7SG18 Solkor N

Numeric Differential Protection

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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 and is compatible with these relays.

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

List of Symbols

I_L	Local current
I_R	Remote current
I_S	Differential Current setting
Ires	Restraint current
I_D	Differential current
ThsM	Differential magnitude threshold
ThsA	Differential angle threshold
B_2	Bias Break Point (defines beginning bias slope 2)
S_1	Bias slope 1
S_2	Bias slope 2

1 Introduction

This series of Current Differential relays are numerical, multi-function devices, which have been designed to be applied for the protection of two terminal overhead line and cable feeders. The relay may be used on generation, transmission, distribution or industrial power systems. The end to end signal can be via several types of fibre-optic, RS485 cable or twisted pair pilotwire.

This series of Current Differential relays are part of the comprehensive range of Argus-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.

The relay includes backup over current and earth fault protection. The relay may be set to have this backup protection in service permanently or only when a protection signal disturbance is detected by the relay.

The relay conforms to the relevant IEC 60255 standards.

Current differential elements:

In principle, current differential protection works by monitoring currents entering and leaving the protected zone. On a healthy feeder, these should be equal and opposite (assuming current flow out of a terminal to be negative). Any difference equates to current lost within the protected zone. Fault conditions generally cause high differential currents. Low levels of differential current can exist on a healthy feeder caused by capacitive current shunted off along its length, or low-level tapped loads. Generally, the difference between a fault current and any standing differential is large. Also, a large step change occurs in differential current as a fault crosses the zone boundary defined by the geographic location of the line CTs. An internal fault can therefore be detected accurately with a Go / No-Go detector which does not require great accuracy in its self.

This protection is designed to work within the limitations of an asynchronous digital communication channel for its end-to-end current information exchange. As such, the protection has to work with low data rates. This involves minimising the content of each current sample and minimising the rate at which they are transmitted, consistent with acceptable protection performance.

Intertripping elements:

The relay has three independent intertripping channels. One of the intertrip channels is an internal intertrip channel and is dedicated to the differential protection. The other two channels are external intertrip channels and are independent of the differential protection. These may be used for inhibits, intertrips, operation tripping or protection signals used in distance protection schemes.

The transmission or reception of an intertrip command can be inhibited by the use of a status input.

Overcurrent elements:

The relay has three phase fault and one earth fault overcurrent characteristic elements.

These elements have a programmable pick-up level, characteristic, time multiplier and time delay and can be inhibited via a status input or when the protection signalling channel is healthy. The programmable characteristics consist of four IDMTL (inverse definite minimum time lag) curves, NI, VI, EI, LTI, and one DTL (definite time lag) timer.

These elements may be assigned as guard relays for the differential protection. For the majority of applications the use of over current and earth fault guards is not recommended as the relay automatically supervises the protection signalling channel and automatically blocks the differential protection when its loss is detected. For longer feeders the instantaneous over current may be used to trip very fast for close up internal phase faults. Its use and setting will depend upon the relative feeder and source impedances.

Lowset elements:

The relay has three phase fault lowset and one earth fault lowset elements. These elements have a programmable pick-up level and time delay and can be inhibited via a status input or when the protection signalling channel is healthy.

These elements can also be assigned as guard relays for the differential protection.

Highset elements:

The relay has six Phase Fault (P/F) and two Earth Fault (E/F) Highset elements. These are grouped and designated as follows:

Highset 1 comprising 3 PF + 1 EF

Highset 2 comprising 3 PF + 1 EF

These elements have a programmable pick-up level and time delay and can be inhibited via a status input or when the protection signalling channel is healthy.

These elements may also be assigned as guard relays for the differential protection. These lowest and highest elements may be set as instantaneous or definite time delayed (DTL).

2 Hardware Description

2.1 General

All types of these relays share common hardware components and modules with the Argus range. The design for the mechanical arrangement of the relays has been carefully chosen to provide a high level of EMI screening using multi-layer PCB's with ground planes, RFI suppression components and earthed metal screens. The internal arrangement has been divided into 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 optical serial communications interface, which is immune to radiated or conducted interference.

2.2 Output Relays

The relays have 7 physical output contacts that are fully user configurable and can be programmed to operate from any or all of the protection functions. In addition, a watchdog feature within the relay can be mapped to any of the output relays. The normally closed contact of one of the three changeover outputs is generally required for this.

All output relays are of the same design, all capable of handling direct circuit breaker-tripping duty.

In addition to the physical output contacts, a virtual output contact is provided for use as a guard relay. This allows any element to control the guard function of the relay and does not require any external wiring to the relay.

In their normal mode of operation, output relays, including the virtual guard relay, will remain energised for a minimum user programmable delay. By default this is 100msec. If required, however, outputs can be programmed to operate as latching relays. These latched outputs can be reset by either pressing the TEST/RESET button, by energising a status input, or by sending an appropriate IEC60870-5-105 communications command.

A trip test feature is provided to exercise the output contacts.

For a list of terminal numbers and their usage see Table 1.

2.3 Status Inputs

Standard four pole relays have 1 status input. An expansion card can provide an extra 8 status inputs giving a total of 9.

All status inputs are fully user programmable and each has a pick-up and drop-off timer. These timers allow software filtering to be applied, which provides security in the presence of any induced A.C. voltages in the external wiring. The default pickup timer of 20ms provides extra immunity to a.c. pickup on dc scheme wiring. If high-speed operation is required, then the pick-up delay should be set to zero.

Each of the status inputs can be programmed to perform one of the following functions:

- Initiate the External Inter-trip.
- Provide Trip Circuit Supervision
- Inhibit operation of any one or more protection functions.
- Select an alternative settings group.
- Trigger storage of a waveform record.
- Synchronise the real-time clock.
- Reset latched output relays.
- Energise an output relay.
- Raise a user definable alarm string that is scrolled across the LCD display.

Additionally, each status input can have its operating logic inverted with the Status Invert feature. This allows normally open or normally closed contacts to drive the status inputs.

For a list of terminal numbers and their usage see Table 1.

2.4 Self Monitoring

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

A watchdog timer continuously monitors the microprocessor and the relay program memory is continuously checked for data corruption using a cyclic redundancy check (CRC) routine. The internal voltage supply rails are also continuously supervised and the microprocessor is reset if any of the rails are detected outside their working ranges. Any failure is detected in sufficient time for the microprocessor to shut down in a safe and controlled manner.

2.5 Measuring Principles

The input phase currents to the relay are passed through current transformers, which step down the phase currents to levels suitable for the electronic input stage of the relay. The transformers have balanced outputs which are lowpass filtered and fed into a differential amplifier. This provides excellent common mode and high frequency noise rejection. The single ended output from the differential amplifier feeds into a switched gain amplifier and then into an Analogue to Digital Converter (ADC) for sampling. The switched gain adjusts the signal level to give optimum sampling resolution, and increases the effective dynamic range of the ADC.

The main current measuring algorithm for the differential protection is a Discrete Fourier Transform (DFT). This extracts the fundamental power frequency component and attenuates d.c. and harmonic components. The DFT output is not a sine wave, but a pair of scalar (d.c.) signals representing a phasor in terms of its quadrature Real and Imaginary components. Phasor Magnitude and Angle are derived from these using trigonometrical relationships. The DFT uses 16 samples per cycle over a one-cycle moving window.

The main current measuring algorithm for the overcurrent protection is an RMS calculation, again using 16 samples per cycle over a one-cycle moving window.

All relays are fully calibrated during manufacture using an accurate current source. Calibration coefficients are stored in EEPROM and are used by the processor to compensate for any inaccuracies in the input stage, which have been introduced by the analogue circuits. Errors in magnitude and phase are eliminated using this method.

3 Protection Functions

3.1 Differential Element

This relay uses a combination of both phase and magnitude differential comparison to determine operation.

The differential element takes a sampled version of the instantaneous current waveform as its local input and compares it with a corresponding current from the remote end. The signal is converted to magnitude and angle information for comparison

The relay is a biased differential protection, whereby the differential threshold is increased with increasing load to accommodate any measuring and CT errors. The bias is a compromise between accommodating errors and spill currents on one hand, while retaining sensitivity to genuine faults on the other. Some of the largest sources of error result in angular errors (e.g. Communications delay, sample synchronisation, capacitive current) whereas low level fault currents tend to be in phase with any through current. Separate limits for angle and magnitude difference allow larger angular errors to be accommodated without sacrificing sensitivity.

A block diagram for a single phase of the differential protection is shown in Figure 1. Differential comparison is performed at each end of the feeder, so an identical algorithm runs in the remote relay. The relay performs a pole by pole magnitude and angle comparison using three separate algorithms, one per phase. A full cycle DFT is used to measure the instantaneous current waveform which gives outputs for magnitude and angle. This phasor information is used in the local differential comparator. An identical copy of the local measurement is sent to the remote end. For transmission, magnitude and angle values are compressed to reduce the number of bits required per sample. At the receiving end the values are expanded back to their original scale. Magnitude compression inherently clips its signal at a maximum limit. The consequence to the protection is linear differential comparison at low fault levels, turning to phase comparison at high fault levels. Since this protection works on each phase individually, the stability angle can be larger than phase comparison schemes using a single summated relaying quantity.

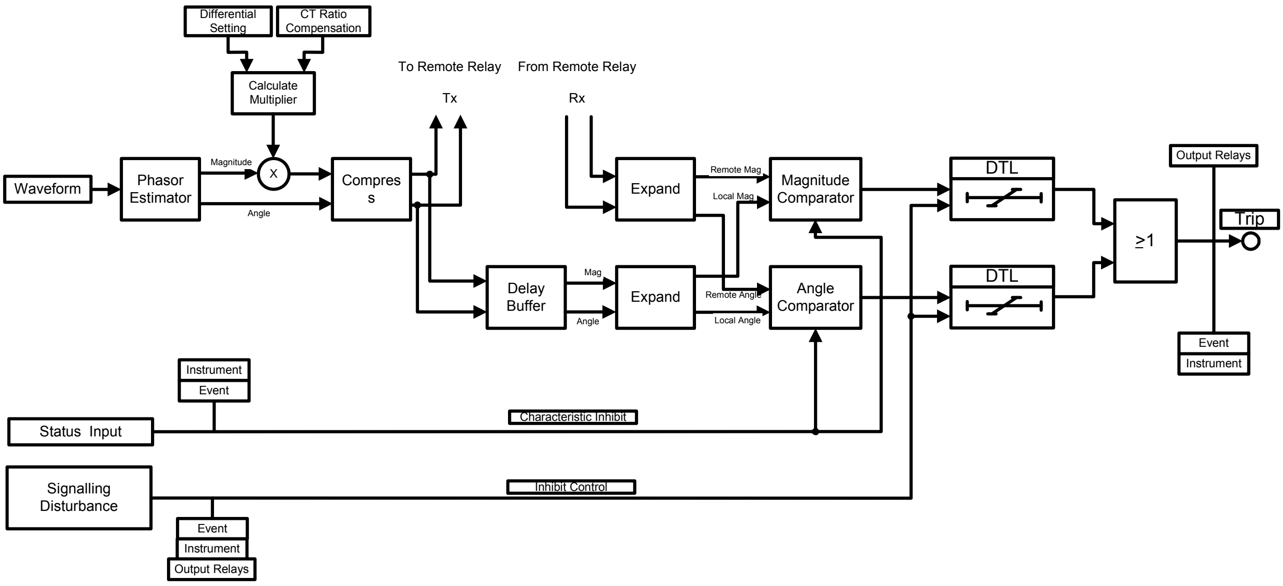


Figure 1 – Differential Protection Element (1 Phase)

The local signal path goes through the same compression / expansion (companding) process as the transmitted path, so that when local and remote currents are compared balance is maintained.

Separate magnitude and angle comparators compare the local and remote phasors and make a tripping decision based on how closely matched they are. For operation, either magnitude *or* angle must exceed the relevant differential threshold.

To improve security in the presence of communication disturbances, CT saturation, or other transient errors, the final tripping decision is based on the comparator's decision made over several samples. A counter is incremented if the comparator operates and decrements if not. If the cumulative count exceeds a set target, the trip command is issued. This target is user selectable allowing a trade-off between security and operate time for onerous conditions such as excessive CT saturation.

If a communications error condition is detected an error signal is raised. As a safeguard against corrupted data causing an unwanted trip, the differential protection count is held on a fleeting occurrence, or reset on a prolonged occurrence.

3.1.1 End To End Synchronisation

The DFTs on each relay work to a common time base. This is achieved by numbering the ADC samples at each end and synchronising them in time. The DFTs at each end start their reference cycles at the same sample number, hence at the same instant.

Transmitted samples are subject to delay inherent in the communication channel, buffering, etc. In addition to synchronising at source, it is also important that the correct samples are matched up for comparison at the receiving end.

When data is transmitted, a sample number goes with it. A copy is stored locally, also tagged with the same sample number. At the receiving end, the sample number associated with the received data is used to retrieve the corresponding local sample from a history buffer. Comparison is therefore done on sets of data originating at the same time, irrespective of transmission delays etc (See Figure 1).

3.1.2 Differential Operation

For operation the following conditions must be met:

The difference between local and remote magnitudes must exceed the magnitude differential threshold.

or

The difference between local and the inverted remote angle must exceed the Angle differential threshold.

Expressed mathematically:

$$|I_L| - |I_R| \geq Ths_M$$

or

$$\arg(I_L) - \arg(I_R + 180°) \geq Ths_A$$

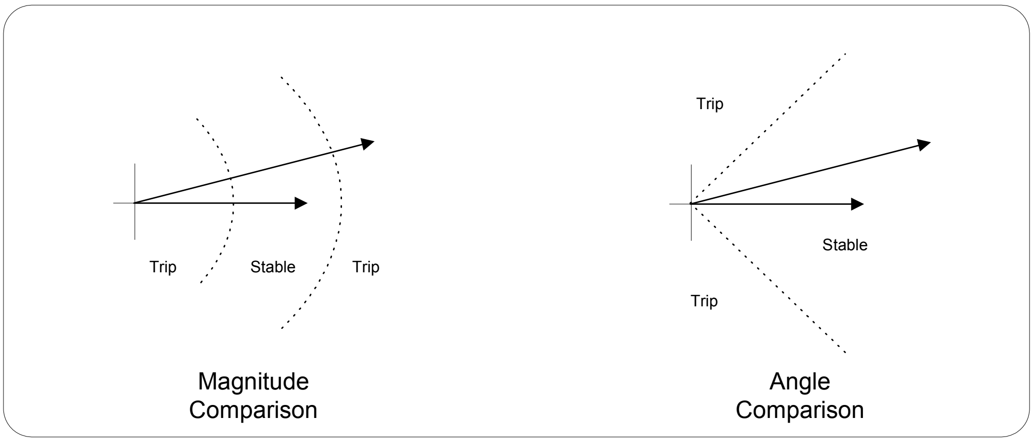


Figure 2 – Magnitude and Angle Comparison

A point of convention: The stable condition shown in the diagrams corresponds to two phasors superimposed, i.e. the reference phasor is in the centre of the stable area. Normal convention regards currents flowing *into* the protected zone as having the same sign, so a balanced (stable) condition has equal and *opposite* currents. If the remote current is taken as reference, then the reference phasor shown in the centre of the stable area is -R.

3.1.3 Biasing

Both magnitude and angle comparators are biased so the overall stable area on the polar plane increases with current magnitude. The same restraining quantity is used for both, derived from the mean scalar current.

$$I_{res} = \left(|I_L| + |I_R| \right) / 2$$

A multi-stage bias is used giving thresholds as follows:

Magnitude Threshold: The operating threshold is given by the equation:

$$
\begin{aligned}
Ths_M &= I_S && \text{for } I_{res} < 0.5I_S \\
&= I_S \quad + S_1\left(I_{res} - 0.5I_S\right) && B_2 > I_{res} \geq 0.5I_S \\
&= I_S \quad + S_1\left(B_2 - 0.5I_S\right) + S_2\left(I_{res} - B_2\right) && I_{res} \geq B_2
\end{aligned}
$$

This is shown graphically in Figure 3. The first stage of bias accommodates proportional errors in the system to maintain a stability margin at least equal to the original differential setting. The second stage of bias accommodates any additional differential current caused by the likes of CT saturation at higher current levels.

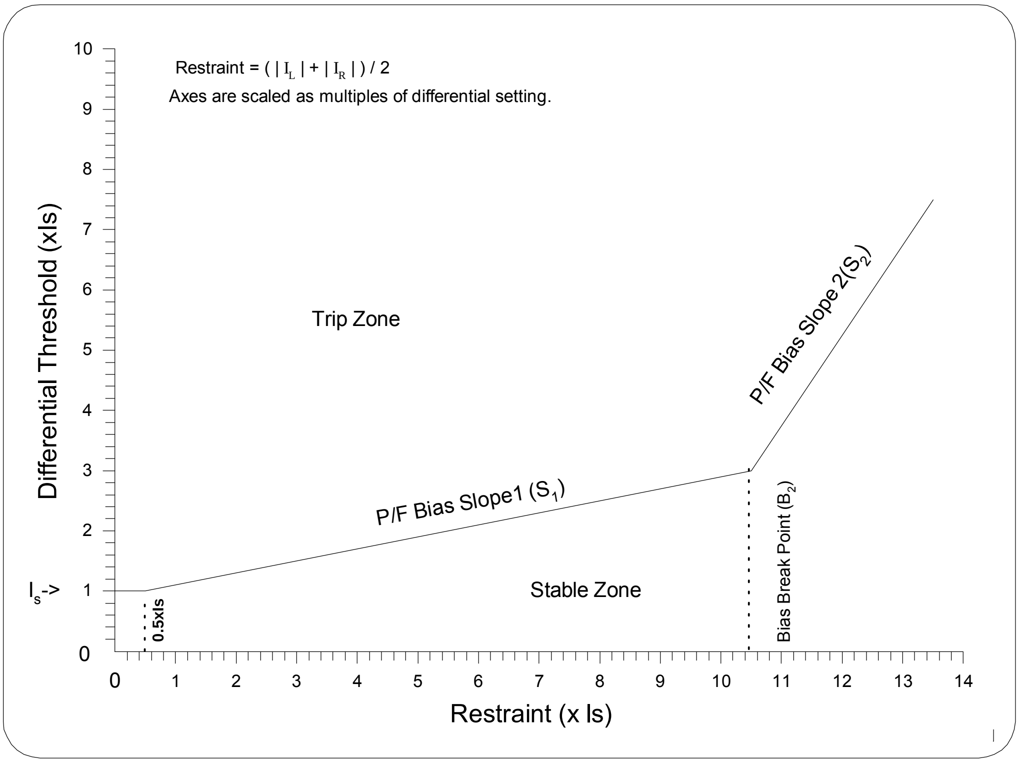


Figure 3 – Magnitude Comparator Bias Characteristic

Settings:

I_S = P/F Differential Setting **S_1 = P/F Bias Slope 1 Setting**

S_2 = P/F Bias Slope 2 Setting **B_2 = Bias Break Point Setting**

Angle Threshold: The operating threshold is given by the equation:

$$
\begin{aligned}
Ths_A &= \pm 180^\circ && \text{for } I_{res} < 0.5 I_S \\
&= \pm 45 + Shaping && B2 > I_{res} \geq 0.5 I_S \\
&= \pm 67.5^\circ && I_{res} \geq B_2
\end{aligned}
$$

Figure 4 shows the bias characteristic graphically. The lowest level of currents for which the protection can correctly operate, result in a restraint of 0.5 Is. Phasor angle measurement becomes inaccurate at very low levels and near zero it can swing full circle. The angle comparator is therefore turned off for restraint current below 0.5Is by giving it a threshold greater than ±180° (i.e. ±200°). Above this, the angle threshold is set to accommodate phase shifts caused by sample synchronisation errors, data compression and whatever margin is required by power system conditions etc. At high current levels, the angular threshold is opened up to accommodate additional phase shifts caused by CT saturation.

Relay software Revision 4 code released in July 2004, altered the phase angle comparator to a shaped characteristic to allow more sensitive differential settings to be used on long cable feeders and hence improve fault detection.

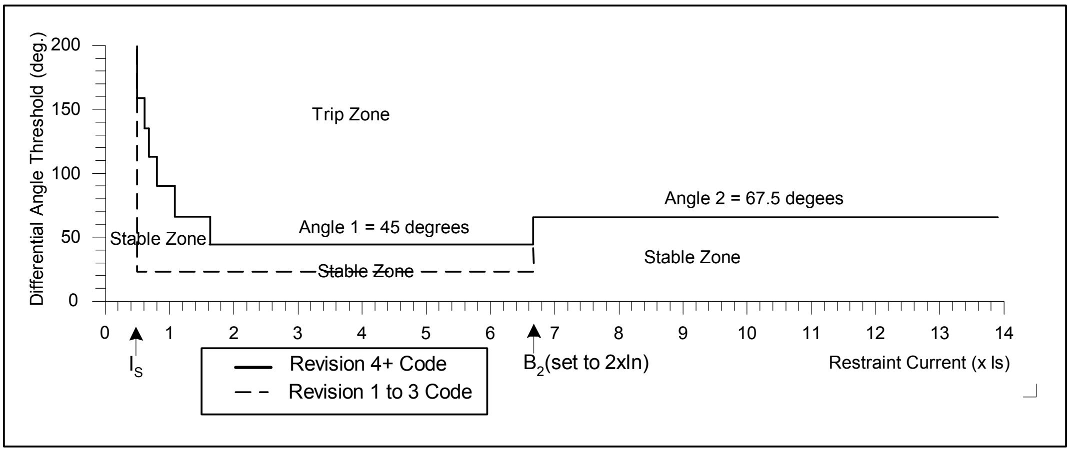


Figure 4 – Angle Comparator Bias Characteristic

Polar diagrams resulting from the combination of these two characteristics are illustrated in Figure 5.

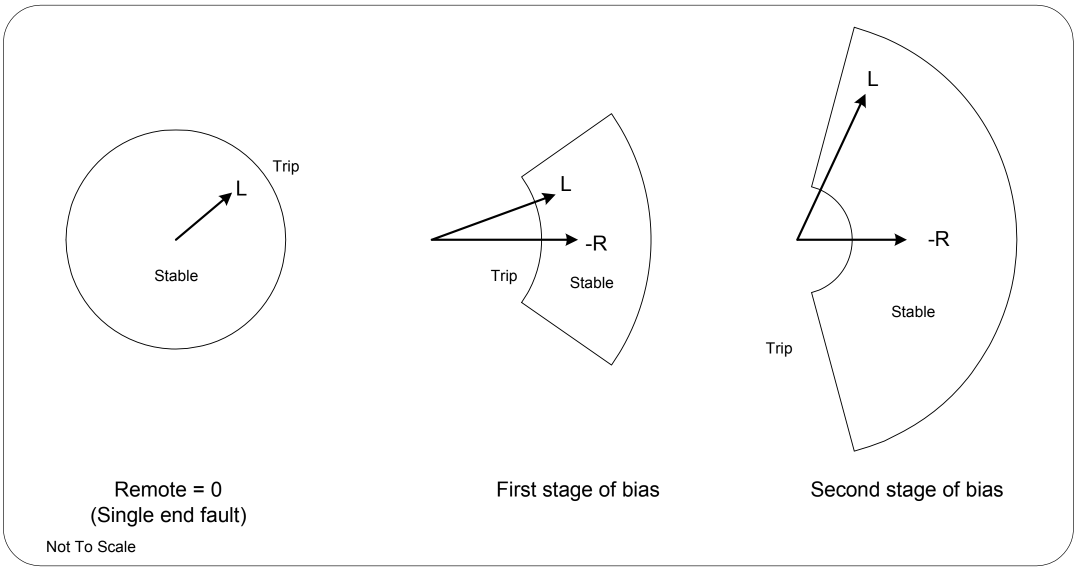


Figure 5 – Overall Polar Characteristic

3.1.4 Trip Decision Processing

If a threshold is exceeded a counter is incremented, otherwise it is decremented. This occurs at each pass of the algorithm. If the count exceeds a set value a trip signal is issued. The trip is made on the outcome of a number of successive comparisons. The output from the magnitude and phase comparitors at each stage, are “OR” gated to assist with tripping with arcing and evolving faults.

This decision period is user adjustable via the “Differential Delay” setting. This is set to zero in most cases. The Differential delay may be used if concern of CB breaking capacity may be compromised, to allow the dc offset component in the fault current to subside, before a trip signal is sent.

The trip decision process can be interrupted in two ways if an alarm or error signal is raised elsewhere:

1) The count can be frozen, i.e. present comparisons are effectively ignored but previous ones retained.

2) The count can be reset, i.e. previous comparisons are dumped and present ones ignored.

The algorithm is processed every 5 ms, therefore each count adds 5 ms to the protection operating time. The overall operating time also includes the response time of the DFT, communications delay, output contacts and any delay incurred transferring data to and from various processor modules in the hardware.

3.1.5 Supervision of the Protection Signalling Channel

The relay software includes several types of error checking (such as scew and parity) in the frames sent and received. The relay provides complete supervision of the channel, and will instantaneously block the differential elements if frames cannot be synchronised due to a loss of the channel for a severed fibre or broken wiring.

This feature may be checked by removing the signalling medium to both relays and applying a simulated internal fault after the Signal Healthy LED has commenced flashing on both relays. The Signal Alarm output contact can be used to indicate a fault in the channel to a remote point. This feature removes the need for over current and earth fault guard elements to supervise a differential trip.

3.2 Intertripping Elements

3.2.1 Internal Intertrip

The internal intertrip is used to ensure both ends of a feeder are cleared if the differential protection is used with a guard qualifying its trip output. (A guard is used when additional security is required, usually against false tripping under difficult communication conditions.) If an internal fault is fed largely from one end, the differential comparators at *both* ends operate identically, but the guard at the low current end may not pick up and the trip will be blocked at this end.

To ensure tripping at both ends, an intertrip is sent if both Differential AND Guard operate. At the receive end, the intertrip output can operate any user selected contact. The additional security provided by the guards is still present as the intertrip only sends if a differential is detected coincidentally with a large current.

3.2.2 External Intertrip

Two external inter-trip channels are provided. These channels are of the Direct Intertrip (Transfer Trip) type and are independent of the differential protection. They are driven from mapped status inputs. At the receiving end, the intertrip output follows the state of the sending end status input. The outputs can independently operate any user selected contact.

An external intertrip can be configured as a permissive type intertrip by connecting its output contact in series with an instantaneous overcurrent contact. Intertrip output is therefore blocked unless local current is present.

3.2.3 Intertrip Operation

When either an internal or external intertrip send command is raised the appropriate bits for that intertrip are set in the data message frame.

After the message has passed security checks at the receive end, a counter is incremented whenever these bits are detected. If the count exceeds a predetermined target value, an intertrip output is issued. This way, making the tripping decision on a number of received messages enhances the system security.

Each intertrip channel has its own count, which also serves as the intertrip delay timer. The target value determines the intertrip delay time, subject to a minimum value required to ensure adequate security. The target values on the two external intertrip timers are derived from the user setting “Ext Intertrip Delay”. The target value on the internal intertrip timer is derived from the user setting “Differential Delay”, so it takes on the same delay as the differential element.

3.3 Overcurrent Characteristic Elements

The main overcurrent element can operate with either an Inverse Definite Minimum Time Lag (IDMTL) or a Definite Time Lag (DTL) characteristic. Four IDMT curves are available:

Normal Inverse (NI)

Very Inverse (VI)

Extremely Inverse (EI)

Long Time Inverse (LTI)

The IDMT algorithms operate correctly for developing faults where current varies with time.

Intermittent or flashing faults are detectable by applying a delayed reset to the overcurrent timer.

These elements can be inhibited using either status inputs or when the protection signalling communications channel is healthy.

There are 3 phase fault overcurrent elements and 1 earth fault overcurrent element.

The output of the element can also be used as a guard relay for the differential protection.

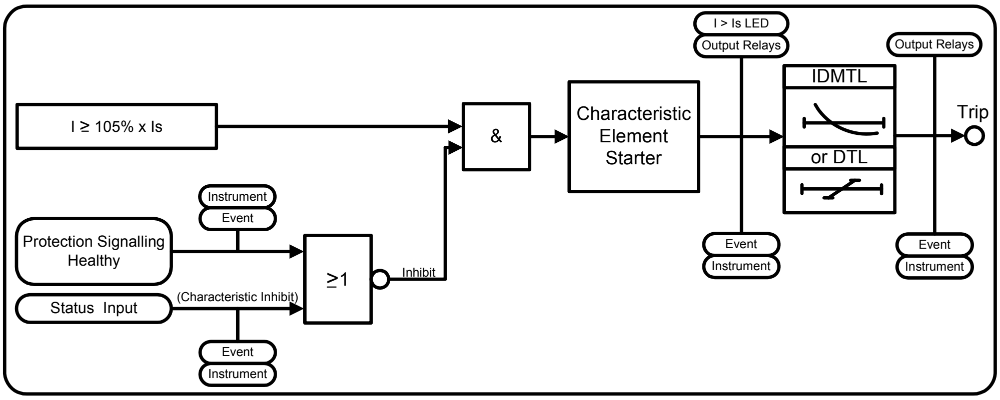


Figure 6 – Overcurrent Characteristic Element

3.4 Lowset Elements

There are three Phase Fault (PF) lowest elements and one Earth Fault (EF) lowset element. These elements have programmable pick-up levels and time delays. They can be inhibited via a status input or when the protection-signalling channel is healthy.

The lowset element consists of a shaped instantaneous starter characteristic followed by a DTL. The instantaneous outputs are designed for transient free operation where high values of system X/R are experienced.

The output of the element can also be used as a guard relay for the differential protection.

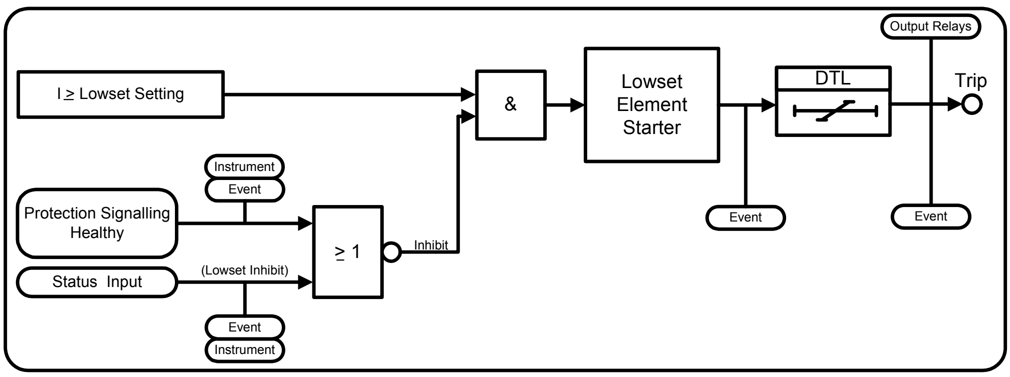


Figure 7 - Lowset Element

3.5 Highset 1 & Highset 2 Elements

There are two sets of Highset elements. Each set comprises three PF Highset elements and one EF Highset element. These have programmable pick-up levels and time delays. They can be inhibited via a status input or when the protection signalling channel is healthy.

All Highset 1 and Highset 2 elements consist of a shaped instantaneous starter characteristic followed by a DTL. The instantaneous outputs are designed for transient free operation where high values of system X/R are experienced. Highset 1 and Highset 2 are independent from one another.

The output of the elements can also be used as a guard relay for the differential protection

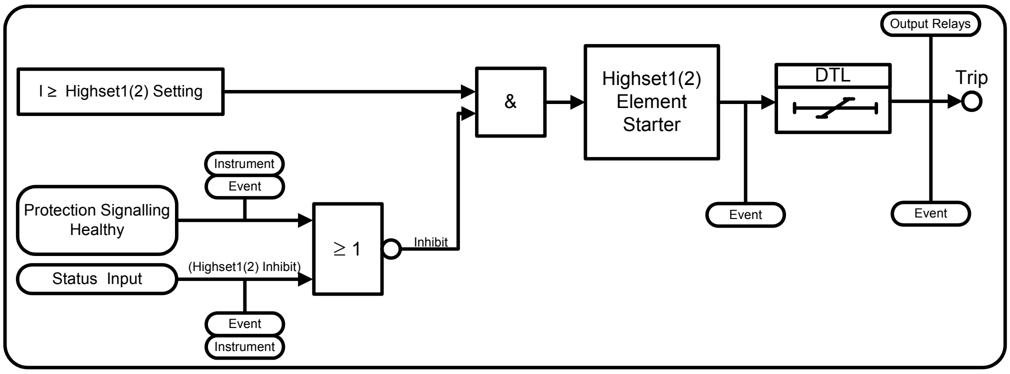


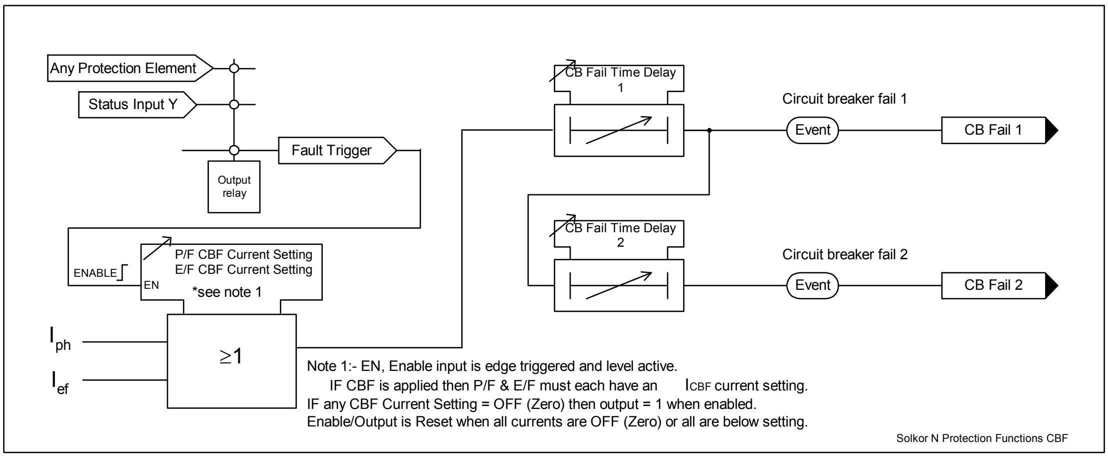
Figure 8 – Highset 1 and Highset 2 Element

3.6 Guard Relay operation

Any of the Highset and Lowset elements may be assigned as guard relays. Generally these guard elements are not required for this relay, as the Signal Loss Detection will block the differential elements if a break in the protection signal channel causes an loss of frame synchronism.

3.7 Circuit Breaker Fail

A two-stage circuit breaker fail timer is provided. CBF timer 1 begins to run following a trip output from any one of the protection algorithms and issues a back-trip output if current is still above setting. CBF timer 2 then begins to run and issues a second back-trip output. The correct operation of the CF Fail depends upon all trip outputs being assigned as “Fault Triggers” in the Wavefrom storage menu. As an additional check the CB Fail Level detectors Provide a means of checking the continuation of the fault current.



An externally triggered CBF initiate, for instance from an external SEF relay, requires a Status input to be mapped to as “Fault Trigger” allocated output contact. When this output operates the CBF level detectors are Enabled.

Figure 9 – Circuit Breaker Fail

3.8 Trip Circuit Supervision

A trip circuit supervision feature is provided within the relay. The relay can monitor its own trip circuit(s) by configuring any one of its status inputs using the ‘Trip Circuit Fail’ setting and connecting the status input(s) into the trip circuit. Indication is then given instantaneously of ‘Trip Circuit Fail’ should a fault be detected and this display also identifies which input has detected the fault. Since the status inputs can be programmed to operate output contacts, an alarm can be also generated from the trip circuit supervision feature.

3.9 CT Supervision

This feature provides detection for a CT becoming disconnected from the relay due to loose or broken wiring. It operation depends upon the relay detecting a one or more phase currents being below the CT Supervision Pickup level and at least one being above for the set CT Supervision time delay setting. If the load is high enough at the point where the CT becomes detached from the relay the magnitude comparator will trip. If a CT supervision elements operates without the load being high enough to operate the relay, a method of blocking the differential protection at both ends of the feeder is possible using one of the external intertrip channels.

3.10 External Tripping

Any status input can be programmed to receive a trip signal from another device. The status input should firstly be mapped to the trip output contact in the Output Configuration Menu, so that energisation of the status input results in a trip signal being issued. If the same trip contact is specified in the ‘Fault trigger’ setting then the relay will switch to the fault data mode and indicate that an external trip has occurred.

4 Other Features

4.1 Circuit Breaker Maintenance

The $\sum I^2$ feature and the trip counter provide circuit breaker condition monitoring. Alarm outputs with programmable settings are available from both features.

All of this information is accessed either from the relay front panel or via the IEC60870-5-103 communications interface.

The values of current used for the $\sum I^2$ are those measured at the time of issuing a trip signal. A $\sum I^2$ is generated for each phase element and the highest value is used for alarm and display purposes.

It is also possible to initiate the $\sum I^2$ algorithm from an external tripping device via a status input if required.

Note: both the trip count and $\sum I^2$ count can be reset when viewing the appropriate instrument screen by pressing the TEST/RESET button.

4.2 Metering

Real time measurements and data are available at the fascia (in “Instrument Mode”) through the metering functions or via the auxiliary communications interface. The following displays are available:

- Primary local RMS currents for IA, IB, IC and IE
- Secondary local RMS currents for Ia, Ib, Ic and Ie
- Primary remote RMS currents for IA, IB, IC and IE
- Secondary remote RMS currents for Ia, Ib, Ic and Ie
- Differential current magnitudes for Ia, Ib and Ic
- Output relay status
- Digital input status
- Trip circuit status
- General alarm screen
- Trip counter
- $\sum I^2$ counter
- Circuit breaker status
- Number of waveforms recorded
- Number of events stored
- Date - displayed in DD/MM/YY format
- Time - displayed in HH:MM:SS format
- Overcurrent characteristic information for phase and earth poles
- Differential characteristic information for phase poles
- Protection signalling communications channel status
- Protection signalling delay

Note: the instrument displays are updated as often as the software routines can service them, however the RMS current measurands have a response time of approximately 500msec.

Figure 10 shows the display menu structure from where the available instruments can be accessed. Note that pressing the ⇨ Test/Reset key can clear three of the instruments, the Trip Counter, Waveforms and Events.

4.3 Data Storage

Details of relay operation are recorded in three forms, namely Waveform records, Event records and Fault Data records. All records are time and date tagged by a real time clock which maintains the time even when the relay is de-energised [see Note below]. Time and date can be set either via the relay fascia using appropriate commands in the System Config menu or via the IEC60870-5-103 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 status input. To use this feature one of the status inputs has to be assigned to the 'Clock Sync' feature in the Status Config menu. Additionally the 'Clock Sync Period' setting in the System Config menu should be set to either 'seconds' or 'minutes'. If 'seconds' are selected then the energisation of the selected status input will result in the clock being synchronised to the nearest second with the milliseconds set to zero. If 'minutes' are selected then the clock is synchronised to the nearest minute with both seconds and milliseconds set to zero.

Note: the real-time clock, waveform records and event records are all maintained, in the event of loss of auxiliary d.c. supply voltage, by the backup storage capacitor. This capacitor has the ability to maintain the charges on the real-time clock IC and the SRAM memory device for typically 2-3 weeks time duration. This time, however, is influenced by factors such as temperature and the age of the capacitor and could be shorter.

4.3.1 Waveform Records.

The waveform record feature stores analogue and digital information for the current inputs, status inputs and output relays. The waveform record is 1.0 second long with a sampling resolution of 16 samples per cycle. The recorder feature has the ability to store records for the previous five trip operations of the relay. These are labelled 1-5 with 1 being the most recent record.

The waveform recorder can be triggered in the following ways:

- Via the waveform trigger status input signal.
- From any element trip operation, including, overcurrent, differential and intertrip elements.
- From a disturbance on the protection signalling communications channel.
- Via the IEC60870-5-103 communications interface.

The waveform recorder has a settable pre-fault triggering capability.

4.3.2 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 5ms. There is capacity for a maximum of 500 event records to be 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 each output relay.
- Change of state of each status Input.
- Change of state of any of the protection functions of the relay.
- Protection signalling disturbances and alarms.
- Trip indication reset
- Trip test.
- Trip supply failure.

For a full list of all the events available see 6 Event Codes.

4.3.3 Fault Data Records

When issuing a trip output under fault conditions, the relay will illuminate the Trip LED, store a fault record and display the fault indication screen. The fault indication screen displays a summary of the fault data record, giving immediate, easily understood information on what has occurred. It displays date (DD/MM), time (HH:MM:SS) and the poles which were picked up when the trip signal was issued e.g.

25/04 17:25:51 **TRIP A B C**

This display is held until the TEST/RESET button is pressed, upon which the LED will turn off and any latched output relays are reset. The relay enters ‘Fault Data Display Mode’ at which point the fault indication screen is replaced by a more detailed scrolling fault data display. This shows the date and time of fault and for each pole the elements that were picked up and the currents measured at the time of trip. Elements in angled brackets, <>, caused the trip e.g.

FAULT 1 25/04/00 17:25:51.5400 G1, IA= 10.00xIn <DIFF> IDMTL LS, IB= 0.00xIn, IC = 0.00xIn, IE = 10.00xIn HS1 HS2, INTERTRIPS=Remote Int

FAULT 1
<< Fault Data >>

The fault record is viewed in the ‘Fault Data Display Mode’ of the menu system and can be viewed again at a later date. The relay will store the last 5 fault records, which are numbered 1-5, with 1 being the most recent record. To view them, scroll down using the ⇩ button.

Depending upon the relay application, some of the protection elements may not be used for tripping purposes but for alarm purposes. In these cases it would be undesirable for the relay to light the Trip LED and give fault indication. It is therefore necessary to define a ‘Fault’ for the cases where a trip is issued. A ‘Fault Trigger’ setting exists in the Data Storage Menu, which allows a fault condition to be defined by selecting any combination of output relays as tripping outputs. The Trip LED and the fault record storage will be triggered when any of the selected output relays are energised. Note that a trip output can still be generated even if the fault trigger setting is not used, though no trip indication will be given.

Fault records are stored in non-volatile memory.

4.4 Protection Signalling Communications Channel

End to end protection signalling can employ any of the following communication circuit options:

See Performance Specification for the available communication channels.

4.5 Communications

IEC60870-5-103 or MODBUS RTU protocols are available as a user selectable setting.

A fibre optic communication port is provided which gives superior EMC performance or an optional RS485 electrical connection is available. For communication with the relay via a PC (personal computer) a user-friendly software package, REYDISP EVOLUTION [1], is available to allow transfer of the following:

- Relay Settings
- Waveform Records
- Event Records
- Close Data Records
- Instrument and meters
- Control Functions

Communications operation is described in detail in Section 4 of this manual.

4.6 General Alarm Screens

An independent display function provides up to five alarm messages, each of which may be programmed by the user to display a message associated with an external alarm.

Within the System Config Menu, each alarm message can be text edited by the user to display up to 13 characters. Also, each alarm can be user mapped to any status input, via the Status Config Menu, so that on energisation of that input the associated alarm message is automatically displayed. Where more than one General Alarm is raised then the display will scroll right to left to show all energised screens sequentially, with screens separated by a ‘+’ sign. If required, more than one alarm may be mapped to a single status input, allowing long messages to be displayed.

The message will appear on the LCD for the duration of the time that the status input is energised.

General Alarms
<< Alarm1 + Al<<

4.7 Default Instrument Screens

The menu presentation of the various instruments allows the user to view a single screen at a time. However, for in-service use, it is desirable that a small number of high interest, user selectable, screens are presented automatically by default without user intervention. The instrument screens of interest to the user e.g. those required to be presented to a visiting engineer for record purposes can be selected by the user by pressing **ENTER** when viewing the required screen. On pressing **ENTER** a 'Screen Set As Default' message will be flashed up and a '□' will appear at the top right of that screen. The '□' indicates that a screen is a 'default screen'. To de-select a default screen, simply press **ENTER** while on that particular screen and a 'Screen Cleared As Default' message will be flashed up. The '□' symbol will be cleared.

Differential a	□
0.00	

If no keys have been pressed for a pre-determined time the relay will jump to the default instrument display regardless of where the menu system has been left by the user. It will then scroll through each of the selected default instruments and remain on each for 5 seconds. The main timer which sets the time to elapse before the relay goes into the default instruments mode is found in the System Config Menu. This is the Default Screen Timer setting and it can be set to a range of values from 10 seconds to 1 hour. See relay settings, Section 3 of this manual.

If any General Alarm is raised, then the general alarm screen will be presented in the default screen sequence. The general alarm screen, which has a scrolling display, will present one pass of its display message.

Any key press while in the default screen sequence will result in a return to the 'Relay Identifier' screen at the top of the menu structure.

4.8 Multiple Settings Groups.

The relay provides eight alternative setting groups, making it possible to edit one group while the relay protection algorithms operate using another 'active' group. An indication of which group is being viewed is given by the 'Gn' character in the top left of the display. The relay can then be switched from one group of settings to another to suit alterations in the power system configuration. Changeover will occur within 35ms.

A change of group can be achieved either locally at the relay fascia, remotely via an IEC60870-5-103 communication interface command or by energisation of a status input. In the case of the latter method, the '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. Changing setting groups must ensure the differential settings for a pair of relays remain identical at all times. Therefore changes to the differential settings must only be done with no load current on the feeder.

4.9 Password Feature

The programmable password feature enables the user to enter a 4 character alphanumeric code to secure access to the relay settings. The relay is supplied with the password set to 'NONE' which means that the password feature is not activated. Once a password has been entered then it will be required thereafter to change settings. It can, however, be de-activated by using the password to gain access and by resetting it back to 'NONE'.

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 'logged on' and any further changes can be made without re-entering the password. If no more changes are made within 1 hour then the user will automatically be 'logged off', re-enabling the password feature.

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.

5 User Interface

The user interface is designed to provide a user-friendly method of entering settings and retrieving data from the relay. The relay fascia includes a 16 character by 2 line, backlit, liquid crystal display (LCD), 5 light emitting diodes (LED) and 5 push buttons. Figure 11 shows a relay fascia.

5.1 Liquid Crystal Display

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

To conserve power the display backlighting is turned off if no push buttons are pressed for 5 minutes. After one hour the whole display is de-activated except if the display is left in the 'Instruments Mode' where it will remain visible permanently so that instruments can be displayed continuously. Also, if any default instruments have been selected then the display will not power down, only the backlight will turn off. Once the backlight is turned off, any following keypress will turn the backlight on without changing the display.

5.2 LED Indications

The following indications are provided:

- **Protection Healthy – Green LED (flashes with fault).**

This LED is solidly illuminated to indicate that DC volts have been applied to the relay and that the relay is operating correctly. If the internal relay watchdog detects a permanent fault then this LED will continuously flash. If this LED is not lit, then the dc supply to the relay or its' power supply has failed

- **Intertrip – Red LED (latched).**

This LED indicates that an intertrip has occurred. This may be generated from either the internal intertrip or one of the external intertrip channels.

- **I > Is – Yellow LED (self resetting).**

This LED indicates that any pole is picked up and is measuring current above one of the IDMTL / DTL characteristic current settings. Visually this is equivalent to an induction disk relay starting to turn.

- **Trip – Red LED (latched).**

This LED indicates that a trip as defined by the user has occurred. Such a trip may be issued by any of the relay's protection functions. Only the operation of outputs set as "Fault Triggers" in the Waveform Storage Menu will illuminate this LED.

- **Signal Healthy – Green LED (flashes with comms disturbance).**

This LED is solidly illuminated to indicate that the protection signalling communications channel is in synchronism, and is operating correctly and error free. If a disturbance is detected on the signalling communications channel then this LED will flash. A permanent fault detected on the communications channel will cause this LED to flash continuously.

5.3 Keypad

Five pushbuttons are used to control the functions of the relay. They are labelled ⇧ ⇩ ⇨ **ENTER** and **CANCEL**. Note that the ⇨ button is also labelled **TEST/RESET**.
When the relay front cover is in place only the ⇩ and ⇨buttons are accessible. This allows only read access to all the menu displays. It is not possible to change settings.

5.4 Navigating the Menu System

The display menu structure is shown in Figure 10. This diagram shows the three main modes of display, which are the Settings Mode, Instruments Mode and the Fault Data Mode.

On relay start up the user is presented with a default relay identifier,

SOLKOR N **Factory Settings**

which shows that the relay has been set with the standard factory default settings. The top line of the LCD can be changed to some user-definable identifier or code if preferred.

Pressing the ⇨key on this display initiates an LED test. Pressing ⇩ at this display allows access to the three display modes that are accessed in turn by pressing the ⇨key.

The ‘Settings Mode’ contains 9 setting sub-menu’s. These hold all of the programmable settings of the relay in separate logical groups. The sub-menu’s are accessed by pressing the ⇨ key. This enters the sub-menu and presents a list of all the settings within that sub-menu. Pressing the ⇩ key scrolls through the settings until after the last setting in the group the next sub-menu is presented. Access to this group is via the same method as before. If a particular sub-menu is not to be viewed then pressing the ⇩ key will skip past that particular menu and present the next one in the list. Note that all screens can be viewed even if the password is not known. The password only protects against unauthorised changes to settings.

While viewing an editable screen pressing the **ENTER** key allows the user to change the displayed data. The editable field will be indicated by a flashing character(s). Pressing ⇧ or ⇩ scrolls through the available setting values or, pressing the ⇨key moves right through the edit fields. Note that all settings can be incremented or decremented using the ⇧ or ⇩ keys and they all wrap-around so that to go from e.g. a setting minimum value to the maximum value it is quicker to press the ⇩ key, rather than scroll up through every setting. Also, to facilitate quicker setting changes an acceleration feature is available which if ⇧ or ⇩ are depressed and held, then the rate of scrolling through the setting values increases.

If **CANCEL** is pressed during a setting change operation the original setting value is restored and the display is returned to the normal view mode.

If changes are made to the setting value then pressing **ENTER** disables the flashing character mode and displays the new setting value. This is immediately stored in non-volatile memory.

Note: the relay exhibits a method of hiding settings which are not relevant to a particular customer scheme which is known as setting dependencies. Some settings are dependant on others being enabled and if a function is not enabled then associated settings are not displayed e.g. if the P/F Lowset is not required then set,

Gn P/F Lowset Setting to OFF; the following associated setting will not be displayed;

Gn P/F Lowset Delay,

Also hidden are all associated output relays options and status input inhibits.

There are many examples of setting dependencies and care must be taken to ensure a function is enabled before looking for other associated settings which otherwise would be hidden.

The ‘Instruments Mode’ contains a list of instruments. Pressing the ⇩ key scrolls down through the list of instruments and pressing ⇧ scrolls up through them. For more information on the relay’s instruments see Section 4.2.

The ‘Fault Data Mode’ can contain a maximum of 5 fault records. These are accessed in the same way as the other display modes. For more information on the fault record displays see 4.3.3 Fault Data Records

For a complete list of all possible settings see Section 3 – of this manual. This section also shows all setting ranges and factory default values, as well as including a brief description of each setting function.

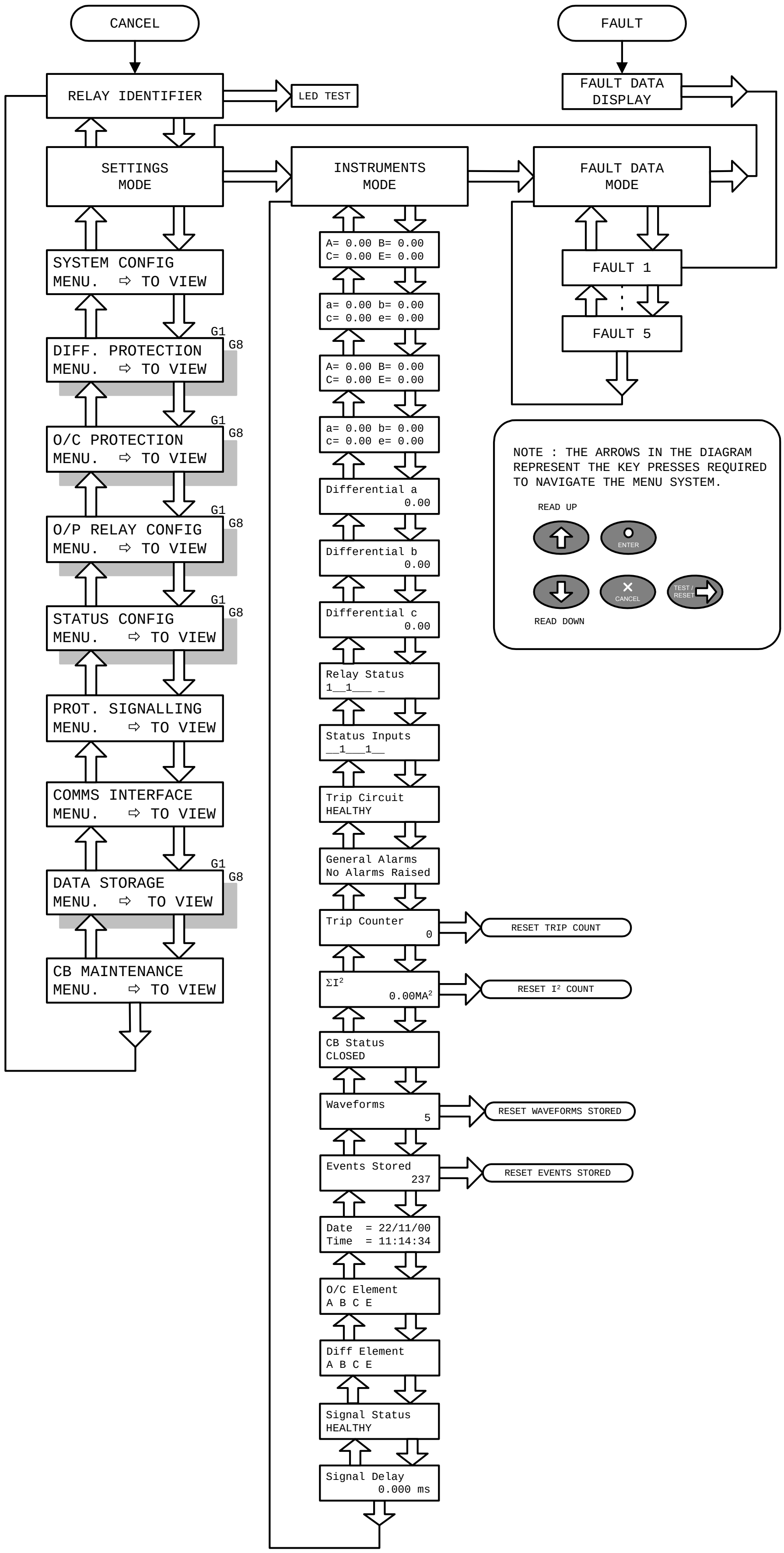


Figure 10 - Display Menu Structure

Figure 11 –Relay Fascia

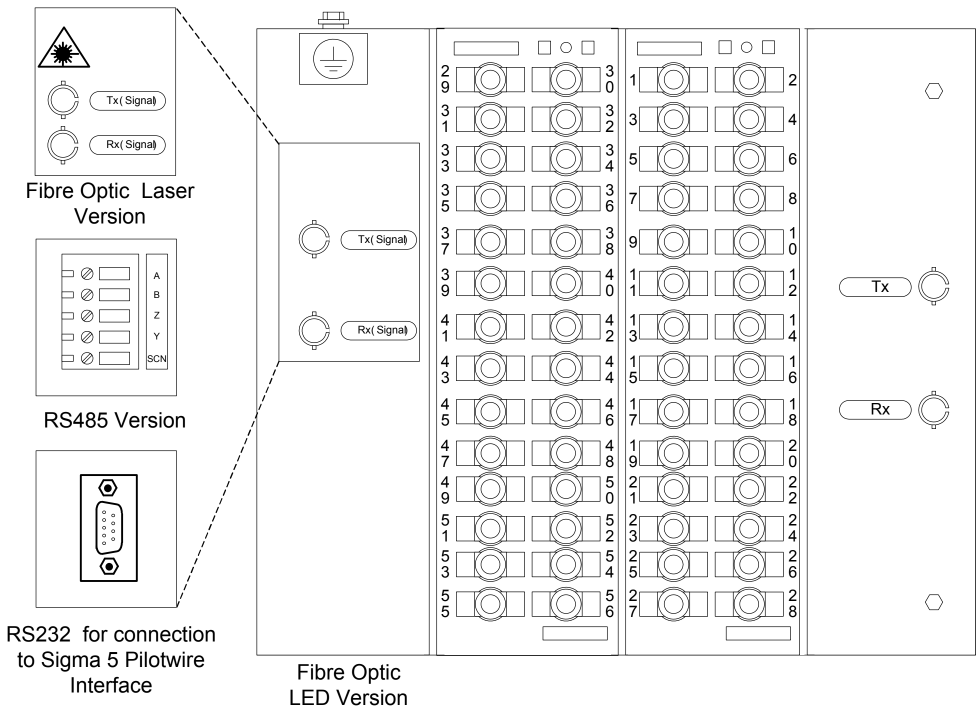


Figure 12 –Rear View

	Function		Terminal	Terminal		Function
Terminal Block 1	Not Used	–	**1**	**2**	–	Not Used
	Status Input 1	(+)	**3**	**4**	(–)	Status Input 1
	Relay 1 (N/C)	–	**5**	**6**	–	Relay 1 (COM)
	Relay 1 (N/O)	–	**7**	**8**	–	Relay 2 (N/O)
	Relay 2 (COM)	–	**9**	**10**	–	Relay 2 (N/C)
	Relay 4 (N/O)	–	**11**	**12**	–	Relay 4 (N/O)
	Aux. Volts	(+)	**13**	**14**	(–)	Aux. Volts
	Earth	(⏚)	**15**	**16**	–	Relay 3 (N/O)
	Relay 3 (COM)	–	**17**	**18**	–	Relay 3 (N/C)
	Relay 5 (N/O)	–	**19**	**20**	–	Relay 5 (N/O)
	Relay 6 (N/O)	–	**21**	**22**	–	Relay 6 (N/O)
	Relay 7 (N/O)	–	**23**	**24**	–	Relay 7 (N/O)
	Earth 1A CT	Start	**25**	**26**	Finish	Earth 1A CT
	Earth 5A CT	Start	**27**	**28**	Finish	Earth 5A CT
Terminal Block 2	Status Input 5	(+)	**29**	**30**	(–)	Status Input 5
	Status Input 4	(+)	**31**	**32**	(–)	Status Input 4
	Status Input 3	(+)	**33**	**34**	(–)	Status Input 3
	Status Input 2	(+)	**35**	**36**	(–)	Status Input 2
	Status Input 9	(+)	**37**	**38**	(–)	Status Input 9
	Status Input 8	(+)	**39**	**40**	(–)	Status Input 8
	Status Input 7	(+)	**41**	**42**	(–)	Status Input 7
	Status Input 6	(+)	**43**	**44**	(–)	Status Input 6
	C Phase 1A CT	Start	**45**	**46**	Finish	C Phase 1A CT
	C Phase 5A CT	Start	**47**	**48**	Finish	C Phase 5A CT
	B Phase 1A CT	Start	**49**	**50**	Finish	B Phase 1A CT
	B Phase 5A CT	Start	**51**	**52**	Finish	B Phase 5A CT
	A Phase 1A CT	Start	**53**	**54**	Finish	A Phase 1A CT
	A Phase 5A CT	Start	**55**	**56**	Finish	A Phase 5A CT

Table 1 - Connection

6 Event Codes

IEC 60870-5-103

The relay has four groups of event codes with function codes 160 (IEC60870 overcurrent), 164 (Reyrolle overcurrent), 192 (IEC60870 line differential), and 196 (Reyrolle line differential). The event codes are shown in Table 2 to

Table 5.

The General Interrogation column indicates those events that are returned in a general interrogation sequence.

The type column determines the type of frame used (type 1 = Absolute time stamp, type 2 = Relative time stamp, type 5 = Initialisation).

The General Command column indicates which commands can be issued to the relay via the IEC60870-5-103 frame ASDU20.

The Measurand column indicates which measurands are returned via the IEC60870-5-103 ASDU4 frame. A private ASDU9 frame is also used to return the four local and remote currents.

All events are time stamped to a resolution of 1ms. There can be a maximum of 500 events stored in the event buffer as per the Argus range of relays.

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
A-O/C starter	64	•	2			Circuit breaker fail 1	85		2		
B-O/C starter	65	•	2			P/F-general HS trip	91		2		
C-O/C starter	66	•	2			E/F-general HS trip	93		2		
E-O/C starter	67	•	2								

Table 2 - IEC60870 Overcurrent Event Codes (Function code 160)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
A-lowset starter	1		2			E-HS1 trip	16		2		
B-lowset starter	2		2			A-HS2 trip	17		2		
C-lowset starter	3		2			B-HS2 trip	18		2		
E-lowset starter	4		2			C-HS2 trip	19		2		
A-lowset trip	5		2			E-HS2 trip	20		2		
B-lowset trip	6		2			A-HS1 starter	26		2		
C-lowset trip	7		2			B-HS1 starter	27		2		
E-lowset trip	8		2			C-HS1 starter	28		2		
A-delayed trip	9		2			E-HS1 starter	29		2		
B-delayed trip	10		2			A-HS2 starter	30		2		
C-delayed trip	11		2			B-HS2 starter	31		2		
E-delayed trip	12		2			C-HS2 starter	32		2		
A-HS1 trip	13		2			E-HS2 starter	33		2		
B-HS1 trip	14		2			Circuit breaker fail 2	39		2		
C-HS1 trip	15		2								

Table 3 - Private Overcurrent Event Codes (Function code 164)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
Reset FCB	2		5			Input4	30	•	1		
Reset CU	3		5			Trip circuit fail	36	•	1		
Start/Restart	4		5			Signalling Disturbed	39	•	1		
Power On	5		5			Alarm	47	•	1		
LEDs reset	19		1		•	A-Diff Starter	64	•	2		
Test Mode	21	•	1			B-Diff Starter	65	•	2		
Settings changed	22	•	1			C-Diff Starter	66	•	2		
Setting G1 selected	23	•	1		•	General trip	68		2		
Setting G2 selected	24	•	1		•	A-general trip	69		2		
Setting G3 selected	25	•	1		•	B-general trip	70		2		
Setting G4 selected	26	•	1		•	C-general trip	71		2		
Input1	27	•	1			General Starter	84	•	2		
Input2	28	•	1			CB Status	128		1		
Input3	29	•	1								

Table 4 - IEC60870 Line Differential Event Codes (Function code 192)

EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)	EVENT	CODE	GENERAL INTERROGATION	TYPE	MEASURAND (ASDU4)	GENERAL COMMANDS (ASDU 20)
Data lost	0		1			Output2	52	•	1		•
Internal Intertrip Sent	2		2		•	Output3	53	•	1		•
Internal Intertrip Received	3		2			Output4	54	•	1		•
External Intertrip 1 Sent	4		2		•	Output5	55	•	1		•
External Intertrip 1 Received	5		2			Output6	56	•	1		•
External Intertrip 2 Sent	6		2		•	Output7	57	•	1		•
External Intertrip 2 Received	7		2			Trip count alarm	70	•	1	•	
External Trip	8		2			CB maintenance alarm	71	•	1	•	
A-Diff Trip	9		2			Waveform stored	80		1		•
B-Diff Trip	10		2			Remote control interrupted	81		1		
C-Diff Trip	11		2			E/F-general trip	92		2		
Remote Test Mode	21	•	1			General alarm 1	121	•	1		
Setting G5 selected	35	•	1		•	General alarm 2	122	•	1		
Setting G6 selected	36	•	1		•	General alarm 3	123	•	1		
Setting G7 selected	37	•	1		•	General alarm 4	124	•	1		
Setting G8 selected	38	•	1		•	General alarm 5	125	•	1		
Input5	45	•	1			General alarm 6	126	•	1		
Input6	46	•	1			General alarm 7	127	•	1		
Input7	47	•	1			General alarm 8	128	•	1		
Input8	48	•	1			General alarm 9	129	•	1		
Input9	49	•	1			Ends In Synch	130	•	1		
Output1	51	•	1		•	P/F Guard	131	•	1		•

Table 5 – Private Line Differential Event Codes (Function code 196)