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Energy Division
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Installation and Operating Instructions
R.O.C.O.F Protection Relay

Crompton INSTRUMENTS

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Crompton R.O.C.O.F
Protection Relay
Embedded Generator Protection

Installation & Operating Instructions
Type 256-ROCL & Type 246-ROCL

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Section 1

Introduction

This product is designed for applications where a generator is running parallel with a mains supply either from a utility or other generators.

This protection relay is specifically designed to protect the mains from the potential damaging effects of asynchronous generator output.

It is designed to detect disconnection of a generator from the network and trip the generator's circuit breaker. For optimum safety each generator should have its own protection relay.

This relay senses a Vector shift and a Rate Of Change Of Frequency (R.O.C.O.F) as measurement parameters as part of UK Utilities recommendations G.59/1 and ETR 13.

1. This product is intended to be used with gensets. The applications for gensets can be grouped as follows:-

   Single stand alone use:

   Standby Emergency replacement for (part) load supply (UPS)

Mobile	Temporary local islanded load supply
Independent	Full time local islanded load supply with optional CHP

   Networked use:

Co-generation	Multiple gensets connected together, or Single or multiple gensets connected to a Utility grid.
Uninterruptible Power Supplies (UPS)	Full or part time running, connected to or switching over from the Utility supply.
Base Load	Full time base load supply, via Utility connection
Peak lopping	Part time peak load supply, via Utility connection
Combined Heat and Power (CHP)	Full time load supply, normally via Utility connection with waste heat recovery.

2. This protection relay is intended to be used with networked gensets as listed above. In this application, the gensets used are connected to the Utility grid at least part time, and therefore require the specific protection provided by this relay as explained below.

   Due to a lightening strike or other fault on the network the automatic reclosers on the network line will disconnect momentarily to clear this fault. During this fault clearing period the islanded generator will drift slightly out of synchronism with the grid. Having cleared the fault, which may take less than a second, the auto reclosers would then attempt to reconnect the grid to an unsynchronised genset. Other faults may occur on the network, but however long the fault clearing process takes, it is clearly important to have high speed detection of the genset having become islanded.

3. Problems which may arise are:-
   - The genset attempts to keep the remains of the network and the attached load live. The remaining load may be too large for the genset to handle and instability may occur, which may damage certain loads.
   - Personnel working on the lines would be subject to the hazards from a live genset in the area.
   - When faults have been cleared, the network would be connected to an out of synchronism genset, with damaging results.

4. Utilities require that their approval be given before the gensets are connected to the grid, and that protection devices with known performance are installed. Requirements vary with countries and with application.

5. When a genset becomes islanded, the output voltage and frequency do not necessarily change a large amount: this will depend on the remaining load size relative to the generator capability. Therefore voltage and frequency relays cannot be relied upon.

6. The loss of mains relay should detect a shift in phase between generator and the supply. This phase angle should be less than the angle used when synchronising the generator. Additionally, allowance must be made for time taken for the circuit breaker to have moved into the open position, and consideration should be given to the time it takes for the auto recloser to have completed its reclosing process.

7. Preferred methods of detection of loss of mains are Rate Of Change Of Frequency and Vector Shift.

8. The Vector shift relay measures the length of each cycle of the voltage wave. At the moment a genset becomes disconnected, the sudden change in load causes a sudden change in cycle length. The single cycle becomes shifted with time: it takes longer or shorter. The speed of sensing is fast enough to complete the opening of the genset main circuit breaker before the auto recloser completes reclosing. Hence the Vector shift relay is an excellent method of detecting disconnection from the gird.

9. The R.O.C.O.F. relay senses stability of the frequency. A genset in routine operation will have a normal frequency excursion due to changing loads and the compensated fuel inlet. These frequency excursions are small. The rate at which the frequency changes inside these excursions is relatively high compared with those of a large network. The speed of sensing is fast enough to complete the opening of the genset main circuit breaker before the auto reclosers complete reclosing. Hence a R.O.C.O.F. relay adjacent to the genset is also an excellent method of detecting disconnection from the grid.

Benefits

- For G59 duty.
- Professional, small, economical, versatile.
- Simple to install and operate
- Permits fast, reliable and accurate mains failure detection to protect grid, load, and the generator.
- Provides continuous supervision; simultaneously using both vector shift and rate of change of frequency functions in one unit, which monitor power quality and disconnections.
- Improved discrimination between operational switching effects and true grid disconnections.
- Fault values, which caused a trip, may be accurately read using the data output.
- Special advanced algorithm, design to avoid nuisance trips.

Features

Specifically designed to comply with Utility requirements, G.59/1, ETR 113, and other recommendations and approvals.

- Unique new algorithm.
- Continuous self supervision.
- Controlled power up/down.
- Status and fault indication.
- Digital data and status output.
- Status LED's show: Mains on, Vector trip, R.O.C.O.F trip, near trip. Input live and being monitored.
- 2 to 24° phase shift. 0.1 to 1Hz R.O.C.O.F
- Remote health check indication and reset feature.
- Continuous monitoring for phase steps and rate of change of frequency.
- Separate LED's to indicate type of trip: Vector (=phase step) or rate of change of frequency.
- Internal self check functions control the LED marked 'Self Test OK' and the health status output relay. On detection of any of the following, this LED will go out and this relay will move to the 'not ready' state:
  - input signal level too low to support valid measurements
  - auxiliary supply too low to support operation of the unit
  - either of the two watchdog circuits timing is out
  - detection of an internal maths error condition, possibly as a result of the input frequency being too high.
- External input to inhibit ("holding off") the operation of the unit until other external monitoring or control functions have stabilised e.g. generator has synchronised and been connected to the grid.
- Changeover relay contacts to indicate that the unit is monitoring the input signal.
- Changeover relay contacts to indicate that the unit has detected signal conditions causing a trip.

- User selectable delay of 2-12 seconds starts after;
  a) unit completion of self test and initialisation routine and/or
  b) release of the hold off function provided by the inhibit terminals. (whichever is the latest).

- User selectable setting of phase step (vector shift) from 2 to 24° with a resolution of better than 2° using the data output.

- User selectable setting of rate of change of frequency from 0.1 to 1.0 Hz/second in 0.05 Hz/second steps (visible using the data output).

- Fibre optic output for software display of:-

  Waveform Frequency
  Vector shift set point
  Vector shift value when trip occurred
  R.O.C.O.F. set point
  Present R.O.C.O.F. value (i.e. this acts as a R.O.C.O.F. meter)
  R.O.C.O.F. value when trip occurred

Models Available

Model No. 256-ROCL or 246-ROCL may be ordered having one of the following standard voltages:

110, 120, 220, 230, 240, 380, 400, 415.
Exceptionally, any voltage in the range 63 to 480V will be considered.

This model covered the frequency range of 40 to 70Hz.

Order Code:

256 – ROCL
246 – ROCL

Please also supply the Voltage requirement, bearing in mind this relay can be connected Line to Neutral, but preferably should be connected Line to Line.

Label code details
for product identification

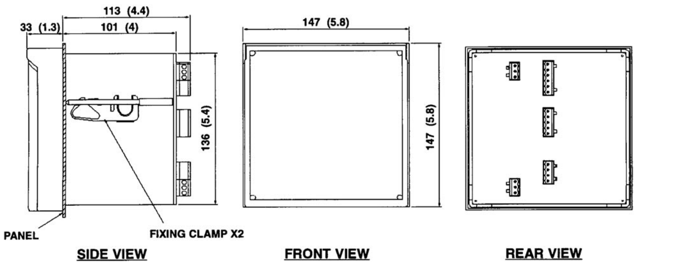
256 – ROCL - ??BX – C2??
246 – ROCL - ??BX – C2??

C = 3 Wire
L = G 59 Spec
Input Voltage
Relay Output
C2 = 40 / 70 Hz
Aux. Volt See Input Voltage Code

110 V = PM
120 V = PQ
220 V = R4
230 V = RQ
240 V = RR
380 V = RU
400 V = SC
415 V = SB

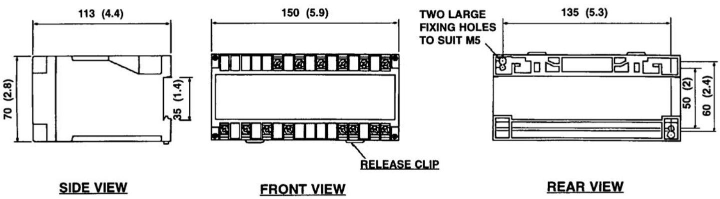
Dimensions

Model 246



All dimensions are shown in mm with inches in brackets

Model 256



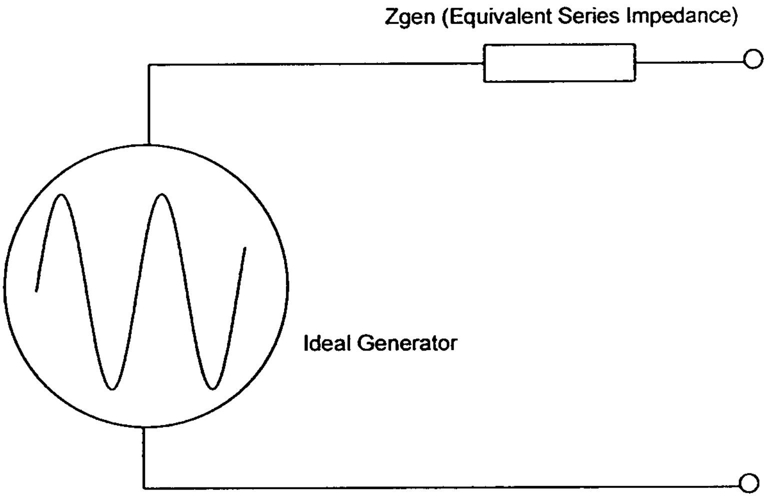
Crompton INSTRUMENTS

Section 2

Technical

Theoretical Considerations

The Vector Shift Concept
Any generator may be represented by an "Ideal Generator" i.e. a generator with a source impedance of zero, and an equivalent series impedance (See Figure 1). When operating at no load the signal at the output terminals of the generator will be identical to that of the ideal Generator. However, when a load is applied there will be a voltage drop and attendant phase shift across the series impedance.



When paralleling a generator to the mains supply it is necessary to ensure that the Output voltage of the generator (by definition at no load) and the voltage of the mains are equal to within close limits, and that the phase of the two waveforms (which includes frequency) is similarly equal to close limits, at the instant of connection very little current flows.

In order for the generator to deliver power to the mains, current must flow in the series impedance resulting in a phase shift (Vector Shift) of the signals between the mains and the "Ideal Generator".

It may now be seen that if the mains is removed and the generator experiences a relatively large change in load (in either direction) then there will be a near instantaneous change in the phase shift across the series impedance of the generator. See fig 3. The equivalent series impedance and resultant phase step magnitude versus load changes may be calculated if the generator characteristics are known but this is beyond the scope of this document.

This protection relay continually monitors the phase of the signal waveform compared with that of preceding samples and looks for the instantaneous change in phase. The unit can produce a signal to disconnect the generator from the mains within two cycles of the signal waveform.

On start up, the unit trip circuit may be inhibited for a period to allow for synchronising and stabilising of the system after initial paralleling using either the “inhibit” connections or simply setting the delay timer.

Product Internal Function

The product has a separate signal and an auxiliary supply input, for self powered situations these terminals are connected in parallel externally.

The auxiliary input is transformer coupled, rectified and regulated to generate the single supply used by the product. The auxiliary input is monitored by two DC supply monitors, the first, monitoring the unregulated supply determines when the supply is high enough for the unit to start. A second monitor on the regulated supply will force the product into the reset condition if the regulated supply falls below the level at which reliable operation can be maintained.

The signal input is transformer coupled and then passed through surge protection devices and a low pass filter before being converted to a square wave by the zero crossing detector.

The square wave signal is connected to two inputs of a microprocessor which is used to determine the period between consecutive rising edges and the periods between consecutive falling edges, see figure 2.

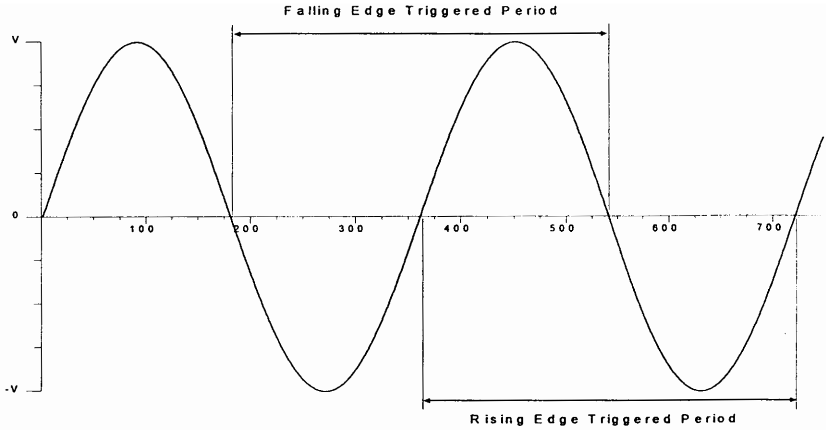


Figure 2

The microprocessor holds 32 consecutive periods in a cyclic butter from which it determines the present average period of the incoming waveform called the "current average".

Each cycle of the square wave signal is compared with the "current average" and any deviations from the average which exceed the limits determined by the vector shift setting read from the front panel potentiometer will initiate a potential vector shift trip.

The unit will wait for the next period of the input waveform to qualify the vector shift trip.

There are a number of possible conditions, which determine the qualification of a vector shift, but basically these may be summarised as:-

"A vector shift will be confirmed if a change in input waveform period is present for not more than one cycle and that the period of the waveform after the disturbance has returned to the average period as calculated before the disturbance".

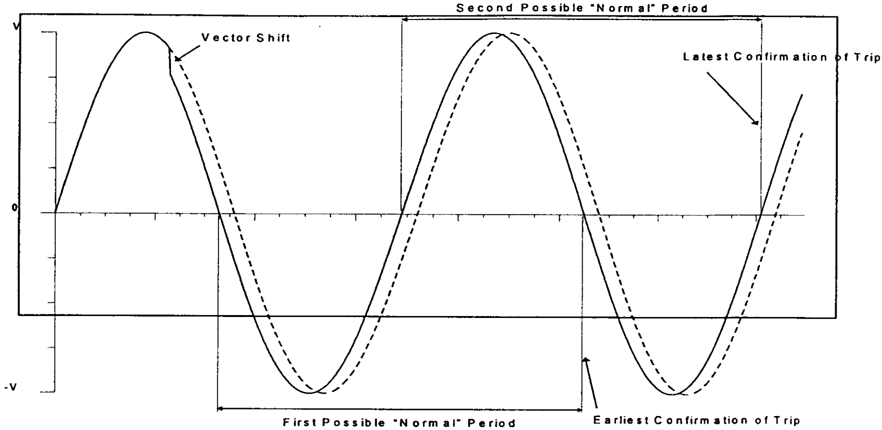


Figure 3

After checking for vector shifts the unit will use the cyclic buffer contents to calculate the rate of change of frequency of the input waveform. The calculated rate of change of frequency is compared with the set point as determined by the front panel potentiometer.

The front panel contains a further potentiometer marked “delay”. The position of the potentiometer determines the period from the end of the initialisation sequence or release of the “inhibit” function (whichever is the latter) before which the vector shift and R.O.C.O.F. detection is enabled. It must be emphasised that this is not a delay from the detection of phase step to relay operation the unit is designed to have a fast response hence there would be little point in introducing a variable delay into the process. The delay is intended to permit the use of the unit in situations where a delay is required from an external event, e.g. generator synchronised to the mains, before monitoring is enabled.

Initialisation

The initialisation period for the unit will require a minimum of 64 cycles of the input waveform to flush the cyclic buffer and averaging routines. The unit will not detect a trip condition during this initialisation period.

Self Test OK. Status o/p

Following the end of the initialisation period and at the expiry of the “delay” period the “self test OK” light emitting diode (LED) will illuminate and the status” relay will energise. This LED and status relay will remain active until any internal errors are detected (auxiliary supply low, maths error, watchdog time-out) at which point the LED will extinguish, the status relay will return to the “not ready” state. The unit will then attempt to restart.

Near Trip LED

As previously stated the vector shift detection algorithm uses a second cycle to confirm the vector shift. In situations where the vector shift is not confirmed e.g. transient signals large enough to pass through the low pass filter and generate additional zero crossings or step changes in frequency, the “near trip LED” will illuminate briefly. This indication may be useful in identifying potential system problems e.g. the presence of interference.

Vector Shift Trip

This LED will illuminate whenever the unit detects a vector shift trip. The LED will remain illuminated and the trip relay will remain energised until one of the following conditions is met.

1. Auxiliary supply removed (and returned).
2. Signal removed (and returned).
3. External reset terminals shorted together.
4. Reset button held down until “self test OK” LED extinguishes.

R.O.C.O.F. Trip

This LED will illuminate whenever the unit detects a rate of change of frequency trip. The LED will remain illuminated and the trip relay will remain energised until one of the following conditions is met.

1. Auxiliary supply removed (and returned).
2. Signal removed (and returned).
3. External reset terminals shorted together. Reset button held down until “self test OK” LED extinguishes.

Reset Switch

The reset button, when held depressed will cause the unit to restart. The switch operates by forcing the watchdog to time out and thus provides a natural defence against inadvertent operation, the switch must be held depressed for the full term of the watchdog timer. A momentary operation of the switch will be ignored. Successful operation is identified by the SELF TEST OK will extinguish when the unit restarts. If the reset switch is held depressed the front panel LED's will illuminate periodically as the unit attempts to restart.

External Reset Contacts

The external reset contacts provide a method for resetting the unit remotely. It must be emphasised that these contacts are not isolated from the unit internal power supply and only "Basic insulation" is provided from both auxiliary and signal connections.

It must be emphasised that these contacts are not isolated from the unit's internal power supply and thus only "Basic Insulation" is provided from both auxiliary and signal connections.

Connecting these terminals together through impedance of less than 1k ohm will force the unit into the reset condition. The unit will perform self check procedures up to the point of illuminating the front panel LED's and then wait for the reset terminals to be released (greater than 10k ohm) before continuing. Holding these terminals in the reset state is a convenient way of performing the lamp test function.

Inhibit Contacts

Inhibit input is marked "CONTROL" on unit. The inhibit contacts provide a mechanism for preventing the unit from detecting vector shift or rate of change of frequency trips.

It must be emphasised that these contacts are not isolated from the unit's terminal power supply and thus only "Basic Insulation" is provided from both auxiliary and signal connections.

Connecting these terminals together through an impedance of less than 1k ohm prior to resetting the unit will disable the detection of signal trip conditions until the contacts are released (greater than 10k ohm).

NOTE: If the contacts are connected together after the self test OK LED has illuminated will have no effect. The unit only uses this signal at power up.

The self test OK LED will not illuminate until the inhibit terminals are released (impedance of greater than 10k ohm) and the delay period has expired.

Vector Shift and R.O.C.O.F.

Although there is no interconnection between the vector shift and the R.O.C.O.F. setting, it must be stressed that they are not independent.

In operation, the unit will exclude any potential “vector shift” periods, i.e. periods which exceed the vector shift trip criteria, from the “running average cyclic buffer”. Hence if the vector shift trip is set to a minimum of say 2°, and the input signal is changing frequency at a rate which continually generator potential vector shifts 2° per cycle (at 40Hz this is approximately 10Hz/second), the near trip LED will illuminate and the Vector Shift Trip will not operate.

Having detected two cycles with a potential vector shift, the vector shift algorithm identifies a potential change of frequency and will temporarily disable itself until the cyclic buffer has refilled, (minimum of 32 cycles, maximum of 63 cycles), thus allowing the rate of change of frequency detection algorithm to operate.

Conversely, if the vector shift trip point is set high then a vector shift below the trip point will be allowed to enter the cyclic buffer and may itself generate a ROCOF trip.

There is a relationship between phase steps entering the cyclic buffer and the rate of change of frequency. For 50Hz this is:-

R.O.C.O.F (Hz/Second)	Phase Step (Degrees)
0.05	2
0.1	4
0.15	6
0.25	8
0.30	10
0.35	12
0.40	14
0.45	16
0.50	18
0.55	20
0.60	22
0.65	24

What this means is that for each of the R.O.C.O.F trip level settings in column one, the corresponding Phase Step values in column two should not be exceeded. This general rule need not be adhered to. If it is not adhered to, then a trip, which shows up as R.O.C.O.F. may in fact have been Vector Shift.

Limits of Operation

As previously mentioned there is a low pass filter in the input stages to the product to reduce the susceptibility to interference. One effect of this filter is that it “slows down” the fast edges associated with any vector shift. For very large vector shifts this filter may cause the vector shift to “spread” across two cycles of the waveform, and, as described above, the vector shift qualifying algorithm will reject the vector shift if two consecutive cycles exhibit period which exceed the vector shift limit determined by the front panel potentiometer. In the majority of applications this effect is unlikely to cause any problems, however, the maximum vector shift which can be reliably detected when the unit is set to its maximum sensitivity of 2° is 50°.

Note: This characteristic is valid for 50Hz operation, for other frequencies please contact Crompton Instruments.

Vector Shift and R.O.C.O.F Relay

Specification

INPUT:	110, 120, 220, 230, 240, 380, 400, 415V
Range:	-50%, + 50%
Frequency:	40 to 70 Hz
Harmonics:	The monitored waveform must be free from harmonic oscillations near the zero crossover points
Burden:	0.1VA
Overload:	+50% continuous
OUTPUT:	Volt free relay contacts
Relays:	1x status, 1 x fault
Contacts:	Single pole changeover
Rating:	240V, 5A ac, resistive
Operations:	0.2 million
AUXILIARY SUPPLY:	Same as input voltage
Frequency:	40 to 70Hz
Burden:	4VA
Range:	+/-20%
PERFORMANCE:	
Setting Accuracy:	Vector Shift better than 1° R.O.C.O.F 0.05 Hz/s
Temperature Range:	0 to 50°C normal -10 to 50°C extended Performance may not meet published specification but the unit will not sustain permanent damage in this range
Storage Temperature:	-10 to +70°C
Response time:	Phase angle shift: up to 2 cycles +5ms relay time Frequency rate change: 3 to 32 cycles +5ms relay time
Isolation:	BS 142, Section 1.3
Safety:	BSEN61010 – 1993 AMD 8961 1996
EMC:	BSEN 50081-2 emission BSEN 50082-2 immunity

RESOLUTION:	
Delay Range:	0.1s
Phase angle shift:	0.5° at 50/60Hz
Frequency rate change:	0.1Hz/s
PHYSICAL:	
Vibration:	BSEN60068-2-6
Housing:	256 DIN rail or surface mount; 70mm (h), 150mm (w) 112.5mm (d) Weight: 0.8kg
USER ADJUSTMETNS:	Initial auxiliary supply switch-on delay (supervision delay): 1 to 10s Phase angle shift: 2 to 24°. Frequency rate change: 0.1 to 1Hz/s
REMOTE CONTROL:	
Reset:	Interrupt auxiliary supply, press reset button or c onnect remote reset contacts
Inhibit:	For switch-on delay >10s close inhibit contacts
INDICATORS:	
Green:	1. Auxiliary on 2. Unit active, switch on delay expired on self test OK
Yellow:	Near trip
Red:	1. Vector trip and relay energised 2. R.O.C.O.F. trip and relay energised.

Product construction

Model 246

The protection relay is housed in a 144 x 144 DIN 43700 panel mounted case. Two PCB's are used, one holding the transformers and relays, one holding the electronics.

Connections to the unit are made via plug and sockets arranged so that, with the exception of the control and rest lines, the plug / socket combinations are unique.

The control and reset lines are connected using opposite connections in order that incorrect connection of system wiring will result in "non operation" to aid fault finding.

Model 256

The protection relay is housed in an industry standard DIN and surface mount ABS case. Only one PCB is used, which holds all the electronic components as well as the transformers and relays.

To enable this efficient use of space, a double sided PCB is used, which contains the EMC screening. The microprocessor is fitted in a plug-in socket which makes for convenient updating of the software to later issues if the system expansion makes this desirable.

The contraction is strong and rigid, in line with other Crompton Instruments protection relays, and is ideal for mounting in a floor standing or wall hanging panel rather than fitting onto the generator itself.

Section 3

Interfacing

Installation

For reliable operation the unit's signal connections should be connected as close to the generator as is practical. The unit uses the vector shift produced by the generators characteristic impedance when the generator load changes. Any additional impedance introduced by bus bars etc., which could introduce vector shifts during normal operation (not mains failure) should be avoided in the connection to the unit as it may be necessary to "de-sensitise" the vector shift trip point to avoids nuisance trips.

EMC Instructions

While all practical measures have been taken to avoid the susceptibility to Radio Frequency Interference (R.F.I) when used in particularly noisy environments, consideration must be given to providing a screened environment for the product. The unit has been designed to comply with Industrial Immunity Specification EN 50082-2, to withstand voltage surges of 4kV peak and to comply with the limits of emissions detail din EN50081-2.

It is recommended that external Surge Suppression Barriers are introduced into the Auxiliary and Signal connections in situations where 4kV surges are anticipated, as a guide the surge protection barrier should limit the output voltage to 2kV.

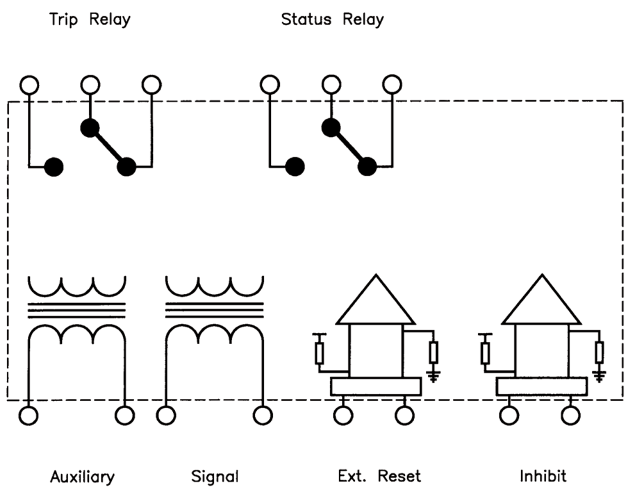
The "Inhibit" and Reset" connections are not electrically isolated from one another and should be connected using cable incorporating a common screen to prevent differential signals entering the unit along these lines. The screened cable used for the Inhibit and Reset connections should be segregated from sources of electrical noise.

Low Voltage Directive

This product complies with BS EN 61010-1: 1993 AMD 8961:1995 for:
Permanently connected use
Normal Condition
Basic Insulation
Installation Category III
Pollution Degree 2

Warning: All terminals are for use only with equipment which has no live parts which are "Accessible" and that the insulation for external circuits is suitable for "Single Fault Conditions".

Interface Diagram



Fusing Recommendation

The unit does not have internal fuses therefore external fuses must be used in the auxiliary and signal connections for safety protection under fault conditions.

The peak input current for the auxiliary may be calculated using the expression:
Peak Current (Amps) = 33 / Nominal Voltage. This peak current will decay exponentially over approximately 10 cycles of the auxiliary supply.

The peak input current for the signal is not affected by a start-up period it is determined from the signal burden.

Data Output Protocol

The fibre optic data output provides the following data:-

9600 Baud, 8 bit data, 1 stop bit, No parity.

The data is generated in blocks of four characters separated by carriage returns. There are no line feeds between the blocks so it may be necessary to introduce these on the receiving terminal in order that a clear display is produced.

AAAA
BBBB
CCCC
DDDD
EEEE
FFFF

Where each of the characters A to F indicated above may be any of the hexadecimal characters 0 through to F.

1. The first line represents the present period between consecutive rising edges, to change this to the value of the frequency of the "Signal" input, convert the number to hexadecimal, multiply by 0.5E-06 and reciprocate:

   Frequency (Hz) = 1/Hex (AAAA) * 0.5E-6)

2. The second line represents the setting of the "Vector Shift" potentiometer, to change this number to degrees, divide it by the present period and multiply by 360:

   Vector Shift Setting (Degrees) = (Hex(BBBB)/Hex(AAAA)) * 360

3. The third line will remain at zero until the unit trips on a phase step, at this point it will contain the period of the cycle which caused the trip. To change this number to the phase step in degrees, subtract the present period, divide the result by the present period and multiply by 360.

   Phase Step Trip value (Degrees) =
   ((Hex (CCCC) – Hex (AAAA)) / Hex (AAAA) * 360

4. The fourth line represents the current Rate of Change of Frequency in 0.05 Hz/Second increments. To change the number to the rate of change of frequency in Hz/second multiply by 0.05.

   R.O.C.O.F (Hz/Second) = Hex (DDDD) * 0.05

5. The fifth line represents the setting of the R.O.C.O.F. potentiometer in 0.05 Hz/second increments. To change the number to rate of change of frequency in Hz/second multiply by 0.05.

   R.O.C.O.F. Limit Setting (Hz/Second) = Hex(EEEE) * 0.05

6. The sixth line will be zero until the unit trips on the rate of change of frequency at this point it will contain the rate of change of frequency at which the unit tripped in 0.05 Hz/second increments. To change the number to the rate of change of frequency in Hz/second multiply by 0.05.

   R.O.C.O.F. Trip Value (Hx/second) = Hex(FFFF) * 0.05

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