7SG17 Rho 3

Multifunction 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

Contents

1. SELECTION OF PROTECTION FUNCTIONS

The 7SG17 relays incorporate a number of protection functions for the protection of induction and synchronous motors and may be scaled to suit the particular application. When selecting the relay and functions some general considerations are as follows:-

- Motor load e.g. pump, fan, compressor, conveyor etc.
- Frequency of operation
- Whether the motor incorporates RTD devices to monitor winding and bearing temperatures
- Whether the motor incorporates a speed switch
- Motor rating

When applying the relay, individual protection functions may be enabled as required and are defined in detail in the Description of Operation.

2. MULTIFUNCTION APPLICATIONS

As a typical example, consider the protection of a 4 pole induction motor with the following parameters:-

Rated voltage:	6.6KV
Rated output power:	800KW
Power factor:	0.85
Efficiency :	95.5%
Starting:	Direct on line
Controlled by:	Vacuum circuit breakers
Locked rotor current:	5 x full load
Run-up time:	4 secs
Safe stall times:	
Starting (cold):	11 secs
Running (hot):	7 secs
Permitted number of Starts per period:	2 per hour (hot)

$$Input\ power = \frac{Output}{P.F. \times efficiency} = \frac{800}{0.85 \times 0.955} = 985KVA$$

$$Full\,load\ current = \frac{KVA}{\sqrt{3}\,kV} = \frac{985}{1.73 \times 6.6} = 86.2\,Amps$$

2.1. C.T. Ratio

The C.T. ratio should be chosen as equal to or the next standard above the motor full load rating in this case choose 100 amp primary. The secondary could be either 1 or 5 amp. The modern tendency is to standardise on 1 amp, so choose a 100/1 ratio.

The relay thermal full load setting is:

$$\frac{MotorFLC}{CT\ Ratio} = \frac{86.2 \times 1}{100} = 0.86\,A$$

2.2.C.T Ratio Thermal Overload Setting

It is usual to choose a thermal overload setting above which the relay starts timing out, of 105%. This allows full utilisation of the output rating of the motor. In this case, this equates to 1.05 x 0.86 = 0.903. As the C.T. secondary is 1 amp the thermal overload (I_θ) should be set to 0.90.

Alternatively, if it is known that the rating of the motor is well in excess of the requirements of the drive, and the motor load current is therefore less than the motor rated current, a setting equal to or less than 1.0 can be employed. The thermal overload is then being employed to protect the drive and over protects the motor.

2.3.NPS weighting factors

The relay computes the positive and negative sequence components from the three phase input line currents. These are used to generate an equivalent thermal current Ieq which is calculated from the equation.

$$I_{eq} = \sqrt{I_1^2 + KI_2^2}$$

Where:
I_1 = Positive phase sequence current
I_2 = Negative phase sequence current
K = NPS weighting factor

K is settable on the relay from 0 to 10. If the motor supplier or manufacturer provides data giving the machine negative sequence withstand (NPS weighting factor), this figure should be used. If no figure is available, it is recommended that K be set to 4. Should this setting give nuisance tripping in service, the stored records should be studied and the motor manufacturer consulted before decreasing the weighting factor.

Negative sequence currents give rise to additional rotor heating, they produce a substantial rotor current at approximately twice system frequency. At this frequency, skin effects in rotor bars can cause significant rotor heating. Usually thermal limit curves supplied by machine manufacturers assume positive sequence currents only from a perfectly balanced supply. The relays are settable to give complete motor protection under all supply conditions.

2.4.Heating time constant, τh

The relay heating time constant τ_h is settable from 0.5 to 100 minutes in 0.5 steps, figure 1 shows the family of curves. Using the example of the motor parameters quoted under item 2 above and reading values from Figure 1:-

At a locked rotor current of 5 x FLC (which is about the starting current) and a run-up time of 4 seconds and allowing two consecutive starts i.e. 8 seconds total run-up time, the τ_h value from figure 1 is just over 3 minutes. As the safe stall time from cold is 11 seconds, the τh value could be set to 5. The stall time from hot, i.e. 7 seconds gives a τ_h value of 3. If this lower value of 3 is chosen, there is the possibility of nuisance tripping after the motor has been in service for some time with longer run-up times and higher currents. It would be better to select the value of 5 which allows two starts in quick succession. Of course, if the actual τ_h heating time constant of the motor is given by the manufacturer, then this figure could be set on the relay.

2.5.Starting time constant, τs

When a motor is running at full design speed, the airflow and ventilation is designed to give optimum cooling. On starting, the current is nearly the stall value but the ventilation is reduced. If this time constant is known, it can be set on the relay. If not, then set the time constant (settable 0.5 to 1.5 of the heating time constant τ_h) to 1.0, i.e. the same as τ_h. The time constant switches from τ_h to τ_s as current levels above the set value of I_{START}. When τ_s is set below 1.0 x I_θ, this feature assists in ensuring that a stall on start up does not exceed the motor withstand time. However where the stall withstand time (e.g. from 'hot') is less than the run-up time it is still necessary to provide a tachometric speed switch on the rotor shaft as described previously. The time constant switches from τ_h to τ_s at current levels above the set valve of I_{START}

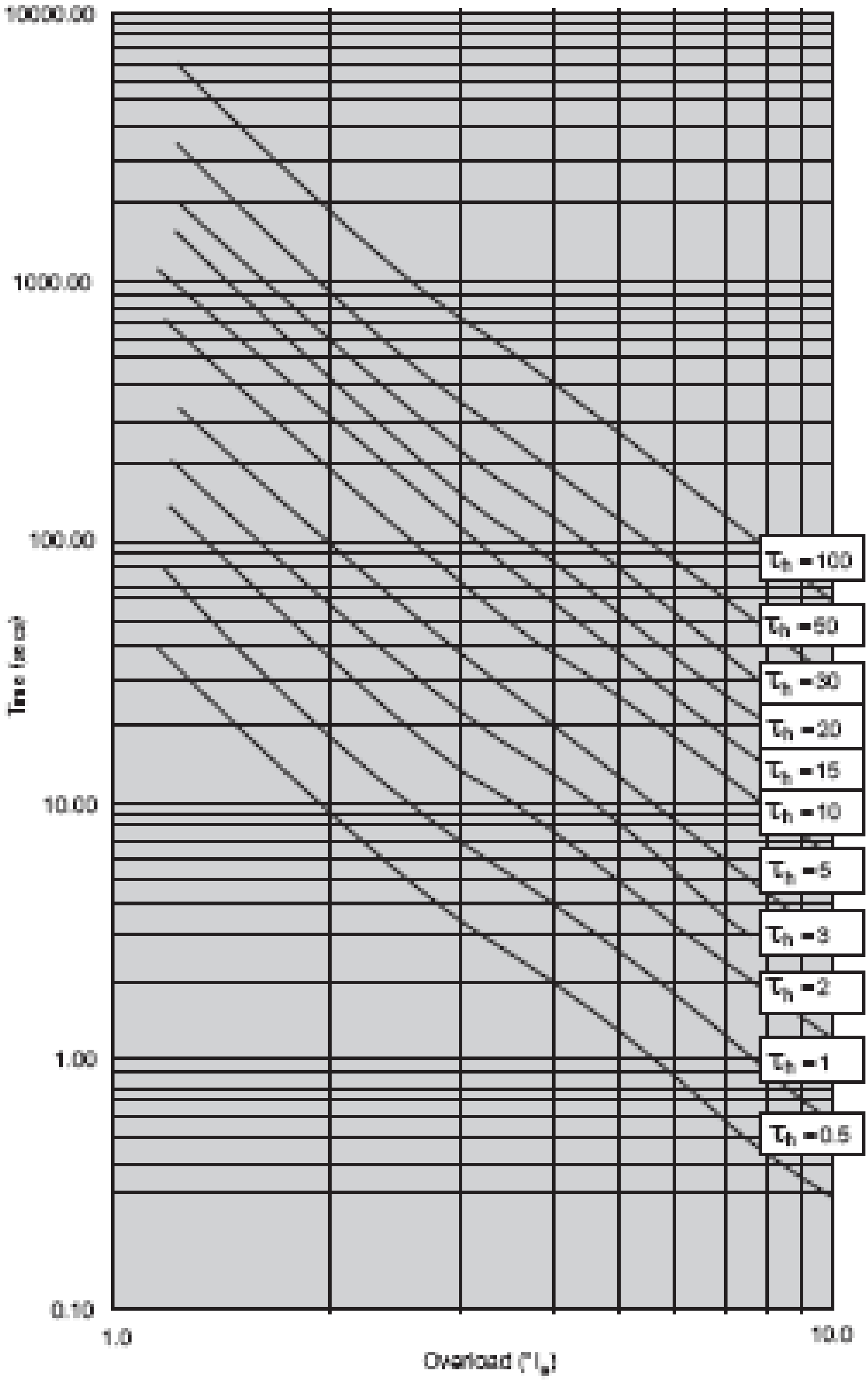


Figure 1 - Thermal overload (cold) characteristics

2.6. Cooling time constant, τc

When a motor is switched off the rotor decelerates and eventually stops. During the run-down state and standstill state the motor windings will cool down but they are likely to have a different time constant for cooling than for heating up during running. This is because during the start-up and running state there is forced cooling experienced by the windings due to the rotor movement.

The cooling time constant of the motor is therefore always longer than the heating time constant for running. The factor of τ_c /τ_h is not specified by the motor manufacturer very often. Typical factors are 5 to 10 x, however for large motors which are totally enclosed and also ones that normally rely heavily on forced cooling due to motion of the rotor, the factor can be as high as 60x.

The net result of choosing a high value for τc is that it may not be possible to start the motor immediately after a shut down.

In this example, the cooling time constant has not been specified either as a time constant or as a multiple of its heating time constant. We will therefore choose 10x, which is the default.

2.7. Hot/cold curve ratio (hot spot weighting)

The relay allows adjustment of the Hot/Cold curve operating time ratio. This allows a weighting factor for motor winding hot spots to be applied. Motors with onerous hot spots are overdesigned for normal load and by selecting a high value of H/C it allows advantage to be taken of the overdesign for overload, i.e. longer operating time. Selecting the Hot/Cold ratio (H/C) to 100% (i.e. a high weighting factor) results in the relay indicating 100% thermal capacity being available when the motor has been running at full load for a sufficiently long time to reach steady after a motor-switch on. The hot and cold operating time curves are the same.

A low weighting factor would be 5%. Switching H/C to OFF is equivalent to H/C = 0. In this case, when operating at full load, the relay would indicate little thermal capacity available, e.g. 100% used. The hot operating time curve is then much faster than the cold.

An indication of the motor hot spot characteristic is the ratio of hot stall withstand to the cold withstand, τ_h/τ_c. With no hot spots (e.g. a cable) this ratio would be = 1.

In our example τ_h/τ_c = 7/11 = 0.64. The nearest H/C setting i.e. 65% should be applied to the relay. Note that at steady state full load current the relay will stabilize at 'Thermal Capacity Used' of 35% with this setting applied.

2.8. Thermal capacity alarm setting

This setting is expressed as a percentage of the thermal capacity set as above. It is settable 50 to 100% of the set capacity and gives an instantaneous alarm output if its setting is exceeded. Typically this would be set to 95%.hermal model

2.9. Load increase alarm setting ts1

This alarm is available to provide warning of a sudden increase of load. The alarm level is set as a multiple of the thermal overload setting (see 2.2). The range is 0.5 to 1.0 x I_θ and a sudden step increase above the set value will initiate the alarm if set.

2.10. Thermal restart inhibit setting

This feature is included to help prevent tripping of the motor during start if there is insufficient thermal capacity to satisfactorily complete the start operation. The calculation of this value is complex and requires motor parameter details not usually available. The practical setting recommended is to initially set this feature to 50%. During commissioning, before starting the protected motor, check the thermal state at the motor by accessing the "Thermal Capacity Used" display and note the value. The motor should then be started with its normal load and, when up to speed the "Thermal Capacity Used" display again checked. The difference between these two values indicates the magnitude of thermal capacity used to start. This amount must always be available before a restart is permitted. For safety, this figure should be multiplied by 1.25. For example, if 20% of capacity is used during starting, then 20% x 1.25 = 25%, and the Thermal Restart Inhibit Setting should be 75%.

2.11. Motor start current (ISTART)

The motor starting current is usually taken to be the same as the locked rotor current but the setting of ISTART should be less than this value. For the example given in 2.0, the value of 4 should be chosen.

2.12. Motor stop current

This current is the value at or below which the motor is considered to be stopped. It is usually set at 10%.

2.13. Stall and locked rotor protection (ts1 and ts2 settings)

The fundamentals of this protection feature are explained in the Description of Operation, 2.2. In the example being considered, the run-up time is 4 seconds and the safe stall time is 11 seconds. In this case the thermal characteristic gives sufficient protection for normal starting and a stalled motor condition can be detected by current/time grading. The time ts1 should be set to be longer than the run-up time and less than the safe stall time, in the example a time setting of 5 seconds should be chosen. If the motor starting time is equal to or exceeds the stall withstand time, it is necessary to have a tachometric ‘zero speed’ switch mounted on the rotor shaft. A voltage signal must be connected via this switch to a status input which is programmed to the ‘No Accel’ function in the status configuration menu. This effectively brings the timer ts2 into service. The switch is closed with a stalled motor and if the current exceeds the starting current set (I_{START}) then the timer ts2 will time out and will give a trip signal after its set time lag. On a healthy start, the switch will open thus stopping the timer. In this configuration, ts1, can be used to provide protection against excessive start time.

2.14. Circuit breaker fail protection (time delays 1 and 2)

The relay incorporates a two stage circuit breaker fail feature. If a designated trip relay operates and the circuit breaker fails to open, the protection algorithm continues to run for as long as current continues to flow. This combination of conditions is programmed to start a definite time lag feature designated “CB Fail 1”. This function can be programmed to energise an output relay when the C.B. fail time delay is completed. The contacts of this are wired to carry out a repeat trip or to trip another circuit breaker typically an incoming breaker. At the same time operation of this timer starts a second time lag feature designated “CB Fail 2” and if the trip outputs already initiated do not stop the current flow through the relay, another relay can be programmed through the output matrix to trip a further breaker eg. a bus section circuit breaker. The timers should be set to operate in 50mSecs plus the longest C.B. tripping time. The circuit breaker fail feature can also be used to implement a multi-stage tripping scheme.

3. OVER/UNDER CURRENT PROTECTION

These protection settings relate to major faults, e.g. short circuits and motor drive shaft failures.

3.1. Phase fault alarm setting (IHA) and time delay (tHA)

If it is necessary to monitor the instantaneous current of the motor, this feature can be employed to effectively act as a contact making ammeter. The time lag feature can be used to prevent operation for current surges.

3.2. Phase fault trip setting (IHS) and time delay (tHS)

This protection feature is supplied to detect and protect against phase faults occurring on the circuit between the controlling device and the motor, for example a fault in the terminal box. Note that if the motor controlling device (contactor or circuit breaker) is not rated to interrupt fault current, this feature should be turned off. Alternatively, this feature can be mapped to a separate output relay with contacts connected to trip a suitably rated upstream device. If this feature is selected, the current setting should be greater than motor starting current. To prevent operation for very short high value starting surges such as may occur in charging the cable between the switching device and the motor, or when power factor correction capacitors are installed, a time delay can be inserted. The delay should be fine tuned to the application such that it operates to isolate faults with a minimum time delay but rides through operational disturbances.

3.3. Earth fault alarm setting IEA and time delay (tEA)

These settings can be selected if required as in 3.1.

3.4. Earth fault trip setting (IEF) and time delay (tEF)

This feature protects against earth (ground) faults occurring on the protected circuits. Ideally, the earth fault input should be energised from a core balance C.T. In this case the time delay can be set to zero without risk of mal-trip at motor switch on. If the earth fault input is energised by the residually connected line C.T's a time delay must be introduced to overcome the transient neutral current that often occurs on motor starting. The actual time setting depends on the current sensitivity selected, the motor starting time and the C.T. characteristics. Typical times are about 0.3 sec but the value should be set as low as possible consistent with reliability and avoidance of nuisance tripping. Alternatively, it may be possible to use a stabilizing resistor to ensure stable, instantaneous tripping. Refer to our 'Application Guide for selection of stabilising resistor when employing residually connected earth fault input'.

3.5. Earth fault inhibit setting (IEI)

This feature is included to block operation of the earth fault device if the fault current is greater than the breaking capacity of a controlling contactor. If this is used, then the earth fault alarm contact can be used to issue a back-trip signal to an upstream circuit breaker.

3.6. Undercurrent protection

An undercurrent element protects against the no-load condition by measuring the RMS current in each phase. Alarm and trip outputs are provided. To prevent spurious trip operations when the relay is first energised or when a motor is disconnected, the undercurrent protection does not operate for currents below the motor stopped threshold I_{STOP}. This protection is typically applied if the protected motor drives a pump cooled by the liquid it pumps. In this case, loss of load may cause pump overheating. If the motor loading should never fall below 0.75 full load current, in the example given in 2.0, the undercurrent trip should be set at 0.7flc = 0.7 x 0.86 = 0.60 and the alarm set at 0.75 flc = 0.75 x 0.86 = 0.65. Time delays should be set to as low a value as possible - typically 1 sec. An undercurrent alarm is given if current falls below the undercurrent alarm setting I_{UA} in any phase (but not below I_{STOP}) for longer than the definite time delay t_{UA}. The undercurrent feature can be disabled. The various threshold setting ranges overlap. The user is responsible for ensuring that the motor stopped threshold is set below the alarm and trip levels, otherwise this protection feature will not operate.

To ensure correct discrimination between the motor stopped and loss of load conditions, the undercurrent protection has a minimum operate time of 200ms.

4. PHASE UNBALANCE PROTECTION

Fluctuations of current unbalance levels are typically caused by variations in the phase supply voltages. Note that a 1% voltage unbalance typically translates into a 6% current unbalance. In order to prevent nuisance trips, the pick-up level should not be set too low but, as current unbalance can cause serious rotor overheating the motor manufacturers recommendation as to the maximum allowable unbalance or negative sequence should be set. As short term unbalances occur, a reasonable time delay should be selected.

Separate protection is available for the conditions of phase unbalance, loss of phase and reverse phase sequence. This feature can be programmed to operate either as phase difference protection or as negative phase sequence overcurrent protection. It can also be disabled altogether. The Alternatives of Phase Difference and Negative Sequence Overcurrent Protection are given in section 2.5 of the Description of Operation.

5. NUMBER OF STARTS PROTECTION

This feature permits a limit to be set on the number of times which the motor may be started within a specified time interval. Settings are provided to allow the user to select the maximum permissible number of starts and the time interval within which these starts may occur. Once the maximum permissible number of starts have occurred within the defined period then starting is inhibited for the duration of the start inhibit delay setting.

Typically, two or three consecutive starts are permitted for a large motor which means that the motor and driven machine have to slow down to a stop before a start is attempted. The coasting down time may be many minutes and the time interval should reflect this. The motor manufacturer should be consulted, and if the start duty is severe then the manufacturer may impose a deliberate waiting time between starts, this must be set on the relay.

A start is detected by the relay when the current rises from zero to exceed the start current setting I_{START} already described in the section on stall and locked rotor protection. A restart is inhibited by the same output contact used for the thermal restart inhibit feature. The restart inhibit output is only energised after the motor has stopped (i.e. current falls below I_{STOP}) so that the start sequence in progress is not interrupted.

A further setting is provided to determine the minimum permissible time between two consecutive starts.

A ‘Start Protection Reset’ command is available in the ‘Maintenance Menu’ which allows the user to reset both the number of starts and the minimum time between starts features. This feature, if set, will prevent the operator from jogging the motor. Jogging is defined as multiple starts and stops that are performed in quick succession.

6. OPTIONAL TEMPERATURE INPUTS

An optional version of the relay incorporates 8 temperature inputs to allow direct temperature monitoring of parts of the motor. The inputs are user programmable to accommodate resistance temperature detectors (RTDs) and thermistors. Different types of inputs cannot be mixed. Each input may be independently programmed to provide alarm and trip thresholds giving instantaneous outputs. These can all be de-activated by programming the settings to OFF.

Temperature inputs are usually incorporated in the motor by the manufacturer and the types and characteristics should be obtained from the supplier.

6.1 RTD Inputs

RTD inputs may be selected from a number of types, namely 100Ω Platinum (standard type DIN 43760), 100Ω Nickel, 120Ω Nickel, 10Ω Copper or ‘other’. The named types have reasonably linear, known characteristics and the measured resistances are converted into temperatures between -50°C and +250°C and displayed. Alarm and trip settings are also programmed in terms of temperature. If the ‘other’ type is selected then measurements and settings are displayed as resistances up to 350Ω.

6.2 Thermistor Inputs

Thermistor inputs may be selected as either positive or negative temperature coefficient types (PTC or NTC).

Thermistors are available with a wide range of generally non-linear characteristics and so settings and displays are given in terms of resistance. Values between 100Ω and 30kΩ are accommodated. For PTC type devices, the protection operates when resistance is measured above the applied setting. For NTC type devices, the protection operates when resistance is measured below the applied setting.

6.3 Detector failure protection

Each active temperature input can be monitored for short circuit and open circuit failure. A temperature input fail alarm output is generated by a failure condition and the failed input is identified in the Instruments Menu. No trip or alarm output is given by a failed input. This feature can be disabled.

6.4 Detector gating

Further security is provided by allowing each temperature input to be AND gated with any other input. If this feature is selected then no trip will be issued unless both gated inputs detect temperature (or resistance) above the trip setting. The temperature input alarm outputs are not subject to gating.

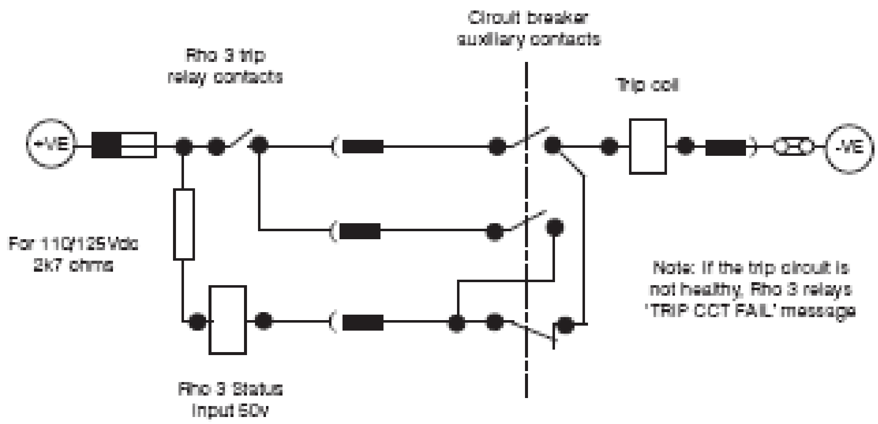
7. OTHER FEATURES

7.1 Trip circuit supervision

Based on the Electricity Association standard schemes referenced H6, a status input on the relay can be used to supervise the trip circuit with the associated circuit breaker open or closed. A low value of d.c. current is passed through the entire trip circuit to monitor the trip coil, its auxiliary switch, the CB secondary isolating contacts and the relevant wiring. If monitoring current flow ceases, the energised status input drops off and if it is user programmed to operate one of the output relays, this relay gives a contact output to signal trip circuit fail. In addition, the LCD display on the Rho relay and any PC connected via the fibre optic communication port and running Reydisp software can be programmed to indicate “Trip CCT Fail”.

To avoid giving spurious alarm messages while the circuit breaker is operating, the status input should be programmed to have a 500mSec drop-off delay. The schemes are shown in figure 1.

Figure 1 - Rho 3 - Trip circuit supervision



ELECTRICITY ASSOCIATION H6 SCHEME