive the CB OPEN status input of the relay to provide circuit breaker position information for the trip and close operation tests.
b) One pair of normally open contacts was used to simulate the circuit breaker main contacts.
c)

The circuit used is shown in figure A1 below. Any suitable latching relay could be used. Alternatively, two 8mm relays connected as in figure A2 could be used in place of the magnetic latching relay.

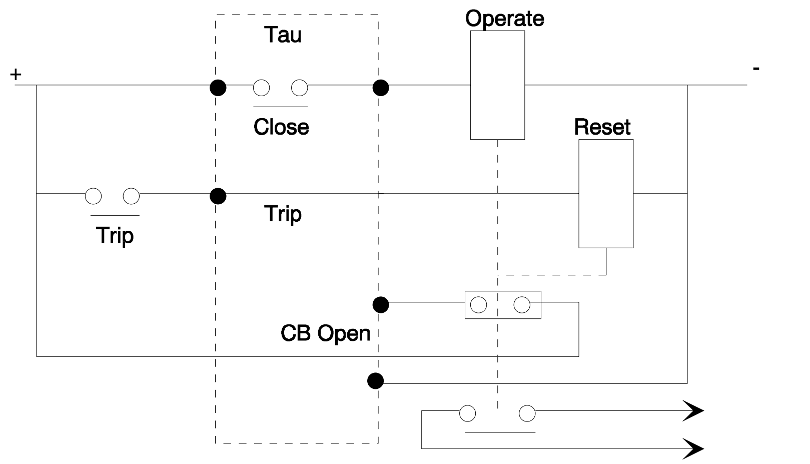

Figure A1

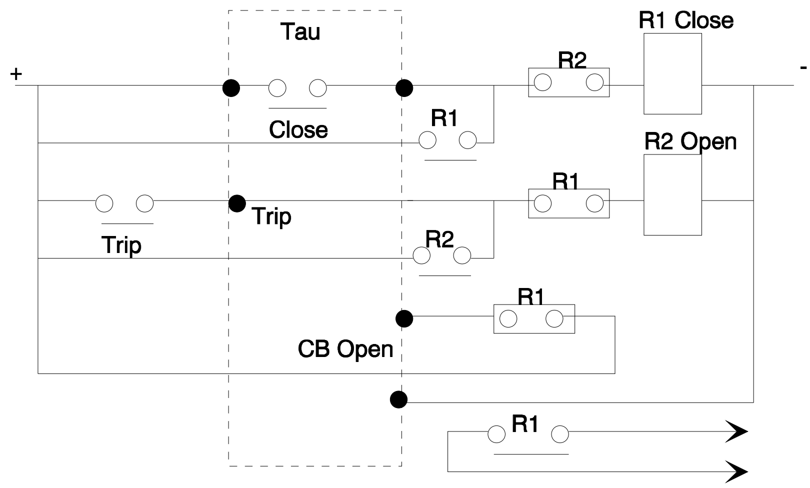

Figure A2

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Distance Protection Relays

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

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Contents

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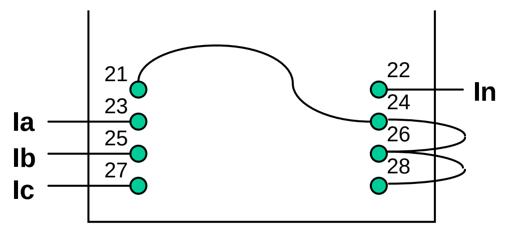
1 Directional Earth Fault Protection

1.1 Applications

Very high resistance earth faults present difficulties to impedance measuring elements since the resistive coverage required can often extend beyond the apparent impedance presented by maximum load conditions. In those cases a directional earth fault element can be used to supplement the basic distance protection.



Connection of residual current input

The design of the directional earth fault element is based on similar techniques as used for impedance measurement. The element is voltage polarised deriving this by summating the three phase to neutral voltages available in the relay. The zero sequence current providing the other input is derived from the fourth C.T. input which must be connected as indicated.

1.2 DEF Operation.

1.2.1 DEF Direction and Characteristic Angle.

The directionality of the relay can be set to either forward or reverse. With the relay set to forward operation will occur for fault current occurring within the forward operating zone. With the relay set to reverse operation will occur for fault current occurring within the reverse operating zone.

The DEF Char Angle setting represents the maximum torque angle of the directional relay. Operation will occur for angles in the range +-85 of this setting. This should be set to the zero sequence impedance angle of the protected feeder.

1.2.2 DEF Current Setting.

This is the level of residual current at which the DEF element picks up.

1.2.3 DEF Time Delay.

This setting provides a time delay on pick-up which is applied to an Aided DEF trip (in DEF POR mode), or Direct DEF trip (in DEF direct mode).

1.2.4 DEF & Single Pole Tripping (Some models only)

When a single pole trip occurs, the unbalance in the system can cause operation of the DEF element. Thus, during a single pole trip, the relay will inhibit operation of its DEF elements. This feature is enabled by default, but can be disabled using the *DEF Pole Open Block* setting.

1.2.5 The DEF Protection Outputs

The *DEF Protection* output operates for any DEF Operation (aided or back-up), and the *DEF Aided Trip* output will only operate for an aided DEF trip.

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DEF Schemes
There are two active schemes for the relay.

1.2.6 DEF Direct Trip

In the *DEF Direct Trip* mode, the relay will trip on detecting an earth fault in the set direction. It is very difficult to grade a DTL overcurrent element on current, so this mode is intended for used mainly to simplify commissioning. This allows easy testing of pickup time delays, etc.

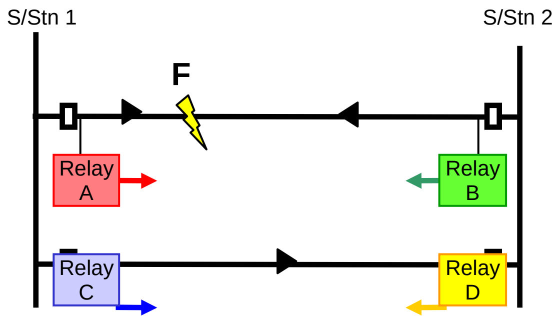
1.2.7 DEF POR

The other DEF scheme is *DEF POR* (permissive overreach). This is designed to be used in conjunction with a signalling channel. When the DEF element operates it sends a permissive signal, using the output contact assigned as *Signal Send 2,* to the remote end. In order to trip instantaneously on DEF the relay must detect a DEF and have received a signal to Status Input *Signal Receive 2* from the remote end. Obviously if the relays at both ends of the line detect a fault in the forward direction, the fault must be within the line section, and tripping should be carried out as quickly as possible. Also the relay will carry out a DEF back-up trip after a time delay known as the *DEF Back-up Trip Time*.

Additional logic is included within the DEF Scheme to ensure correct operation of the relay.

1.2.7.1 Current Reversal Guard

A current reversal guard is included to prevent incorrect tripping on parallel feeders.
Consider a fault at Point F on the parallel line system shown below:



Both Relay A and Relay B will detect earth fault current in the forward direction. Both DEF elements will operate, permissive signals will be sent by both relays, and when these signals are received, Relays A and B will carry out a *DEF Aided Trip*, isolating the fault.
Observing the direction of current flow, Relay C will also detect earth fault current in the forward direction, and send a permissive signal to the remote end (Relay D). Relay D will detect earth fault current in the reverse direction, and will not operate when the permissive signal is received from Relay C.
Now consider a situation, where the circuit breaker controlled by Relay B operates slightly before the circuit breaker at A.
The direction of current seen by relays C and D will change, so Relay C will detect earth fault current in the reverse direction, and relay D will detect earth fault current in the forward direction.
Under these circumstances, there is a “race condition” between the drop off of the *Signal Send 2* output from relay C and the operation of the forward DEF element at relay D.
If the DEF element at D operates before the Signal Send 2 from Relay C drops off, Relay D may mal-trip.

Thus, if the Circuit Breaker is closed, and the relay detects fault current in the reverse direction, the Current Reversal Guard logic is started. If the relay then detects a forward DEF it will enforce a time delay (the *DEF Current Reversal Reset*) on the DEF Aided Trip to allow the remote end Signal Send 2 element to drop off.

1.2.7.2 CB Echo

The DEF POR scheme relies upon relays at both ends of the line detecting the fault. With the circuit breaker at one end of the line open, the DEF element at one end cannot operate. Thus no permissive signal can be sent, so the fault would not be cleared until after the *DEF Back-up Trip Delay* for an in-zone fault.

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Thus, if the local Circuit Breaker is open AND a permissive signal is received from the remote end, the relay will send (or “echo”) a permissive signal back to the remote end. The duration of this permissive signal is set as the *POR CB Echo Pulse Width*

1.2.7.3 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. Thus, 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 present (DEF WI RES OV LEVEL), AND the local CB is closed, the relay will carry out a “Weak Infeed” Trip, and send a permissive signal to the remote end allowing it to carry out a carrier aided trip, also.

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2 Relay Settings

Directional Earth Fault	Disable, **Enable**
DEF Scheme	Def Direct Trip / Def Por
DEF Char Angle	-15..95 **(80 º)**
DEF Weak Infeed Trip	**Disable**, Enable
DEF Pole Open Block	Disable, **Enable**
DEF1 Direction	**Forward**, Reverse
DEF1 Current Setting	0.05..4 **(1x In)**
DEF1 Time Delay	0..20000 **(1000ms)**
DEF2 Direction	Forward, **Reverse**
DEF2 Current Setting	0.05..4 **(1xIn)**
DEF2 Time Delay	0..20000 **(1000ms)**
DEF CR Guard Res OV Level	0..20 **(5V)**
SR2 Dropoff	0..60000 **(1ms)**
DEF Current Rev Reset	0..60000 (**200ms)**
CB Echo Pulse Width	0..60000 (**250ms)**
DEF Backup Trip Delay	0..60000 (**1ms)**
SS2 Dropoff	0..60000 (**1ms)**

Status Inputs: **DEF CB CLOSED, BLOCK DEF**
Relay Outputs: **DEF AIDED TRIP, DEF PROTECTION**

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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

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1 Stub Protection

The Stub protection function in the relay is used to protect a short section of bus bar when the plant configuration is such that the line V.T. is switched out of circuit. The relay uses an over current element who's output is gated with a status input.

When a disconnector is opened the status input is energised enabling the output or the over current detector. This current detector is arranged to measure any current in unprotected zone. Typical CT arrangements are shown in figures 1 & 2.

If the setting is exceeded an LED is illuminated displaying stub protection trip or alarm.

Data storage can only be initiated from a trip condition.

The current elements are instantaneous transient free elements, which have an independent DTL timer. The output can be set to 0s for instantaneous operation or time delayed up to 1000 ms.

To switch on the stub protection function it has to be enabled in the AUXILLIARY PROTECTION MENU. If the function is not enabled any applied settings for that function is ignored.

2 Settings

The current setting can be selected between 10 – 200% of In.

The alarm function can be mapped to any of the output contacts. The trip function will operate whichever contact(s), has been set to cause a trip.

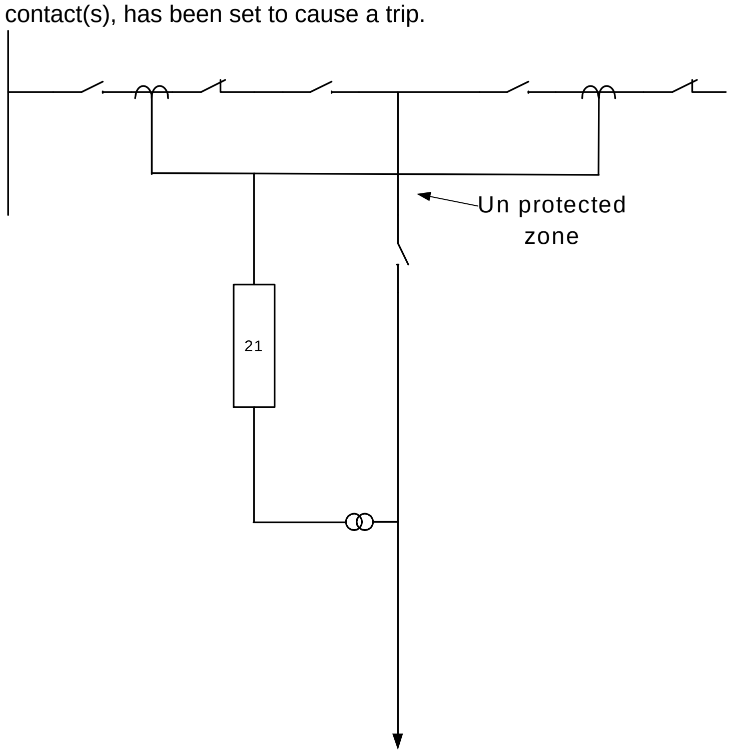

Figure 1

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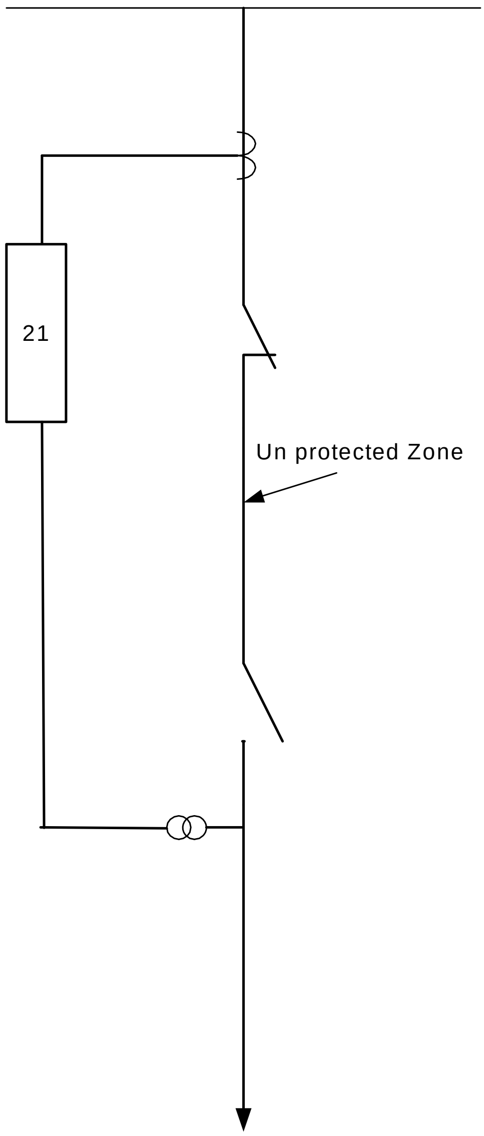

Figure 2

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7SG164 Ohmega 400 Series

Distance Protection Relays

Document Release History

This document is issue 2012/01. The list of revisions up to and including this issue is:
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1 Voltage Protection

Under / over-voltage elements :

Four independent elements are supplied, two of which can be set to operate for under-voltage and the other two are set as over-voltage elements each having separate DTL time delay elements. These can be used to protect generators against over-voltages, motors against loss of supply or applied as backup protection in the event of defective system regulating equipment.

Blocking operation :

The voltage elements can be blocked by the Voltage Blocking Threshold, which has a variable setting range.

2 Analogue Inputs

The input stage measures all three voltage quantities over the range of 5 Vrms to 90 Vrms it maintains accuracy within ±1% (or 0.25V) over the declared frequency performance range. The measuring range of the input stage allows for phase-neutral connections e.g. 63.5Vrms nominal voltages.

Measuring Principles

The input phase voltages to the relay are passed through voltage transformers, which step down the phase voltages to levels which are suitable for the electronic input stage of the relay. The transformers also provide essential isolation between the power system and the relay.

The main signal processing algorithm in the relay is a discrete Fourier transform (DFT) which is performed on each phase input. The DFT extracts the power system fundamental frequency component from the input voltages, effectively filtering out noise, D.C. and harmonics. The DFT is tuned for either 50Hz. Output from the DFT calculations are real and imaginary components for each voltage input.

The real and imaginary components are used to derive the magnitude quantity, which is then scaled to give a RMS value. Part of the DFT calculation includes extra filtering which smoothes the real and imaginary components, giving reduced ripple on the RMS calculation for off-system frequency conditions. In addition, a lookup table is used to compensate for magnitude variations from the output of the RMS calculation for 47-52Hz frequencies.

The real and imaginary components output from the DFT module are also used to derive the phase of the input signal.

3 Protection Functions

Voltage Blocking Element

The voltage blocking element acts as a block to the Voltage, elements in the relay. If all phase voltages fall below the threshold level then the blocking operation will operate.

The setting range for the voltage blocking threshold is ENABLED/DISABLED, 3V - 60V with a 0.5V step. This element is required mainly for under-voltage operation conditions. Under normal circumstances, if all phase voltages fall below the under-voltage setting, a trip output would be the expected response. However, in some applications e.g. auto-reclose schemes, having an under-voltage relay trip when the line is de-energised during the auto-reclose sequence is not usually desirable. Blocking the under-voltage operation in this situation can be achieved by using the Voltage Blocking Threshold, which should generally be set above the level of expected induced voltages on the line.

Voltage Elements

The relay has 4 voltage elements as standard. These are configured as two under-voltage (U/V) and two over-voltage (O/V) elements. If the input voltages exceed the pickup level, whether U/V or O/V, then each element operates through a gate, which selects operation from any one phase or all phases. At this point the element can still be inhibited from starting if the input voltages are below the voltage blocking threshold level. Figure 1 shows the basic operation of each voltage element. The ‘event’ and ‘instrument’ labels in the diagram indicate where this type of information is generated.

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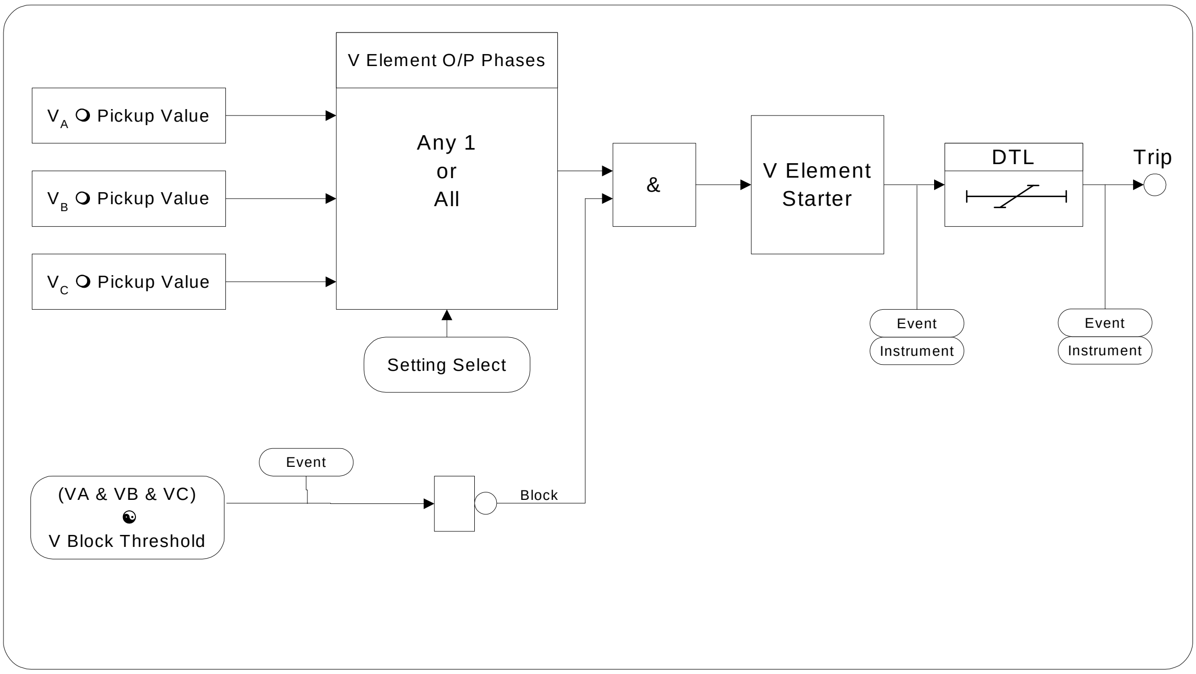

Figure 1 - Voltage Element

The voltage elements each have a variable Hysteresis setting which allows the user to vary the pick-up - drop-off ratio for a particular element.

The over-voltage function in the relay has two independent setting ranges they can be configured for an alarm function or a trip function.

The relay measures the voltage between each phase and neutral and will react to whichever phase exceeds the setting. If the setting is exceeded an LED is illuminated displaying over-voltage trip or alarm.

Data storage can only be initiated from a trip condition.

The voltage elements are instantaneous transient free elements, which have independent DTL timers. The output can be set to 0s for instantaneous operation or time delayed up to 1000 ms.

To switch on the over-voltage functions they first have to be enabled in the AUXILLIARY PROTECTION MENU. If the function is not enabled any applied settings for that function is ignored.

4 Settings

The setting is applied as a voltage. The nominal relay system voltage is 63.5 volts. The voltage settings on this relay operate two ways; any voltage that exceeds the over-voltage setting will cause an output. The reset level will be determined by the Hysteresis setting that allows a variable PU/DO ratio. For the under-voltage setting any voltage below the set value will cause an output. Again the reset is determined by the hysterisis setting. The under-voltage element will be blocked if all three phases are below this setting.

The alarm function can be mapped to any of the output contacts. The trip function will operate whichever contact(s), has been set to cause a general trip.

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