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. INTRODUCTION

The 7SG17 is a multi-function numerical Motor Protection relay suitable for all types of a.c. induction motors up to the highest ratings available. Whilst medium voltage 3-phase motors are very reliable and robust, modern designs operate much closer to their thermal limits and to give adequate protection sophisticated protection relays are required. In addition, increased industrial use of power electronics leads to corruption of power systems and unless specific equipment is installed to eliminate the corruption it can cause considerable rotor overheating. The relay has been designed to protect the motor against these phenomena as well as known abuses such as mechanical overload, stalling, single phasing, terminal box and cabling failures, and too frequent starts. The relay can be set to accurately mimic both the heating and cooling characteristics of the protected motor and consequently ensure that the thermal withstand of the machine is not exceeded, at the same time allowing full use of the motor's thermal capability.

2. FUNCTIONS

2.1 Thermal overload protection

The main protection characteristic of the Rho range conforms to IEC60255-8 (Thermal Electrical Relays) which defines a 'cold' operating characteristic of:

$$t = \tau.\mathrm{Ln}\frac{I^2}{I^2 - (k.I_B)^2}$$

Where:
t = operating time (minutes)
τ = time constant (τh for 7SG17)
I = relay current
I_B = basic current
k = constant

Basic current I_B is equivalent to the full load current of the protected motor. Constant k is a multiplying factor resulting in the thermal overload setting of the relay I_θ (i.e. $I_\theta = k.I_B$)

If a protected motor has been running for a period of time then the IEC60255-8 'hot' operating characteristic becomes applicable for calculation of relay operating time:

$$t = \tau.\mathrm{Ln}\frac{I^2 - I_P^2}{I^2 - (k.I_B)^2}$$

Where:

I_P = steady state relay current prior to the overload

Note that there are actually an infinite number of operating curves for different values of load current from the cold state to full load.

2.1.1 Equivalent thermal current

Positive and negative phase sequence components are calculated from the three phase current inputs. These are then used to generate an equivalent thermal current Ieq which takes the place of the relay current in the IEC60255-8 operating characteristics. The equivalent current is defined as follows:

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

Where:

I_1 = Positive Phase Sequence Current (PPS)

I_2 = Negative Phase Sequence Current (NPS)

K = NPS Weighting Factor

The user selectable value K is a weighting factor allowing for the greater heating effect on the rotor of the negative phase sequence (NPS) component of an unbalanced three phase supply. If K is set to zero by the user, then the thermal protection uses the average of the three RMS phase currents in place of the equivalent current. In such a configuration, no NPS biasing is applied to the thermal protection.

2.1.2 Thermal model

The relay uses the equivalent current to track the thermal state of the motor. The thermal state is expressed as a percentage of the thermal capacity of the motor and the motor is disconnected when the thermal state reaches 100% of thermal capacity. The thermal model accommodates both heating and cooling conditions with exponential curves as illustrated in figure 1.

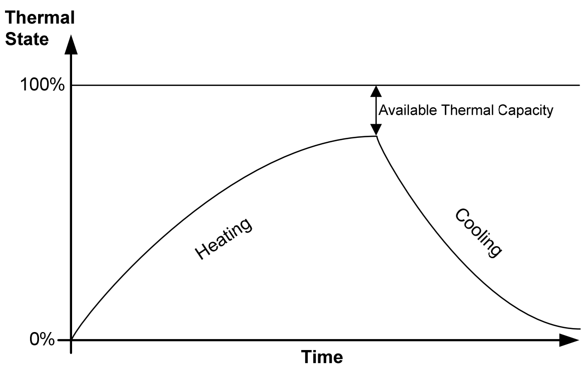


Figure 1 – Exponential heating and cooling curves

For the heating curve:

$$\theta = \frac{I_{eq}^2}{I_\theta^2}\left(1 - e^{\frac{-t}{\tau}}\right) \times 100\%$$

For the cooling curve:

$$\theta = \theta_F \cdot e^{\frac{-t}{\tau}} \text{ or } t = \tau \cdot Ln\frac{\theta}{\theta_F}$$

Where:
θ = thermal state at time t
θ_F = final thermal state before disconnection of motor
I_{eq} = equivalent thermal current (see 2.1.1)
I I_θ = thermal overload current setting (or k.IB)

τ = thermal time constant

The final steady state thermal condition can be predicted for any steady state value of input current since when t >> τ,

$$\theta_F = \frac{I_{eq}^2}{I_\theta^2} \times 100\%$$

The thermal overload setting I_θ is expressed as a fraction of the relay nominal current and is equivalent to the factor $k.I_B$ as defined in the IEC60255-8 thermal operating characteristics. It is the value of current above which 100% of thermal capacity will be reached after a period of time and it is therefore normally set slightly above the full load current of the protected motor.

Three values of thermal time constant τ are available for use during different phases of motor operation as follows:

τ_h = Thermal overload heating time constant for use during normal running and under overload conditions of current up to the motor starting current setting ISTART.

τ_s = Thermal overload heating time constant for use during motor starting and applied for current above the starting current setting ISTART.

τ_c = Cooling time constant used to take account of the reduced rate of cooling of a stopped motor and applied when current falls below the motor stopped current setting ISTOP.

2.1.3 Hot/cold ratio

The hot/cold ratio setting determines the percentage of thermal capacity available for a motor running at full load current compared to that available when the motor is cold. It modifies the IEC60255-8 hot curve as below:

$$t = \tau.\mathrm{Ln}\frac{I^2 - \left(1 - H/C\right)I_P^2}{I^2 - I_\theta^2}$$

The thermal model is modified under normal load conditions (ie when Ieq < Iq) by multiplying the predicted final steady thermal state by (1-H/C).

$$\theta_F = \frac{I_{eq}^2}{I_\theta^2}\left(1 - H/C\right) \times 100\%$$

A setting is available to switch this feature out of service, ie H/C is then equivalent to zero and full account is taken of the prior load current.

2.1.4 Thermal capacity alarm level

The thermal capacity alarm setting is expressed as a percentage of thermal capacity. An instantaneous alarm output is given if the thermal state exceeds the setting.

2.1.5 Overload alarm level

An instantaneous alarm output is given if the equivalent thermal current Ieq exceeds the thermal overload setting Iq.

2.1.6 Load increase alarm level

A further alarm is available to provide warning of a sudden increase in load. The alarm level is set as a multiple of the thermal overload setting Iq.

2.1.7 Thermal restart inhibit level

The thermal restart inhibit setting is expressed as a percentage of thermal capacity. It controls an output contact to prevent the motor from being started until its thermal state has fallen below the setting. The default setting for the output contact is output relay 3, a changeover contact. Its normally closed contact can be connected in the motor starting circuit, thus breaking the circuit when the restart inhibit feature registers thermal state above setting. A thermal capacity reset command is available which resets the thermal state to zero and thus releases the thermal restart inhibit. The thermal restart inhibit setting can be set to 'OFF'.

2.2 Stall and locked rotor protection

Figure 2 illustrates the common situation where the thermal overload protection can be set to provide protection against stalling during running and the locked rotor condition on starting.

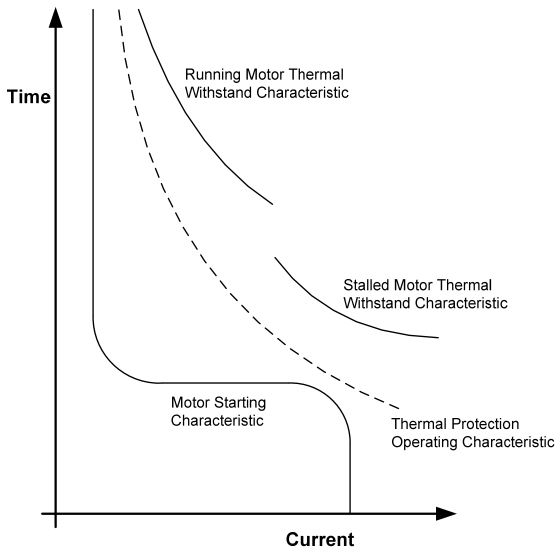


Figure 2 - Thermal protection for running, starting and stalling

In cases where the thermal characteristic does not offer sufficient protection against stalling during running or a locked rotor condition on starting, an additional protection is provided. There are two methods of applying this protection depending on whether the motor starting time is significantly less than the permissible locked rotor withstand time.

2.2.1 Start time less than locked rotor withstand time

Figure 3 illustrates the most common situation where the stalled motor condition can be effectively distinguished from a healthy start by simple current time grading. A single definite time characteristic can give protection during starting and stalling without causing mal-operation during a healthy start sequence. A trip occurs when current above the start current setting I_{START} is measured for longer than the stall withstand delay setting t_{s1}. I_{START} is set as a multiple of the thermal overload current setting I_{θ} and an instantaneous motor start alarm output is also provided. The stall and locked rotor protection can be disabled by setting t_{s1} to 'OFF'.

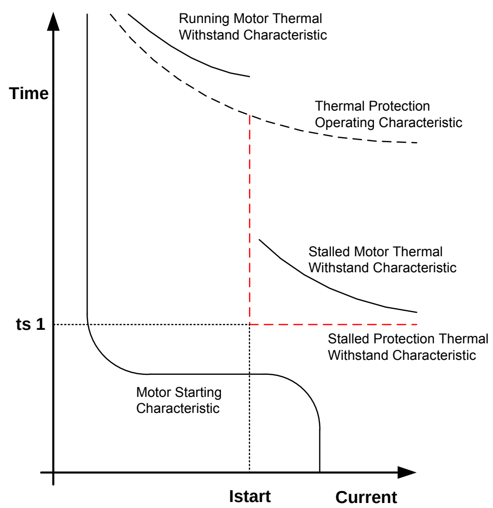


Figure 3 - Stall and locked rotor protection for start time less than withstand time

2.2.2 Start time greater than locked rotor withstand time

In cases where the motor starting time approaches or exceeds the stall withstand time then discrimination between starting and stalling cannot be so easily achieved and the two conditions cannot be protected by simple current, time grading. See figure 4

A tachometric 'zero speed' switch mounted on the rotor shaft can be used to signal that the motor is running up. A relay status input is connected to receive a voltage signal via the switch and is programmed to the 'No Accel.' function in the status configuration menu. In this mode the second stall withstand delay timer t_{s2} is used. This timer will not run unless the status input is energised. If the switch is closed, indicating a stopped motor, and current is measured above the start current setting I_{START} then the stall withstand delay timer t_{s2} begins to run. On a healthy start the switch will open, thus stopping the timer. Under stall conditions, a trip will occur after t_{s2}, which should be set with a delay less than the motor stall withstand time.

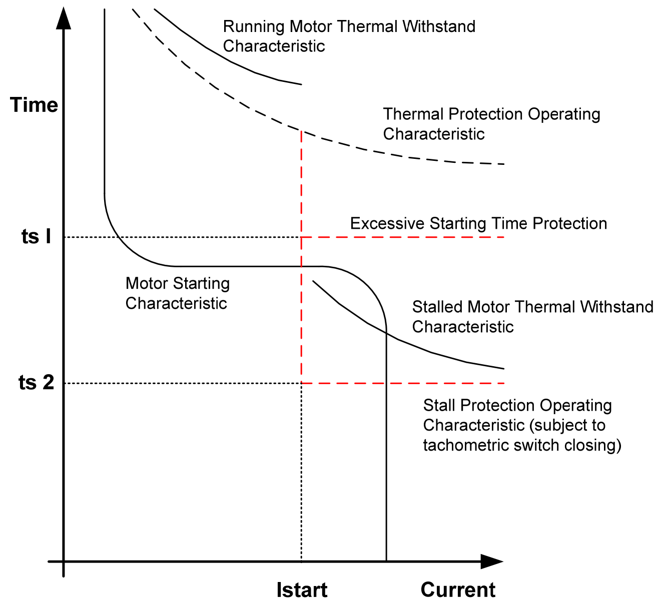


Figure 4 - Start time greater than locked rotor withstand Time

In this configuration, the first timer ts1 can be used to provide additional protection against the motor running up but drawing starting current for an excessive time. Timer ts1 runs for current above ISTART regardless of the signal from the zero speed switch to provide excessive start time protection.

2.3 Overcurrent protection for Phase Short Circuits

A transient free high set overcurrent element measures the RMS current in each phase. The element provides alarm and trip outputs. An alarm output is given if current exceeds the high set alarm setting IHA in any phase for longer than the definite time delay tHA. A trip occurs if current exceeds the high set trip setting IHS in any phase for longer than the definite time delay tHS.

The current thresholds are set as a multiple of the relay nominal current In. The overcurrent alarm and trip features can be disabled by setting IHA and IHS to OFF.

2.4 Earth fault protection

An earth fault overcurrent element measures RMS current either from a core balance CT or in the residual circuit of the phase CTs. In the case of the residual connection method, if a low earth fault setting is applied it is advisable to use a stabilising resistor to increase the burden in the residual circuit, or to introduce a time lag.

The element provides alarm and trip outputs. An alarm output is given if current exceeds the earth fault alarm setting I_{EA} for longer than the definite time delay t_{EA}. A trip occurs if current exceeds the earth fault trip setting I_{EF} for longer than the definite time delay t_{EF}. The current thresholds are set as a multiple of the relay nominal current In. The earth fault alarm and trip features can be disabled by setting I_{EA} and I_{EF} to OFF.

An additional earth fault inhibit current setting I_{EI} is available. The earth fault trip element does not operate for currents above this setting, so preventing damage to contactors which may have a low breaking capacity.

The earth fault alarm is not affected by the inhibit feature and may be used to issue a back-trip signal to an upstream circuit breaker.

2.5 Phase unbalance protection

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.

2.5.1 Phase difference protection

If phase difference protection is selected then the relay calculates the phase unbalance relative to the thermal overload setting as follows:

$$\text{Percentage unbalance} = \frac{I_\Delta}{I_\theta} \times 100\%$$

Where:
$I_\Delta = I_{MAX} - I_{MIN}$
I_{MAX} = highest phase current
I_{MIN} = lowest phase current
I_θ = thermal overload setting

The protection operates with an inverse time characteristic defined below:

$$t = \frac{1}{(I_\Delta / I_\theta)^2} \times t_m$$

where:
t = protection operating time
t_m = time multiplier setting

Figure 5 illustrates operating characteristics for two sample combinations of settings. The relay uses a lookup table to create this characteristic. The phase difference setting determines the minimum percentage phase unbalance for which the relay will operate. The time multiplier determines the maximum operating time at the unbalance setting. Note that a time multiplier of 1.0x gives an operate time of 100 seconds for an unbalance of 10%.
A further setting is used to define the minimum operate time for the protection characteristic.

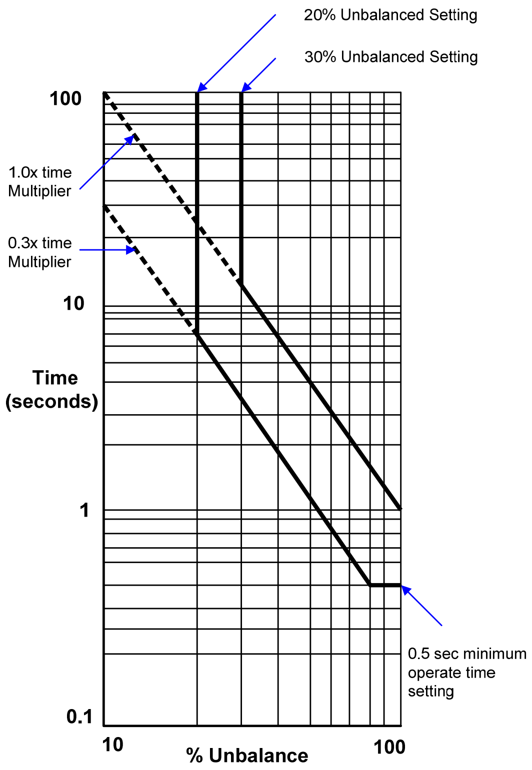


Figure 5 - Inverse time characteristics for unbalance protection

2.5.2 Negative sequence overcurrent protection

If negative phase sequence protection is selected for phase unbalance then the relay uses the negative sequence component of the three phase input currents. If the NPS overcurrent setting is exceeded then the relay operates with the same inverse time characteristic shown above for the phase difference type protection.
Hence:

$$t = \frac{1}{\left(I_2 / I_\theta\right)^2} \times t_m$$

Where:
I_2 = NPS component of current

2.6 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}.

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}. A trip occurs if current falls below the undercurrent trip setting I_{UC} in any phase (but not below I_{STOP}) for longer than the definite time delay t_{UC}. The current thresholds are set as a multiple of the relay nominal current In. 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 motor load conditions, the undercurrent protection has a minimum operate time of 200ms.

2.7 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.

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 Min. Time Between Starts features.

2.8 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.

2.8.1 RTD inputs

RTD inputs may be selected from a number of types, namely 100W Platinum (standard type DIN 43760), 100W Nickel, 120W Nickel, 10W 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 on the display. 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 350W.

2.8.2 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 100W and 30kW 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.

2.8.3 Detector failure protection

Each active temperature input is 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. A failed device will not give a trip or alarm output. Each device is individually addressable and can be disabled. This feature can be disabled.

2.8.4 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.

2.9 Output contacts

The relays provide seven output relays, three of which have changeover contacts and four of which have normally open contacts.

Outputs are user programmable to operate from any or all of the protection characteristics. In addition they can be programmed to generate outputs from the I^2 summation alarm, the trip counter alarm, the status inputs and the relay self-monitoring feature (watchdog). In their normal mode of operation, output contacts remain energised for at least 100ms, or for the duration of fault current. Alternatively, outputs can be programmed to operate as latching contacts if required. Latched output relays can be reset either by pressing the TEST/RESET button, by sending an appropriate communications command or electrically via a status input.

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

2.10 Status inputs

One plant status input is provided as standard, with an expanded version available with nine inputs. Each input can be programmed to perform one or more of the following functions:

- Switch to an alternative setting group
- Trigger the storage of a waveform record
- Trigger operation of the I^2 summation and trip count features
- Inhibit operation of any one or more protection functions
- Monitor the health of the tripping circuit
- Synchronise the real-time clock

Additionally, each input can be independently programmed to operate with time delayed pick-up and time delayed drop off. The status inputs have a default pick-up delay setting of 20ms which provides security against operation in the presence of an induced a.c. input voltage. If instantaneous operation is preferred then the pick-up delay should be set to zero.

2.11 Circuit breaker fail protection

A two stage circuit breaker fail feature is provided by two CBF time delays. 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.

2.12 Trip circuit supervision

The relay can monitor its own trip circuit by configuring one of its status inputs using the “Trip Circuit Fail” setting and connecting the input into the trip circuit (refer to the applications guide for details of how this is achieved). Indication is then given instantaneously of “Trip Circuit Failure” 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 output can also be generated from the trip circuit supervision feature.

2.13 Multiple settings group

Relays provide eight alternative setting groups, making it possible to edit one group while the relay protection algorithms operate using another “active group”. The relay can then be switched instantaneously from one group of settings to another to suit alterations in the system configuration.

A change of group can be achieved either locally at the relay fascia, remotely via a communications interface command or automatically 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 setting 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.

3.0 OTHER FEATURES

3.1 Indications and displays

The Rho fascia includes 5 LEDs, providing indication as follows:

- Protection healthy (Green)
- Motor starting (Red)
- I>Is (Yellow)
- Trip (Red)
- Motor running (Green)

Note that the starter display applies to the phase and earth overcurrent protections as well as to the thermal protection. Additional displays relating to motor protection are also provided.

3.2 Circuit breaker maintenance

Circuit breaker condition monitoring is provided by the I^2 summation feature and the trip counter. 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 communications interface.

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

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

3.3 Standard displays

The metering features provide continuous data available from the relay fascia in “Instruments Display Mode” or via the communications interface. The following data is available:

- RMS current values for IA, IB, IC and IE Primary or secondary current levels can be displayed. Primary quantities are represented by upper case letters and secondary quantities by lower case
- Output relay status information is available in a bitwise manner
- Status input status information is available in a bitwise manner
- Trip circuit healthy/failure
- Trip count and summated I^2 values
- Number of waveform and event records stored
- Time and date
- The starter display indicates which poles are reading current above the main overcurrent setting

3.4 Phase sequence and phase difference ammeters

Additional ammeter displays are provided. These display the positive and negative phase sequence magnitudes I_1 and I_2, as well as their weighted sum, equivalent current I_{eq}, as used in the thermal model. Also available is the phase difference current I_{Δ}, which is the difference between the minimum and maximum phase current magnitudes.

3.5 Motor status

This display shows ‘Motor Starting’ whenever the motor current exceeds the start current setting I_{START}. ‘Motor

Running’ is then displayed when the starting sequence is complete and the current has dropped below I_{START}.

If current drops below the motor stopped current setting I_{STOP} then the display reads ‘Motor Stopped’. Finally, if the relay is inhibiting motor operation then this is indicated. The display reads either ‘Thermal Inhibit’ or ‘Starts Inhibit’ for the Thermal Restart Inhibit and Number of Starts Protection Inhibit respectively.

3.6 Time to trip

If the thermal overload protection algorithm is operating for current above the thermal setting I_θ then the relay displays the predicted time to trip according to the conditions present. If no overload condition is detected then 'No Trip Expected' is displayed.

3.7 Time to start

If motor starting is being inhibited, either by the thermal restart inhibit feature following an overload trip or by the number of starts protection, then the relay can calculate and display the time which must elapse before the motor may safely start again.

When the thermal state has fallen below the restart setting then this display reads 'Start Permitted'.

3.8 Thermal capacity used

The present thermal state is displayed as a percentage of thermal capacity.

3.9 Start counter

The start counter is incremented every time the thermal equivalent current rises from zero through the start current setting I_{START}. The start counter can be reset by a command within the motor maintenance menu. Alternatively, press TEST/RESET when viewing the instrument screen. An alarm can be programmed to be issued when the start counter reaches a user defined value.

Note that the start counter feature is not related to the number of starts per period feature.

3.10 Last starting time

The relay records motor starting period from the time at which current rises through the start current setting to the time at which the current falls below the setting. This record is updated for each starting operation and is displayed in the instruments menu.

3.11 Last starting current

During the period that the starting time is being measured, the relay also monitors the thermal equivalent current magnitude and records its maximum value. This record is updated for each starting operation and is displayed in the instruments menu.

3.12 Motor running time

When the motor is running, the time elapsed since the last starting operation is displayed in hours, minutes and seconds. When the motor stops (i.e. current falls below the motor stopped setting I_{STOP}) this display holds the last running time.

3.13 Cumulative motor run time hours

A cumulative sum of total motor running time is recorded and displayed in hours, minutes and seconds. The Run Time Hours count can be reset by a command within the motor maintenance menu and an alarm can be programmed to be issued when the counter reaches a user defined value. To reset the count, press TEST/RESET when viewing the screen.

3.14 Maximum demand

The relay calculates a moving average value of the thermal equivalent current over a time window defined by the 'Maximum Demand' setting in the 'System Configuration Menu'.

The moving average value is monitored and the maximum value recorded is displayed under ‘Maximum Demand’ in the ‘Instruments Menu’. The time and date when the maximum value was recorded is displayed under Maximum Demand Time’, again in the ‘Instruments Menu’.

The maximum demand instrument can be reset.

3.15 External trip/emergency stop

Any status input can be programmed to receive a trip signal from another device such as an emergency stop signal. 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.

3.16 Temperature inputs

For variants where RTD or thermistor inputs are available then the values returned by each of these are displayed. Failed inputs are identified by the word ‘FAILURE’.

3.17 Default display setting and general alarms

Any one or more of the relay instrument displays can be selected as a default display by pressing the ‘ENTER’ key while viewing the display. A time delay should also be set using the ‘Default Screen Timer’ setting, found in the System Configuration Menu’. If no key is pressed for the period set then the display begins to alternate through the default instruments in turn for five seconds each.

The relay provides up to nine ‘General Alarm’ features. Each alarm can be activated by any one or more status inputs as selected in the ‘Status Configuration Menu’. Each input can be programmed to give a unique message on the LCD, in the ‘System Configuration Menu’. Whenever an alarm is activated then the display automatically jumps into ‘Instruments Mode’ and the ‘General Alarms’ screen is displayed. This screen also becomes a default display.

4 DATA RECORDS

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

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

Alternatively, synchronising pulses can be received via a status input. To use this feature one of the status inputs must be assigned to the "Clock Sync" feature in the Status Configuration Menu. Additionally the "Clock Sync Period" setting in the System Configuration Menu should be set either to "seconds" or to "minutes" as appropriate depending on the period of the synchronising signals expected from the controlling device. If "seconds" are selected then energisation of the selected status input will result in the clock being synchronised to the nearest second with milliseconds set to zero. If "minutes" are selected then the clock is synchronised to the nearest minute with seconds and milliseconds set to zero.

4.1 Fault records

If any protection algorithm issues a trip, then the 'Trip' LED is illuminated and one of the following messages is displayed along with a time/date stamp:

TRIP thermal
TRIP stall
TRIP A B C E (for Short Circuit Protection)
TRIP unbalance
TRIP A B C (for Undercurrent Protection)
TRIP temperature
TRIP external (refer to 2.9.12)
The scrolling fault display repeats the above information in addition to:
Current in each pole I_A, I_B, I_C, I_E
Positive and negative sequence current magnitudes I_1, I_2
Thermal equivalent current I_{eq}
Phase difference current I_Δ

The last ten fault records are stored in this format

4.2 Event records

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

- Change of setting (though not the actual setting changes). Also indication of which group of setting is active
- Change of state of output relays
- Change of state of status inputs
- Change of state of any protection characteristic
- Trip Indication reset
- Trip test
- Trip supply failure
- Circuit breaker maintenance aarms
- Circuit breaker failure

The event storage buffer holds up to 500 records. When the event buffer is full, then any new record overwrites the oldest.

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

4.3 Communications

A fibre optic communication port is provided. Communication is compatible with the IEC60870-5-103 FT 1.2 transmission and application standards. The fibre optic interface gives superior EMC performance. A user friendly software package is available to allow transfer of the following:

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

Communications operation is described in detail elsewhere in this manual.

4.4 Self monitoring

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

A watchdog feature monitors the microprocessor. The relay program memory is continuously checked for data corruption using a CRC routine.

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

4.5 Password feature

The programmable password feature enables the user to enter a 4 character alpha-numeric code. As soon as the user attempts to change a setting the password is requested before any setting alternations are allowed. Once the password has been validated, the user is said to be “logged on” and if no further changes are made within 1 hour then the user will automatically be “logged out”, re-enabling the password feature.

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

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

5 USER INTERFACE

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

5.1 General arrangement

The relay fascia includes a 16 character by 2 line, backlit, liquid crystal display, 5 light emitting diodes and 5 push buttons.

5.2 Liquid crystal display

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

The display backlighting is turned off to conserve power if no pushbuttons are pressed for 5 minutes. After an hour, the whole display is de-activated, except in the case of the default screens, which remain visible permanently.

5.3 LED indications

The following indications are provided:

PROTECTION HEALTHY - Green LED, flashes with fault.
This LED indicates that DC volts have been applied to the relay and that the relay is operating correctly. If a permanent fault is detected by the internal relay watchdog, then this LED will continuously flash.

TRIP - Red LED latched
This LED indicates that a trip, as defined by the user, has occurred. Such a trip may have been issued by any of the relay's protection functions. The user will be given more detailed information concerning the relay operation from the LCD.

I > Is (STARTER) - Yellow LED self-resetting
This LED indicates that any pole is measuring current above the thermal current setting or high set overcurrent.

MOTOR STARTING - Red LED, self-resetting
This LED indicates when the current exceeds the motor starting current.

MOTOR RUNNING - Green LED, self-resetting
This LED indicates that the relay current is greater than the motor stop current but less than the motor starting current.

5.4 Keypad

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

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

6 SETTINGS AND DISPLAYS

The basic setting/display flow diagram is shown in figure 6. This diagram shows the three main modes of display, the Setting Display Mode, the Instrument Display Mode and the Fault Data Display Mode.

On relay start up, the user is presented with a default relay identifier. This can be changed to some user definable identifier or code if the user prefers.

Settings display mode is entered by scrolling down from the relay identifier display. The key can then be used to move to the Instrument and Fault Data Display Modes in turn.

The settings display mode contains all the menus which hold the programmable settings of the relay.

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

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

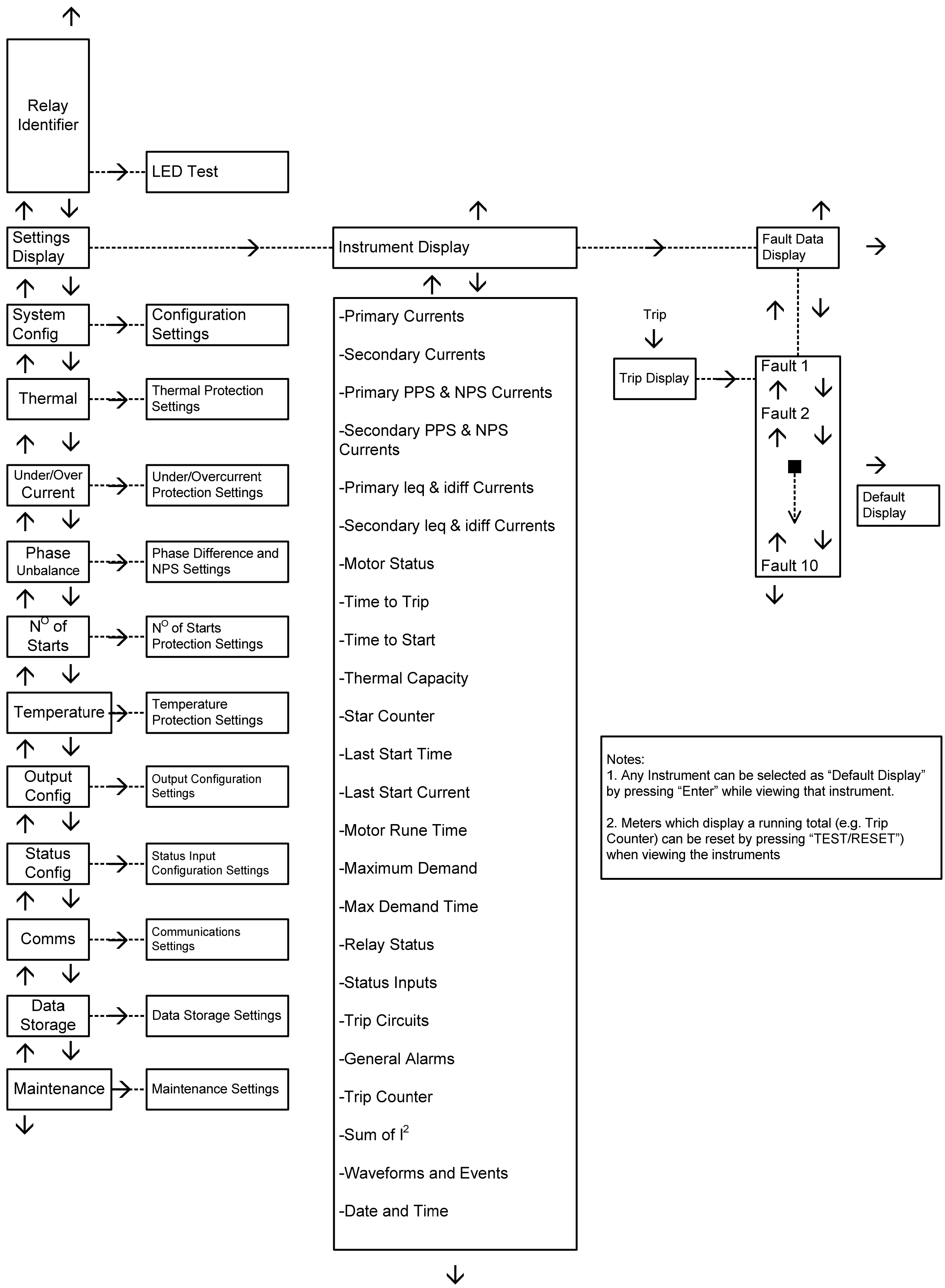
2. While viewing an editable screen, ENTER allows the user to change the displayed data, indicated by flashing character, as long as the changes are authorised via password verification. Pressing / increments/decrements that particular character, while moves right along the edit field or fields. If or are held pressed while scrolling through a
range of numerical settings then the rate of scrolling increases.

3. CANCEL returns the screen to view mode and restores the setting.

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

There are eight separate “Settings Groups”, allowing the relay to be easily switched from one group to another. Grouped settings are found in the protection, O/P relay configuration, status configuration sub-menus and in part of the data storage sub-menu. All other settings are common. The different settings groups can be viewed or edited independently and indication of which group is presently being viewed is given by the “G?” character in the top left of the display.

A description of the purpose of each relay setting, the actual setting ranges and default values can be found elsewhere in this manual.


Relay Identifier
LED Test
Settings Display
Instrument Display
Fault Data Display
System Config
Configuration Settings
Thermal
Thermal Protection Settings
Under/Over Current
Under/Overcurrent Protection Settings
Phase Unbalance
Phase Difference and NPS Settings
N^{O} of Starts
N^{O} of Starts Protection Settings
Temperature
Temperature Protection Settings
Output Config
Output Configuration Settings
Status Config
Status Input Configuration Settings
Comms
Communications Settings
Data Storage
Data Storage Settings
Maintenance
Maintenance Settings
-Primary Currents
-Secondary Currents
-Primary PPS & NPS Currents
-Secondary PPS & NPS Currents
-Primary Ieq & idiff Currents
-Secondary Ieq & idiff Currents
-Motor Status
-Time to Trip
-Time to Start
-Thermal Capacity
-Star Counter
-Last Start Time
-Last Start Current
-Motor Rune Time
-Maximum Demand
-Max Demand Time
-Relay Status
-Status Inputs
-Trip Circuits
-General Alarms
-Trip Counter
-Sum of I^2
-Waveforms and Events
-Date and Time
Trip
Trip Display
Fault 1
Fault 2
Fault 10
Default Display
Notes:
1. Any Instrument can be selected as “Default Display” by pressing “Enter” while viewing that instrument.
2. Meters which display a running total (e.g. Trip Counter) can be reset by pressing “TEST/RESET”) when viewing the instruments

7 RELAY HARDWARE

7SG17 relays are housed in the Epsilon case, with 2 case sizes being necessary to cover the available variants - E6 and E8. Figure 7 shows the Relay HMI layout.

7.1 Internal construction

Relays without temperature detector are housed in E6 cases, those with detectors in E8 cases.

The design for the internal arrangement of each case has been 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 cases have been divided internally 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.

7.2 Front cover

This allows access to the and buttons, allowing all of the menus discussed previously to be viewed but not changed. The only “action” which is permitted is to reset the Fault Data Display, latched output relays and the trip LED by using the TEST/RESET function of the button.

7.3 Terminal blocks

These are of the standard Epsilon design, consisting of 28 terminals per block, with either one or two blocks depending on the variant of the relay. All inputs and outputs (except for the serial communications interface) are made through these connectors. The fibre optic serial communication cables are connected via SMA connectors.

Features
1 Relay type
2 Red LED - motor starting
3 Yellow LED
4 Page-up key
5 Page-down key
6 Green LED protection healthy
7 Contrast adjustment
8 LCD display (backlit)
9 Green LED - motor running
10 Red LED - relay trip
11 Enter key
12 Test and reset key - also enables sub-menu access
13 Cancel key

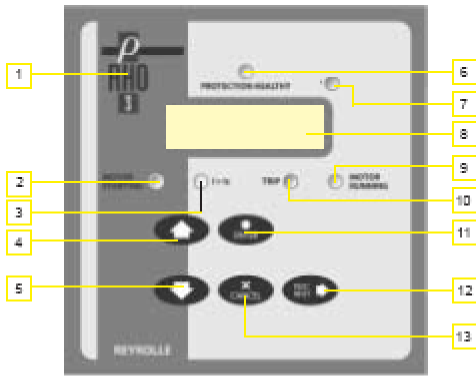


Figure 7 - Rho 3 HMI layout

EVENT	Code	GI	Type
Data lost	0	✗	1
Reset FCB	2	✗	5
Reset CU	3	✗	5
Start/restart	4	✗	5
Power On	5	✗	5
A-Undercurrent alarm starter	6	✗	1
B-Undercurrent alarm starter	7	✗	1
C-Undercurrent alarm starter	8	✗	1
A-Undercurrent alarm	9	✓	1
B-Undercurrent alarm	10	✓	1
C-Undercurrent alarm	11	✓	1
A-Undercurrent starter	12	✗	2
B-Undercurrent starter	13	✗	2
C-Undercurrent starter	14	✗	2
A-Undercurrent trip	15	✗	2
B-Undercurrent trip	16	✗	2
C-Undercurrent trip	17	✗	2
External trip	18	✗	1
LEDs reset	19	✗	1
Trip circuit fail	20	✓	1
Test mode (Trip test)	21	✗	1
Setting changed	22	✗	1
Setting group 1 selected	23	✓	1
Setting group 2 selected	24	✓	1
Setting group 3 selected	25	✓	1
Setting group 4 selected	26	✓	1
Input 1	27	✓	1
Input 2	28	✓	1
Input 3	29	✓	1
Input 4	30	✓	1
Phase unbalance starter	31	✗	2
Phase unbalance trip	32	✗	2
Trip count alarm	33	✓	1
CB maintenance alarm	34	✓	1
Setting group 5 selected	35	✓	1
Setting group 6 selected	36	✓	1
Setting group 7 selected	37	✓	1
Setting group 8 selected	38	✓	1
Circuit breaker fail 2	39	✗	2
Thermal overload alarm	40	✓	1
Thermal capacity alarm	41	✓	1
Thermal overload trip	42	✗	1
Load increase alarm	43	✓	1
Thermal restart inhibit	44	✓	1
Input 5	45	✓	1
Input 6	46	✓	1
Input 7	47	✓	1
Input 8	48	✓	1
Input 9	49	✓	1
E/F inhibit	50	✓	1
Output 1	51	✓	1
Output 2	52	✓	1
Output 3	53	✓	1
Output 4	54	✓	1
Output 5	55	✓	1
Output 6	56	✓	1
Output 7	57	✓	1
A-Overcurrent alarm starter	58	✗	1
B-Overcurrent alarm starter	59	✗	1
C-Overcurrent alarm starter	60	✗	1
A-Overcurrent alarm	61	✓	1
B-Overcurrent alarm	62	✓	1
C-Overcurrent alarm	63	✓	1

EVENT	Code	GI	Type
A- Overcurrent starter	64	✗	2
B- Overcurrent starter	65	✗	2
C- Overcurrent starter	66	✗	2
E/F-Starter	67	✗	2
General Trip	68	✗	2
A- Overcurrent trip	69	✗	2
B- Overcurrent trip	70	✗	2
C- Overcurrent trip	71	✗	2
E/F trip	72	✗	2
E/F-Alarm starter	73	✗	1
E/F-Alarm	74	✓	1
Stall delay 1 starter	75	✗	1
Stall delay 1 trip	76	✗	1
Stall delay 2 starter	77	✗	1
Stall delay 2 trip	78	✗	1
Max. starts exceeded	79	✓	1
Waveform stored	80	✗	1
Remote control interrupted	81	✗	1
Start counter alarm	82	✓	1
Run-time hours alarm	83	✓	1
General starter	84	✓	2
Circuit breaker fail 1	85	✗	2
Motor stopped	86	✓	1
Motor running	87	✓	1
Motor starting	88	✓	1
Motor start inhibit	89	✓	1
Temp input 1 alarm	90	✓	1
Temp input 2 alarm	91	✓	1
Temp input 3 alarm	92	✓	1
Temp input 4 alarm	93	✓	1
Temp input 5 alarm	94	✓	1
Temp input 6 alarm	95	✓	1
Temp input 7 alarm	96	✓	1
Temp input 8 alarm	97	✓	1
Temp input 1 trip	98	✗	1
Temp input 2 trip	99	✗	1
Temp input 3 trip	100	✗	1
Temp input 4 trip	101	✗	1
Temp input 5 trip	102	✗	1
Temp input 6 trip	103	✗	1
Temp input 7 trip	104	✗	1
Temp input 8 trip	105	✗	1
Temp input 1 fail	106	✓	1
Temp input 2 fail	107	✓	1
Temp input 3 fail	108	✓	1
Temp input 4 fail	109	✓	1
Temp input 5 fail	110	✓	1
Temp input 6 fail	111	✓	1
Temp input 7 fail	112	✓	1
Temp input 8 fail	113	✓	1
General alarm 1	121	✓	1
General alarm 2	122	✓	1
General alarm 3	123	✓	1
General alarm 4	124	✓	1
General alarm 5	125	✓	1
General alarm 6	126	✓	1
General alarm 7	127	✓	1
General alarm 8	128	✓	1
General alarm 9	129	✓	1

Table 2 - Rho 3 private event codes (function code 165)