SPAM 150 C
Application examples

Technical information

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Application examples for the relay SPAM 150 C

Contents

Introduction

The motor protection relay SPAM 150 C is a versatile multifunction relay, mainly designed for protection of standard a.c. motors in a wide range of motor applications. Due to the large number of protective functions integrated, the relay provides a complete protection against motor damage caused by electrical faults.

The relay can also be applied on other objects calling for a thermal overload protection such as feeder cables and power transformers.

General about the protective functions

The thermal overload unit of the relay protects the motor against both short-time and long time overloading. The highest permissible continuous load is defined by the relay setting I_θ. Normally the setting equals the rated full load current of the motor at 40°C ambient. Under the above conditions a 5% increase in the motor current will cause the thermal unit to operate after an infinite period of time. If the ambient temperature of the motor is constantly below 40°C, the setting I_θ can be chosen to be 1.05... 1.10 times the motor full load current (FLC).

Overload conditions of short duration occur mainly during motor start-ups. Normally two starts from a cold condition and one start from a hot condition are permitted. Thus the setting t_{6x}, which defines the characteristic of the thermal unit, is worked out according to the starting time of the motor. The setting can easily be defined by means of the hot curve time/current diagram. The t_{6x} curve allowing the starting current for the start-up time (plus a margin) is selected. Using the same t_{6x} curve in the cold curve diagram, the total starting time can be read out, referring to a cold motor condition. As a rule of thumb, a setting of $t_{6x} \approx 1.6...2.0$ times the motor start-up time generally gives the wanted two cold/one hot start-up behaviour.

The prior alarm from the thermal unit can be used to avoid unnecessary tripping due to a beginning thermal overload. When the prior alarm contact operates, the load of the motor can be reduced to avoid a trip. The level of the prior alarm can separately be set in per cent of the thermal trip level. The prior alarm level can thus be set to a suitable level, which makes it possible to use the motor to its full thermal capacity without causing a trip due to long-time overloading.

The thermal stress during any single start-up condition is monitored by the start-up supervision, which is normally used to monitor the thermal stress equivalent product $I^2 \times t$. Another possibility is also to use the relay unit as a definite time overcurrent monitor. The latter in particular is used with non-motor applications.

Regardless of which function mode is used, the external input to the relay can be programmed to link an external trip inhibit order e.g. from a speed switch on the motor shaft to make a distinction between a jammed motor condition or a start-up condition.

The high-set overcurrent unit constitutes an interwinding short-circuit protection for the motor and a phase-to-phase short-circuit protection for the feeder cable. The current setting is automatically doubled during start-up. Thus the current setting can be given a value lower than the motor starting current. Normally the setting can be chosen to 0.75 times the motor starting current. With a suitable operating time set, this feature will enable the high-set overcurrent unit to operate, if the motor is jammed while the motor is running.

When the relay is used for protection of contactor-controlled motors, the high-set overcurrent unit is set out of operation. In this case the short-circuit protection is provided by the backup fuses.

The non-directional earth-fault unit protects both the motor and the feeder against earth-faults. In solidly or low resistance earthed networks, the neutral current can be derived from the line CTs when these are wired into a residual connection and the operating time for the earth-fault protection is then normally set to a low value, e.g. 50 ms.

In a contactor controlled application, the earth-fault unit is blocked when the line currents exceed a preset value of four, six or eight times the full load current setting of the thermal unit. This is done in order to avoid destruction of the contactor, which cannot break these high currents. The trip is in this case handled by the backup fuses. This blocking feature can also be used to ensure that the unit will not cause nuisance trippings even though the line CTs should partially saturate during a start-up, causing a virtual neutral current. The sensitivity of the earth-fault unit is typically set at 15...40% of the rated current of the motor.

A core balance transformer is recommended to be used in networks with isolated neutral or in high resistance earthed networks. The transforming ratio of the core balance transformer can be freely selected according to the earth-fault current and, consequently, the sensitivity of the earth-fault protection too. Due to the extremely small burden of the relay, very small transforming ratios may be used in the cable current transformers, in a KOLMA type transformer even as small as 10/1 A. A transforming ratio of at least 50/1 A or 100/1 A is recommended to be used. The setting of the earth-fault unit is typically selected in the range 5...30% of the fully developed earth-fault current and a typical trip time could be 0.5...2 sec. The phase unbalance unit monitors the current asymmetry of the network and protects the motor against heavy network unbalance or single-phasing. The phase unbalance unit is stabilized against maloperation due to heavy currents and also allows a higher degree of unbalance when the motor is running at a load less than the full load current. The operating time of the unit follows an inverse time characteristic.

A separate unit checks for phase reversal conditions and operates within a fixed time of 600 ms on a wrong phase sequence.

The unbalance and phase reversal units can be separately selected or taken out of use. If e.g. a motor is used also with a reversed direction of rotation, the phase reversal is taken out of service and does in this way not cause a trip when the direction is reversed.

The undercurrent unit operates upon a sudden loss of load. The unit is used e.g. for submersible pumps, where the cooling is based on a constant flow of liquid. If this flow is interrupted, the cooling capacity of the motor is reduced. This condition is detected by the undercurrent unit, which trips the motor.

The start-up totalling counter constitutes another way to control the number of start-up attempts within a certain time and can be set to comply with the motor manufacturers´ statements on start-up number limiting.

By using the memorized fault parameters a comprehensive after-fault analysis can be performed and a continuous follow-up of the start-up and other parameters can give good indications about the condition of the motor.

The serial communication facilities finally make it possible to achieve all the measured and memorized parameters in the easiest possible way, direct to a control room or a similar place.

Some notes and useful hints

Connection with two phase current transformers

If phase current transformers are used only in two phases, a third current is recommended to be summed from the currents of these phases. This current is conducted to the input circuit of the missing phase. This procedure has two advantages, i.e. the phase failure protection does not have to be disconnected and the measurement of the load currents is more accurate than in a two-phase measurement.

Stabilizing for virtual earth-fault currents

The apparent neutral current caused by the difference of the phase current transformers connected in parallel may cause an unnecessary operation of the earth-fault unit, especially in an overload situation. This can be avoided by using a stabilizing resistor R in the neutral current circuit. The resistor must have a continuous power rating of e.g. 30 W and can have a resistance value of e.g. 100 Ω for the 1 A input versus 10 Ω when the 5 A secondary input is used. The value of the knee-point voltage must be checked > 2 x U_{stab}. The stabilizing resistor will also slightly reduce the E/F sesitivity.

Problems with false E/F or U/B trips during start-up

If the unbalance or earth-fault units cause false trippings during a start-up e.g. because of main CT saturation or severe amounts of harmonics, the units can be blocked by a control from the starter over the external control input. If no control signal is available, in some cases the start information available from the realy itself can be used for this blocking purpose by feedback to the external control input.

Increasing the sensitivity of the earth-fault protection

The sensitivity of the operation of the earth-fault protection can be increased by using the 1 A input instead of the 5 A input. This is possible in a solidly earthed network too, because the thermal withstand is normally high enough when using a tripping earth-fault protection.

Optimizing the needed time left to restart

The approximate time until a restart is allowed can be read out from register 9 on the measuring module. Also note that this value is updated even when the motor is in service. For a motor with a long cooling time this can give valuable information on how to cool down the motor before shutdown in order to reduce the needed downtime before restart. If possible, the motor is allowed to run with a minimum load thus that the register showing necessary time to restart has been reduced to a suitable value. An idling time of e.g. 15 minutes can save an hour in cooling at standstill.

Time constant versus safe stall time t_{6x}

If the thermal unit is to be set according to the single time constant of an object the time constant can be calculated as: $\tau = 32 \times t_{6x}$. This is correct provided that the factor p is set at 100%.

External trip via control input

If an added function is needed, e.g. undervoltage, RTD-trip or a similar, an external relay can be linked to trip via the control input (SGB/5 = 1). The benefits are that the external relay can have a light duty output relay because the trip is carried out by the SPAM. Furthermore all event and memorized information from the trip instant can be achieved from the SPAM 150 C also over the communication link.

Disabling of restart inhibit for use outside SPAM 150 C

A switch SG4/2 can be used to lock out the restart enable signal when the module SPCJ 4D34 is used in other packages than SPAM 150 C. This might often be necessary as the restart enable signal can otherwise interfere with a trip output. The switch is found in submenu position 4 in the register "A" and is normally = 0 but should bet set = 1 to disable the restart inhibit signal.

Mutual restart inhibit for multi-motor applications

If a number of large motors are run in a weak network, a simultaneous start of two or more motors may cause complete network breakdown. Under these circumstances a restart inhibit logic is needed and the easiest way to obtain such an arrangement is to link the start-up information from each motor relay to the external control input of all the other relays and to program the inputs to operate as restart inhibit inputs. In this way the start-up of one motor always prevents a simultaneous start of any one of the other motors.

Note about the contactor versus circuit-breaker drives

Different output relay cards needed for contactor versus circuit breaker controlled drives:

Power and output relay modules type SPTU 240 R2 and SPTU 48 R2 comprise normally open trip contacts for circuit breaker operation whereas modules SPTU 240 R3 and SPTU 48 R3 have a normally closed trip contact for contactor controlled drive use. When ordering the relay, this power module type as well as the relay rated frequency are indicated by the RS-number of the relay.

The actual RS-numbers for SPAM 150 C are:

For circuit-breaker drive applications:

RS 641 014 - AA ;50 Hz, 80...265 V ac/dc
RS 641 014 - CA ;50 Hz, 18...80 V dc
RS 641 014 - DA ;60 Hz, 80...265 V ac/dc
RS 641 014 - FA ;60 Hz, 18...80 Vdc

For contactor drive applications:

RS 641 015 - AB ;50 Hz, 80...265 V ac/dc
RS 641 015 - CB ;50 Hz, 18...80 V dc
RS 641 015 - DB ;60 Hz, 80...265 V ac/dc
RS 641 015 - FA ;60 Hz, 18...80 Vdc

Example 1. Protecting a circuit breaker controlled motor in an isolated network

Given data of the squirrel cage motor to be protected:

Rated power P_{nm}	4500 kW
Rated voltage U_{nm}	3300 V
Rated current I_{nm}	930 A
Starting current I_s	6.2 x I_{nm}
Starting time t_s	11 s
Stall time permitted under cold conditions	19 s
Ambient temperature	20°C
C.T. current ratio	1000 /1A
Network earth-fault current at fully developed fault (100 % e/f)	10 A
Earth-fault sensitivity required	20 %

Calculation of settings:
Due to the ambient temperature <40°C, the full load current (FLC) is increased by 5%:

FLC = 1 .05 x 930 A

The relay setting I_θ is then

$$I_\theta \;/\; I_n \;=\; \frac{1.05 \text{ x } 930 \text{ A x } 1 \text{ A}}{1000 \text{ A x } 1\text{A}} = 0.98$$

The motor is directly started, .i.e. p = 50 %.

The setting t_{6x} is selected from the time/current characteristic corresponding to a hot motor condition. This will enable one hot / two cold starts.

First the ratio between the starting current and the full load current is calculated :

$I_s \;/\; I_\theta \;=\; I_s \;/\; (\,1.05 \;\text{ x } I_{nm}) = 6.2 \;/\; 1.05 \;\approx 5.9$

A setting $t_{6x} \approx 25$ s is selected, permitting a starting time which is a few seconds longer than the given motor starting time.

As the safe stall time is longer than the start-up time no speed switch arrangements are needed. For a single startup from a cold condition, the thermal unit would trip only after about 25 seconds, which is longer than the permitted 19 seconds. A single startup is instead protected by the startup supervision, i.e. I_s^2 x t_s. The starting current is set directly to the value I_s= 6.2 x 930 A x 1/1000 ≈ 6.1 x In, whereas the startup time is set at about 10% above the normal startup time in order to give a safety margin for the operation. Thus t_s is set at 11 s x 1.1 ≈ 12 s.

The prior alarm setting can be selected e.g. Θ_a=80...90 % for a reasonably early alarm.

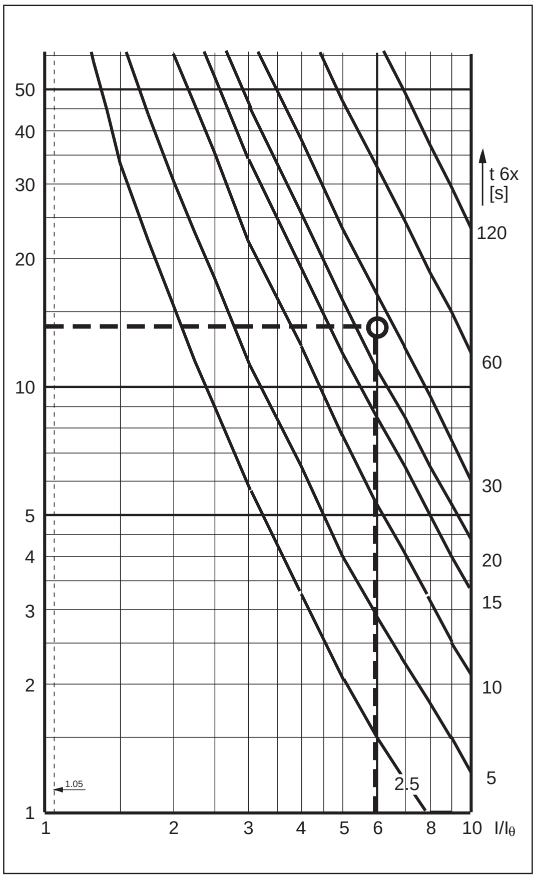


Fig. 1. How to find the setting t_{6x} from the hot thermal curve

As the start-up consumes 11 s / 25 s ≈ 45% of the full thermal capacity, the restart inhibit level Θ_i must be set lower than 55%, e.g. at 50%.

The cooling factor k_c is set e.g. at 4 because the motor is a normal, totally enclosed unit, cooled by a fan on the the rotor shaft.

If we want the high-set overcurrent to double as a running stall protection, the basic setting should be lower than the startup/stall current and be doubled during start. Thus this element can be set to a value of 75 ...90 % of I_s:

I>> = 0.75 x 6.2 x 930 A x 1 / 1000 ≈ 4.3 x 1A.
Doubling during the start-up -> SGF/2 =1.

Generally a setting as low as 75% should be giving good results but if the inrush current should cause trippings during startup, a higher setting must be chosen.

For the earth-fault a core balance transformer with a CT ratio of 100 / 1 A is used.

The earth-fault protection should detect an earth-fault of 20% of the fully developed fault current, i.e.: 20% x 10 A = 2.0 A

I_0 = 2 A x 1 A / 100 A = 2.0% x 1 A

The possibility to use an external trip is also indicated in the block diagram in Fig. 2. By setting switch SGB/5 = 1, the control input is linked to the trip output. In this case e.g. an undervoltage relay can be used to supervise the busbar voltage and will in a fault condition perform a trip using the SPAM 150 as an interface. In this way all signals, events and memorized parameters can be accessed via this relay.

The earth-fault unit is energized from a core balance CT in order to obtain a sensitive earth-fault protection. Because of the low input impedance of the relay a low turns ratio of the core balance c. t. can be used . When using the core balance c.t. type KOLMA 06 A1, a turns ratio of 100 /1 A is recommended.

The high-set overcurrent unit constitutes an interwinding short-circuit protection for the motor and a phase-to-phase short-circuit protection for the feeder cable. The current setting is automatically doubled during start-up. Thus the current setting can be given a value lower than the motor starting current. Normally the setting can be chosen to 0.75 times the motor starting current. With a suitable operating time set, this feature will enable the high-set overcurrent unit to operate, if the motor is jammed while the motor is running.

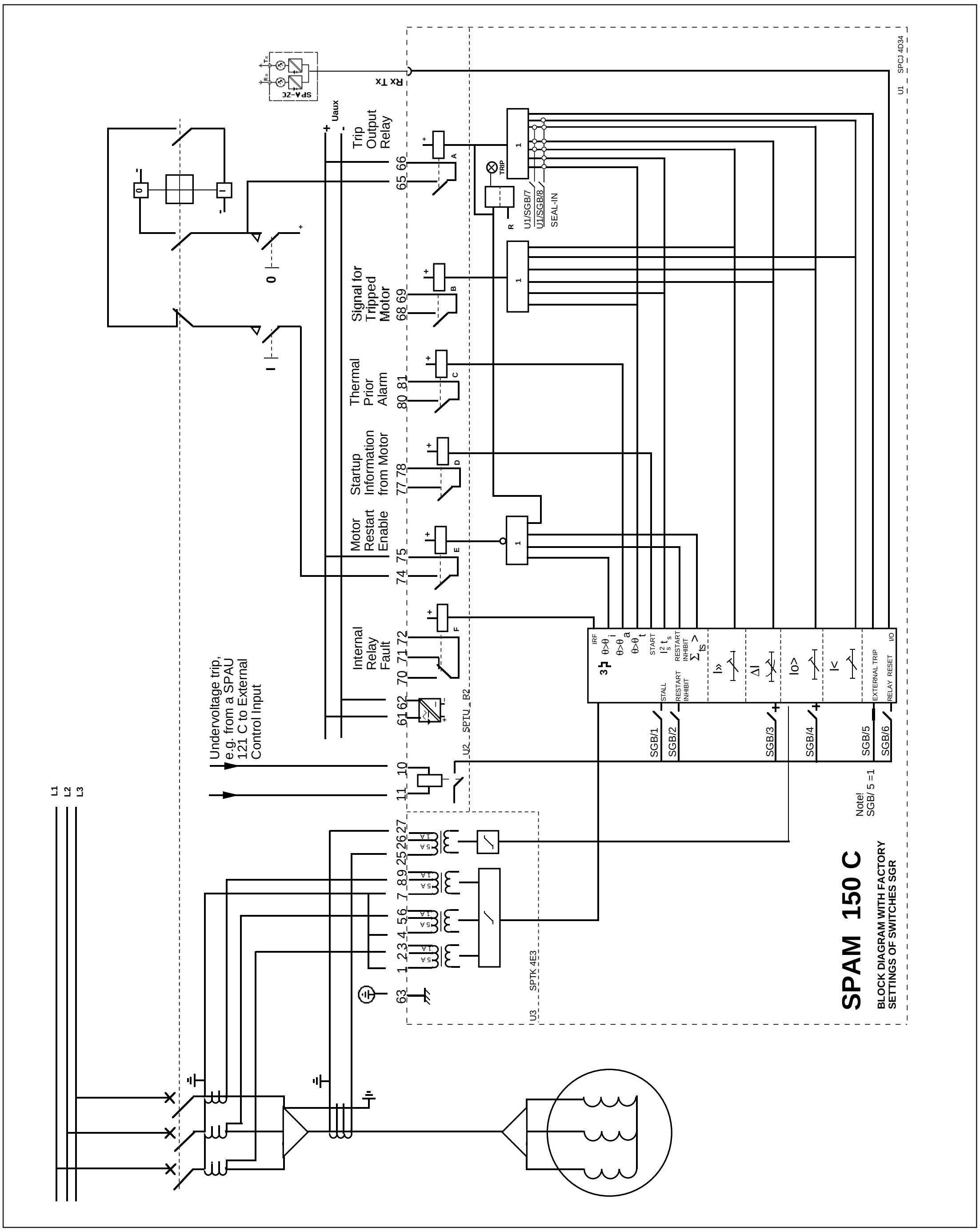


Figure 2. A circuit-breaker controlled drive in an isolated net with core balance approach for the earth-fault protection.

The behaviour of the thermal model under a couple of typical drive conditions is shown in Fig. 3 and 4. Figure 3 shows the thermal behaviour during a dual start-up sequence from a fully cold state. During the first start-up, the start current is heating up the motor during the start time and a total of about 65% of the thermal capacity is used. After the start, the motor is left running for a few minutes with a normal load of about 90% of the full load current. As soon as the motor leaves the start-up condition, the hot spots start levelling out and the used thermal capacity decreases rapidly to a level determined by the long term thermal loading of the motor. The second start brings the thermal capacity used up to a level close to tripping but still allows the motor to run up. After the second start the motor is left running for a long time with a normal load and we can see the thermal capacity curve level out, first by eliminating the hot spots and then by successive cooling to a steady state where about 37% of the thermal capacity is used.

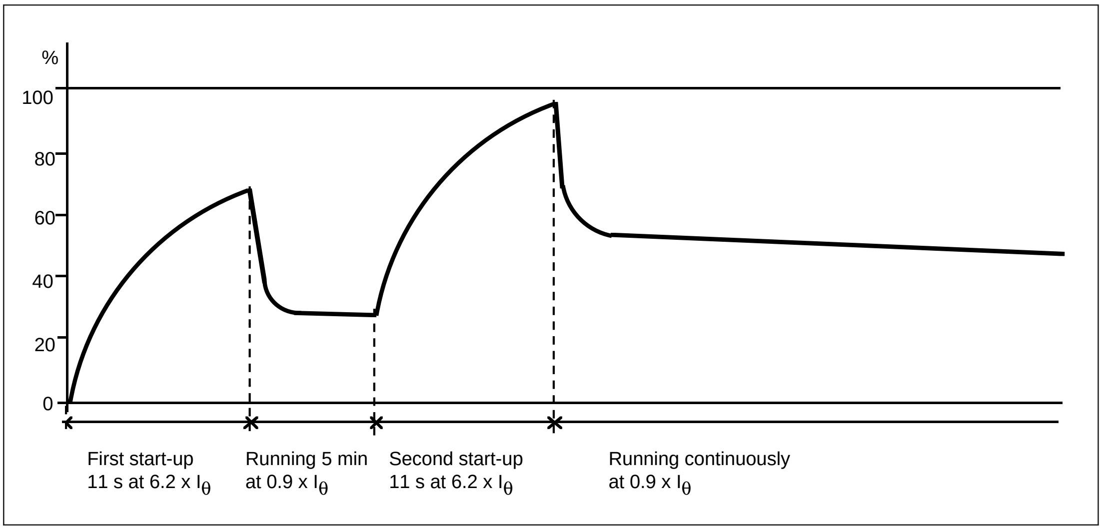


Fig. 3. The thermal behaviour for two cold starts followed by a motor running at normal load.

Figure 4 shows a situation where the motor has been running for a long period, whereafter it is overloaded until the relay carries out a trip. The restart enable relay is reset as the thermal level is higher than the set level, which in this case is 40%. The motor begins to cool down, first by levelling out hot spots and then by slowly reducing the thermal curve now mainly consisting of used thermal capacity due to a long term thermal overload. As the motor is at standstill, the cooling rate is reduced as the cooling fan on the motor shaft is not running. The reduced cooling is also taken into account by the relay by a suitable setting of the cooling time multiplier k_c, e.g. 4 ....8. When the used thermal capacity has fallen below the set restart inhibit level 40%, the restart enable relay of the motor protection is activated and the motor can again be started.

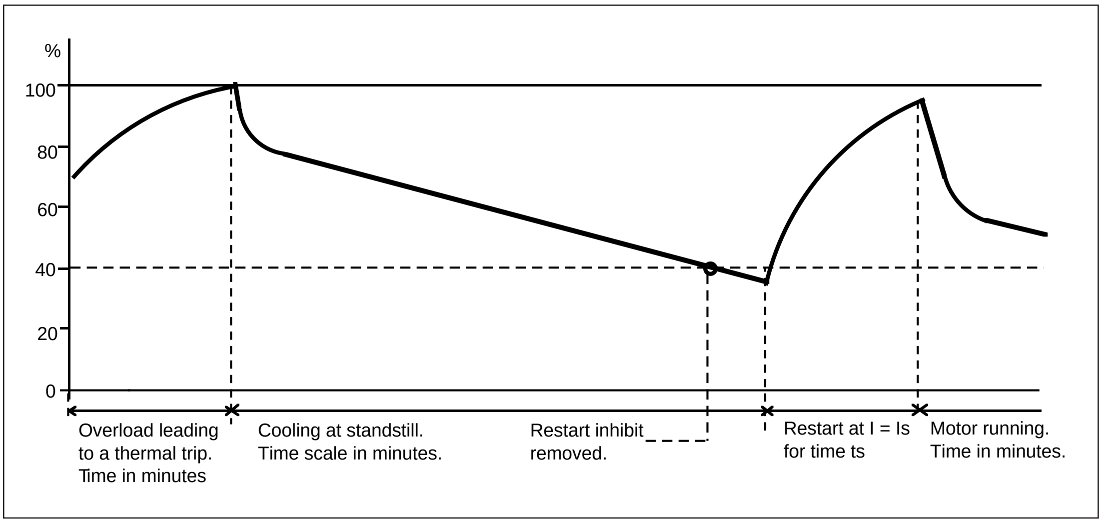


Fig. 4. The thermal behaviour of an overload trip and cooling, followed by a motor restart.

Example 2

Determining suitable setting values for a standard, contactor controlled direct started motor

Data on the motor to be protected:

Type = squirrel cage motor with direct start, totally enclosed with fan cooling

Rated power P_{nm}	900 kW
Rated voltage U_{nm}	380 V
Rated current I_{nm}	1650 A
Motor directly started, i.e. p =	50%
Starting current I_s	6.0 x I_{nm}
Starting time ts	9 s
Two starts from cold required	
Max. stall time from cold condi.	21 s
Ambient temperature	20°C
C.T. current ratio	2000/1A

Network solidly earthed	
Earth-fault sensitivity required	20% of I_{nm}

Calculation of settings:
Due to the ambient temperature <40°C, the full load current (FLC) is increased by 5%:

Thus FLC = 1 .05 x 1650 A = 1733 A

The relay setting I_θ is then:

$$I_\theta \ / \ I_n = \frac{1.05 \text{ x } 1650 \text{ A x } 1 \text{ A}}{2000 \text{ A x } 1 \text{ A}} = 0.87$$

The motor is direclty started, i.e. p = 50%.

The setting t_{6x} is selected from the time/current characteristic corresponding to a hot motor condition. First the ratio between the starting current and the full load current is calculated :

I_s / I_θ = (6.0 x 1650 A)/(0.87 x 2000 A) = 5.7

The starting current 6.0 x 1650 x 1/2000 ≈5.0 is used together with the starting time 9 s + 10 …15% safety margin = 10 s to set up the startup supervision, based on I_s^2 x t_s .

As the start-up time is smaller than the maximum motor safe stall time of 21 seconds, no speed switch inhibited stall protection is needed.

A setting t_{6x} = 15 s is selected from the hot curve (see Fig. 5), permitting a starting time which is a bit longer than the given motor starting time. The corresponding time read out from the cold curve gives a trip time of about 16 seconds.

The prior alarm setting can be selected e.g. Θ_a = 85 ...90 % for a reasonably early alarm.

As the start-up consumes 9s/15s ≈ 60% of the full thermal capacity, the restart inhibit level Θ_i must be set at 40% or lower.

The cooling factor k_c is set at 4...6 beacuse the motor is a normal, totally enclosed unit, cooled by a fan on the the rotor shaft.

As the drive is contactor-controlled and the contactor cannot break a high current fault, the high-set overcurrent unit must be set out of operation.

The earth-fault setting is calculated as:
I_0/I_n = 0.2 x 1650 A / 2000 A = 16%.

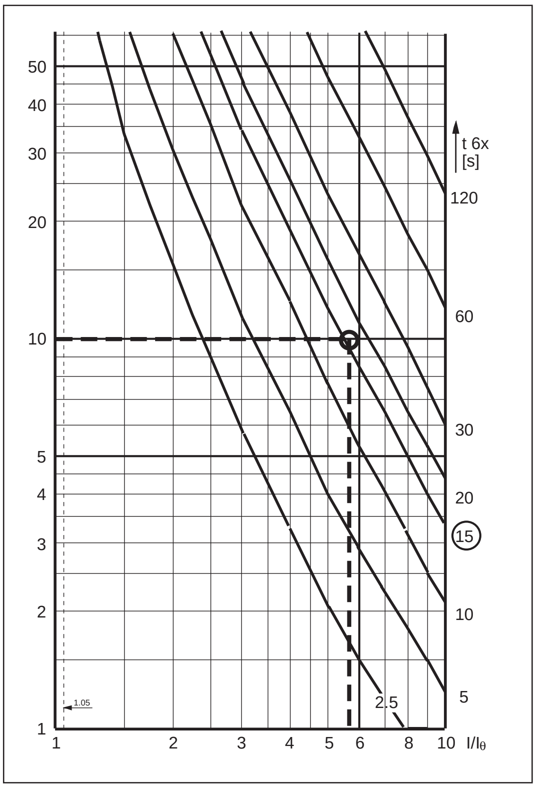


Fig. 5. How to find the t_{6x} setting from the hot thermal curve

The trip time for an earth-fault is set at 50 ms as the network is solidly earthed.

Because the drive is contactor controlled, the earth-fault unit must be blocked at high currents. Whenever the phase currents exceed e.g. 6 times the setting I_θ, the earth-fault unit is blocked in order not to operate the contactor at too high current levels. During the high current conditions the protection is based on the backup fuses. The limit for the blocking current is set by means of the switches SGF/3 and SGF/4.

The thermal unit with a set value of p = 50% is normally used to describe the thermal capacity of a directly started motor.

The feeding network is solidly earthed and thus the operation of the earth-fault protection is selected to be tripping.

Should a unit other than the overload protection or start-up stress monitor of the relay trip, the condition of the motor should be checked. For that reason the operation of the output relay A (contacts 65 - 66) is selected to be manually reset after a trip by means of switch SGB/7. If the latching function is wanted for all trip operations, switch SGB/8 is used instead of the former switch.

Simultaneously with the trip relay, a signalling relay B is operated, giving a trip signal over contacts 68 - 69.

A prior alarm for a beginning overheating is achieved with relay D (contacts 77 - 78) as soon as the thermal level exceeds the set prior alarm level θ_a. This level can preferably be set at e.g. 90%, allowing the motor to be fully utilized at nominal current, but giving an alarm as soon as the load is constantly higher than the full load current.

A too rapid restart attempt is prevented by the restart inhibit feature in the relay. The close signal to the contactor or circuit breaker is linked over the restart enable relay E contact (74 - 75). The relay will not allow a restart until the thermal level of the motor is lower than the set restart inhibit level θ_i.

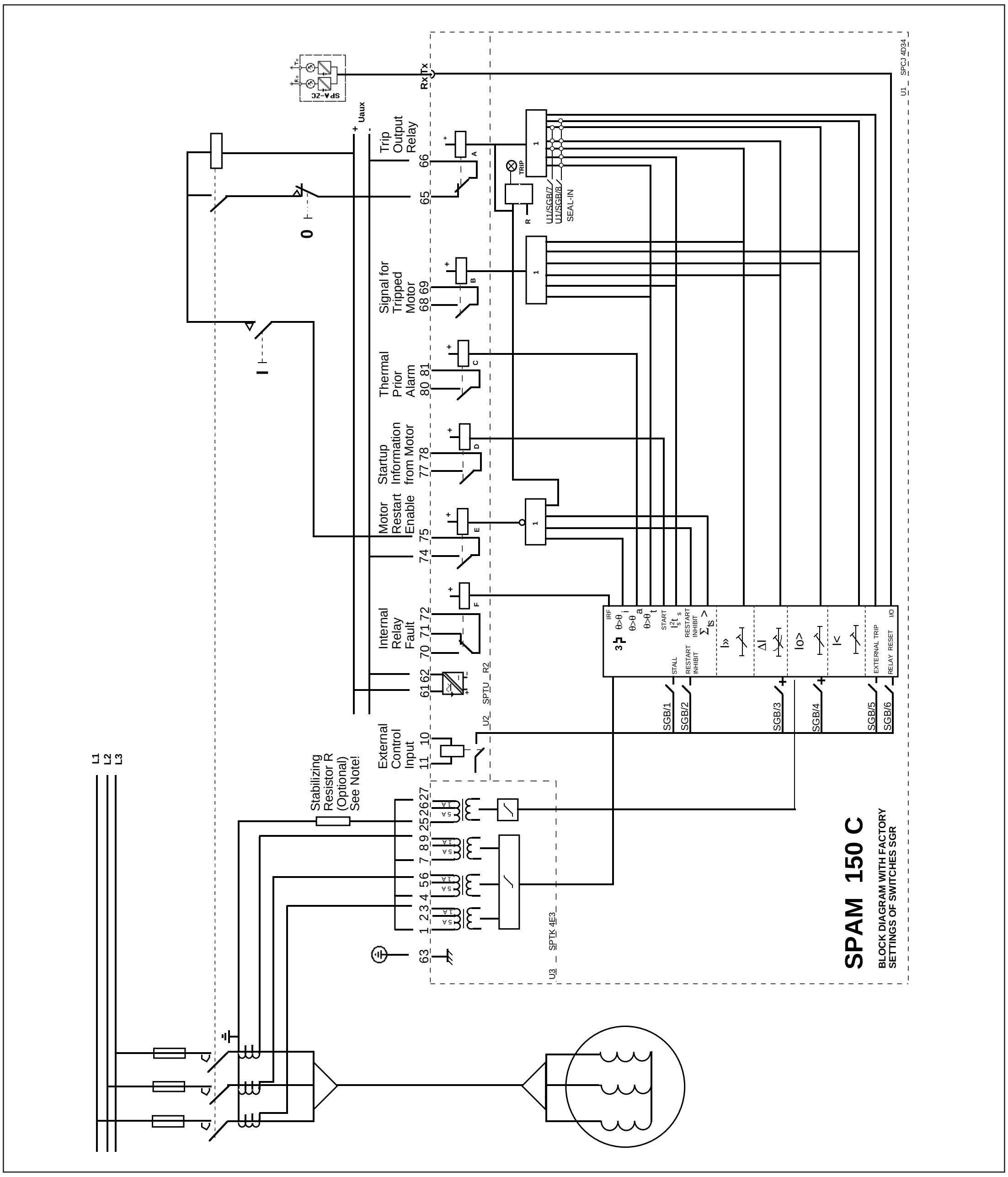


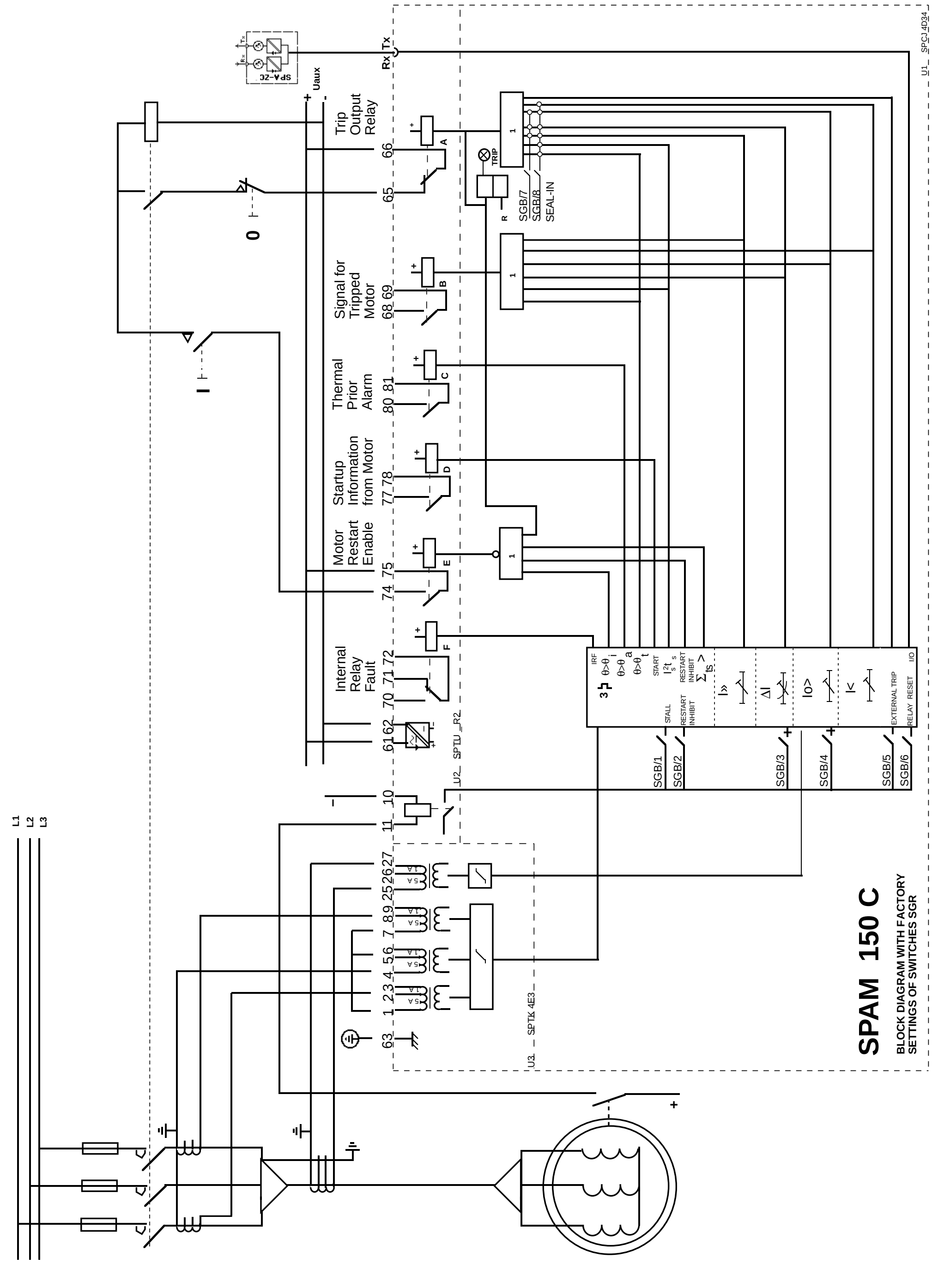
Figure 6. A contactor controlled motor drive with residually connected earth-fault protection. To stabilize against virtual earth-faults an external resistor is added in the return path for the earth-fault current to increase the burden for the main CTs.
Note! A power and output relay module type SPGU 240 R3 or SPGU 48 R3 is used for a normally closed trip contact for contactor controlled drive use.

Example 3

Protecting a direct started motor with a low safe stall time

In many applications, e.g. ExE-type drives, the motor is not allowed to be in a stalled condition as long as its own start-up time. To find out whether the motor is speeding up or not, a speed switch on the motor shaft is used. The switch should be open at standstill and close when the motor speeds up.

The speed switch information is used to control the start-up stress monitor and the setting ts is set a little shorter than the maximum allowed jam time t_e. If the motor starts accelerating, the speed switch will inhibit the start-up supervision unit trip and leave the protection to the thermal unit. If the motor does not speed up, tripping will be carried out after the time $t_s = t_e$.



The speed switch should be open at standstill and close when the motor speeds up.

Fig. 7. Protection of a directly started motor. A speed switch on the motor is used to produce a secure stall protection even though the maximum safe stall time of the motor is less than the start-up time.
Note that because of the fact that only two phase CTs are used, the third phase is reconstructed by summing the two monitored currents through the third winding.

Example 4

Protecting of a feeder cable, a transformer or another non-rotating object

The relay SPAM 150 C can also be used as a multifunction protection for other objects than motors, e.g. feeder cables, resistive elements or transformers. For this purpose some features have lately been added to the original version of the relay.

As the start-up supervision stage in these applications more or less always is used as an overcurrent unit with definite time or I.D.M.T operation, there was a need to have a shorter setting than 2.0 s. For this reason the setting range for the operating time was extended to a range 0.3....80 seconds.

If an I.D.M.T. operation is wanted, the start-up thermal stress unit can be used to perform an operation similar to the extremely inverse. Normally the operation of this unit is tied to a motor start-up condition. For other applications this is not very useful and for this reason the starting condition for the unit was made selectable with a switch SG4/1, found in the submenu, step 4 of register "A" on the relay module SPCJ 4D34.

With the switch SG4/1 in position "1", the starting criterion for the thermal stress unit is switched from the normal, where the current must change from 0.12 x I_θ to 1.5 x I_θ within less than 60 ms for the unit to start, to a condition of activating the unit any time as soon as the setting Is is exceeded. With switch SG4/1 in the default position (="0"), the unit works with a normal motor start-up operation related above.

If the measuring module SPCJ 4D34 is used in another protective combination than SPAM 150 C, the restart enable signal might interfere with trip signals from neigbour modules connecting to the same pins on the mother board. To avoid this, a means of inhibiting the restart enable signal has been implemented. When switch SG4/2 is set from its default position "0" to position "1", the restart enable singal output is cut off and hence no signal is linked to the mother board.

A start signal from the low-set overcurrent unit to the start output relay is in certain applications needed to form the blocking signal for a busbar protection of type blocked O/C relays. This signal can now be linked to output relay D (SS1) by setting switch SG4/3 to position "1".

The high-set overcurrent unit constitutes the short-circuit protection and can be used with settings down to 0.5 x I_n and with trip times down to 40 ms.

The start of the high-set overcurrent unit can be brought out linked to relay D instead of the motor start-up info. This is done by setting switch SGR/3 =1 and SGR/1=0. Now the start signal can be used as a blocking signal for an upstream feeder protection relay, thus constituting a busbar protection based on blocked overcurrent relays.

The use of a core balance transformer for measuring the earth-fault current makes the earth-fault protection very sensitive. When using a core balance transformer the variations in the load current do not interfere with the measuring. Thus a relatively small earth-fault current can be selected for a resistance earthed network.

If a residual connection is preferred, this can also be used even though the settings then must be a bit higher in order to avoid possible stability problems due to unbalances in the main transformers causing virtual earth-fault currents during high phase current conditions. Also note the possibility to use an external stabilizing resistor for helping up too weak main transformers, preventing them from causing these false earth-fault currents.

The thermal unit with a weighting factor setting of p = 100% is suitable for describing the thermal capacity properties of devices with no hot spot behaviour, i.e. for cables or similar objects.

The thermal unit is used in a normal way for protecting against long time overloading and operates in a single time constant mode. The setting of p = 100% means that the heating and cooling of the protected object is always similar regardless of the current levels. When setting the time constant for the relay the expression t= 32 x t_{6x} can be used. A thermal prior alarm can be achieved over a separate output relay, e.g. relay C.

The behaviour of a thermal model with p = 100% is shown in Fig. 8. The load is intermittent with high load sequencies with currents of 1.5 x I_θ and low load sequencies with a current of 0.8 x I_θ. As can be seen, the heating and cooling parts of the curve are behaving in a similar way with the same time constant. Normally the cooling constant k_c for very low currents, corresponding to a motor standstill is set at 1.

A typical connection for a cable protection application is shown in Fig. 10.

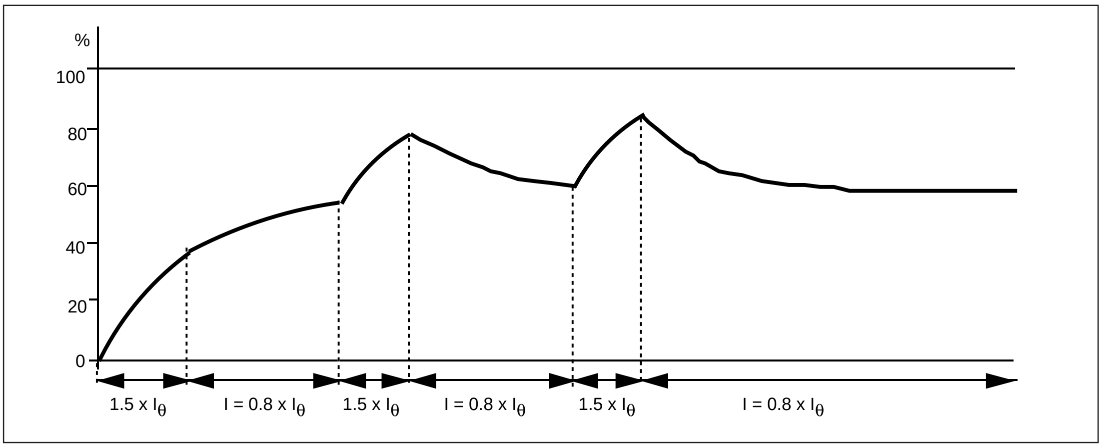


Figure 8. The behaviour of the thermal level in a single time constant object with varying load sequencies

The parameter p of the thermal unit

One of the main settings of the thermal unit is the thermal unit weighting factor p. This parameter is picturing the dualism of the thermal properties of a motor.

A setting of p=100% produces a pure single time constant thermal unit, which is useful for applications with cables etc. As can be seen from Fig. 9., the hot curve with p=100% only allows a stall time of about 10% of the cold safe stall time. For a motor with a curve of e.g. t_{6x} = 10 s, the hot trip time would be only 1 s, whereas the motor can withstand at least 5 or 6 seconds. To allow full use of the motor a lower p-value should be used.

As about one half of the thermal capacity is narmally used when a motor is running at nominal load, this must also be handled by the protective unit. With the normal motor setting of p=50 %, the relay will notify a 45...50% thermal capacity usage at full load.

Generally a choice should be made between 50% for a standard motor started directly on line, and 100% for a non-rotating object or a soft-started motor. Only in special cases, where a closer adjustment of the thermal characteristic is needed and the thermal capacity of the object is very well known, a value between 50 and 100% might be needed.

Note! For applications with e.g. three cold vs. two hot starts a setting of p = 40% has sometimes proved to be useful. Otherwise setting the p-value much below 50% should be handled carefully because in this case there is a possibility to overload the protected object as the thermal unit might allow too many hot starts or "forget" too much of the thermal history background. In Fig.9. you can see that the hot curve of p = 20% is quite close to the cold curve. The cold curve is identical for all p-values.

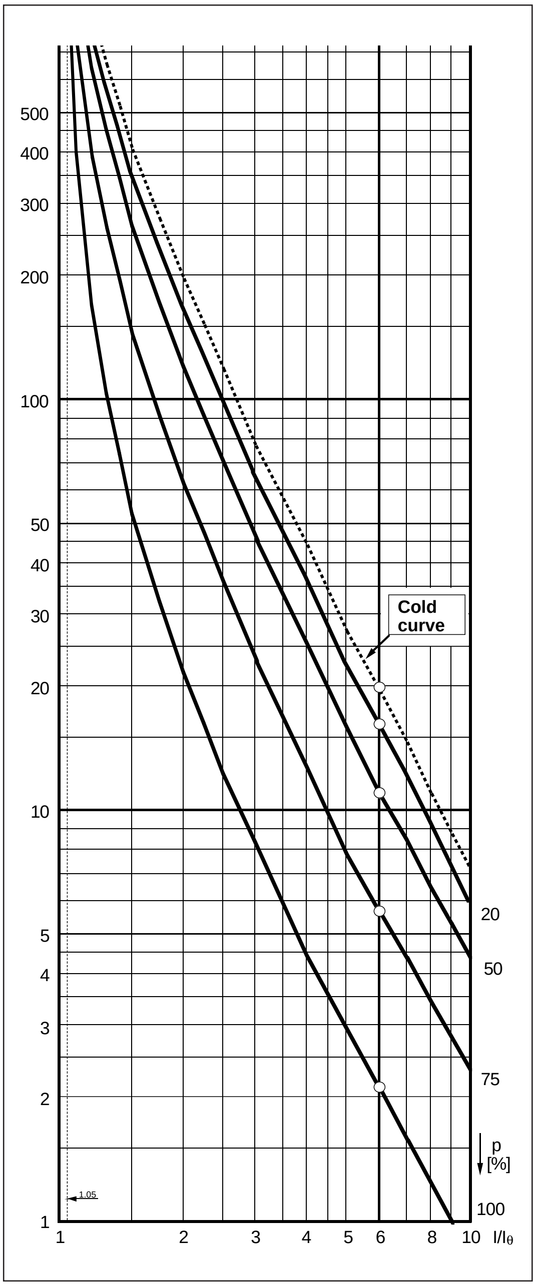


Figure 9. The influence of the p-value on the hot trip time curve with t_{6x} = 20 seconds.

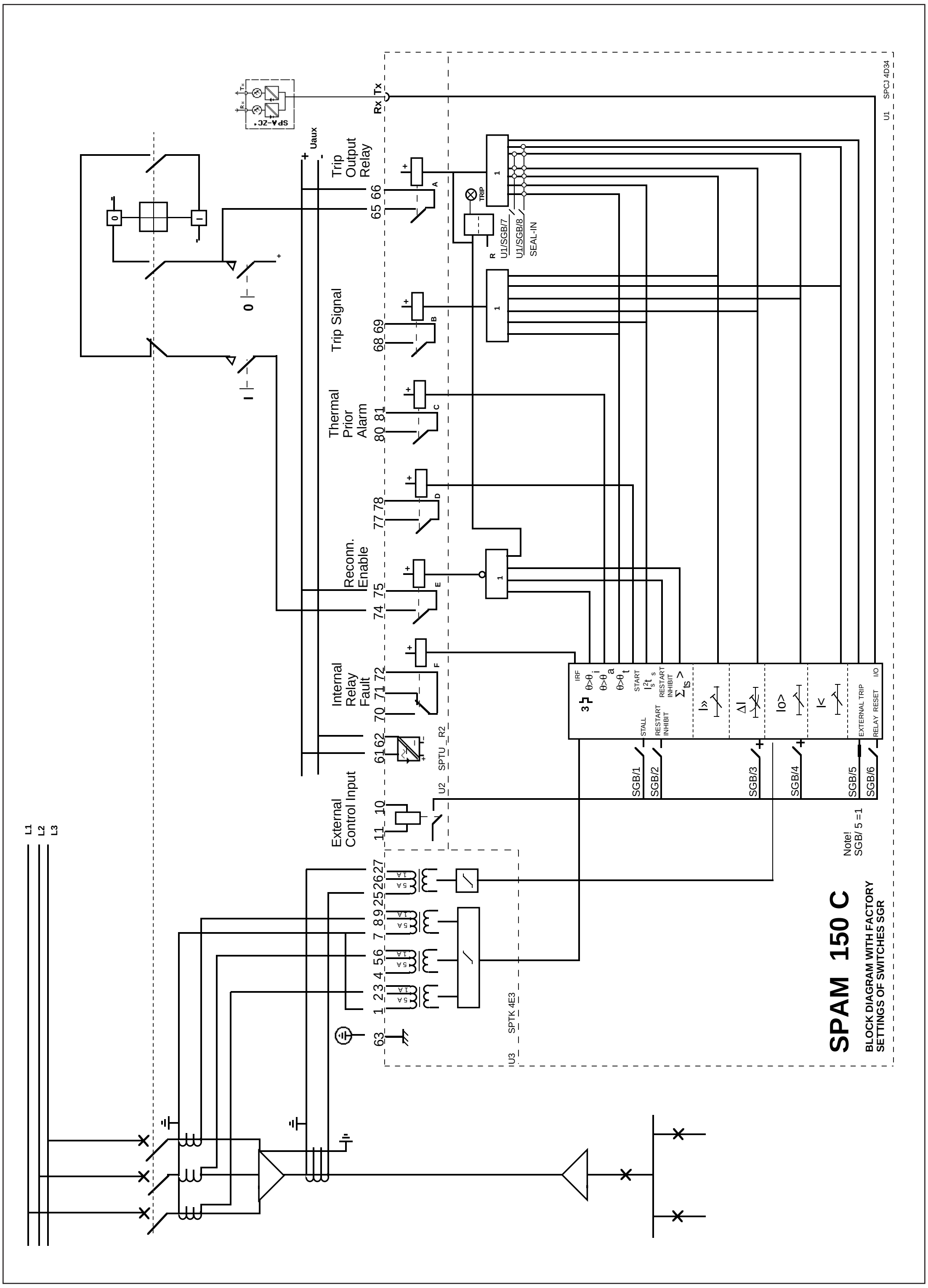


Figure 10. Protection of a feeder.

Example 5

How to use the start-up time counter

Quite often a motor manufacturer gives a statement of how many times a motor may be restarted within a certain time interval. The start-up time totalling check acts as a backup to the thermal protection by keeping track of that restarts cannot be made too frequently, in other words that the recommendations from the manufacturer are not exceeded.

The start-up time counting possibility is integrated in the module SPCJ 4D34 so that no extra timers are needed. To use the start-up time counter, two settings must be worked out. First we must define the restart inhibit level in start seconds and further we must tell the module how rapidly the accumulated amount of start seconds should be counted down.

Let us for example assume that our motor is recommended to be started at the most for three times within 8 hours and that the start-up time is 20 seconds each. By making all the allowed three starts in a row we will get the situation described in the diagram below.

The three 20 second starts add up to a total of 60 seconds. Right after the third start has been initiated, the inhibit should be activated as a fourth start attempt is no more allowed. This means that the setting of the inhibit level in this case is set at 41 seconds. Please note that the start sequence will still proceed even though the inhibit is activated. The inhibit is only interrupting the close path to the circuit-breaker, thus preventing further start-ups.

Furthermore the statement of not more than three starts within 8 hours means that the countdown should reach the inhibit level after 8 hours to allow for a single new start. In our example this means that we should count down 20 seconds in 8 hours, i.e. the countdown rate setting is $\Delta\sum ts/\Delta t$ = 20 s / 8 h = 2.5 s / h.

Please note that for readability reasons, the time scaling in the diagram is not the same for the start-up versus cooling-down sequences!

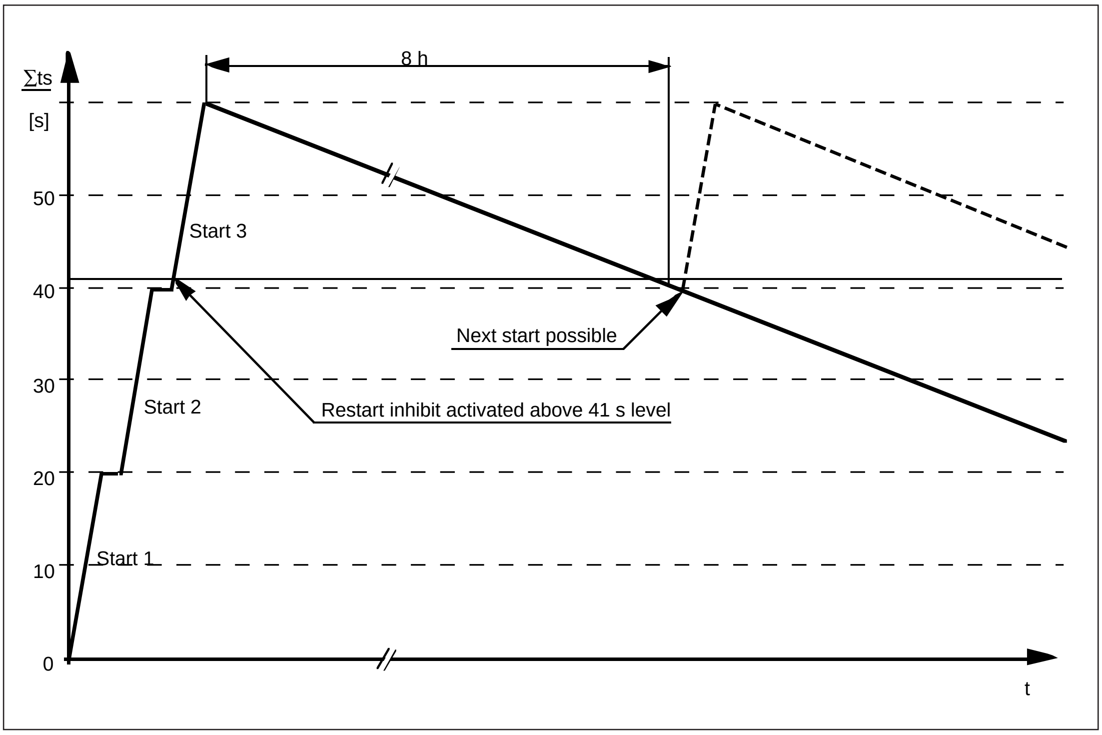


Figure 11. The operation of the start-up time counter.

Example 6

How to set the phase unbalance and phase reversal unit

The phase unbalance and phase reversal unit in SPAM 150 C is based on the measurement of the difference between the three phase currents. The difference between the highest and the lowest phase current is compared in per cent of the highest one.

The benefits with this arrangement is a lower sensitivity to frequency variations and harmonics in the currents. Furthermore the phase reversal protection is separated as a stand-alone unit not dependent of the asymmetry protection.

In a full broken phase condition, the unbalance reading of SPAM 150 C is 100%. This can be compared to the reading of 57.8% with a relay measuring unbalance on a negative phase sequence current basis (e.g. SPAM 110). Thus when comparing n.p.s. values to current difference values, a conversion factor of 0.578 is used.

Example:

We want to have an unbalance unit sensitivity of about 15% in terms of negative phase sequence current on a motor. The unbalance protection should operate with an operating time of 10 s at the 15 % amount of unbalance.

We calculate:
15% (NPS) = 15 / 0.578 ≈26 % (ΔI)

Thus we can set ΔI> =25% on the relay

From the trip time chart we can see that a trip time of the desired 10 s at 25% is achieved by using a time setting tΔ of 60 s. The unbalance unit will not operate for unbalance levels below the set 25% but at this level the trip time is 10 s and for higher degrees of unbalance the time decreases down to 1 s at a full single phasing condition.

The phase unbalance unit is selected to be operative with the switch SGF/5 =1 and the phase reversal protection is made operative with switch SGF/6 = 1.

Finally the output relay is selected with switches SGR1/5 or SGR2/5.

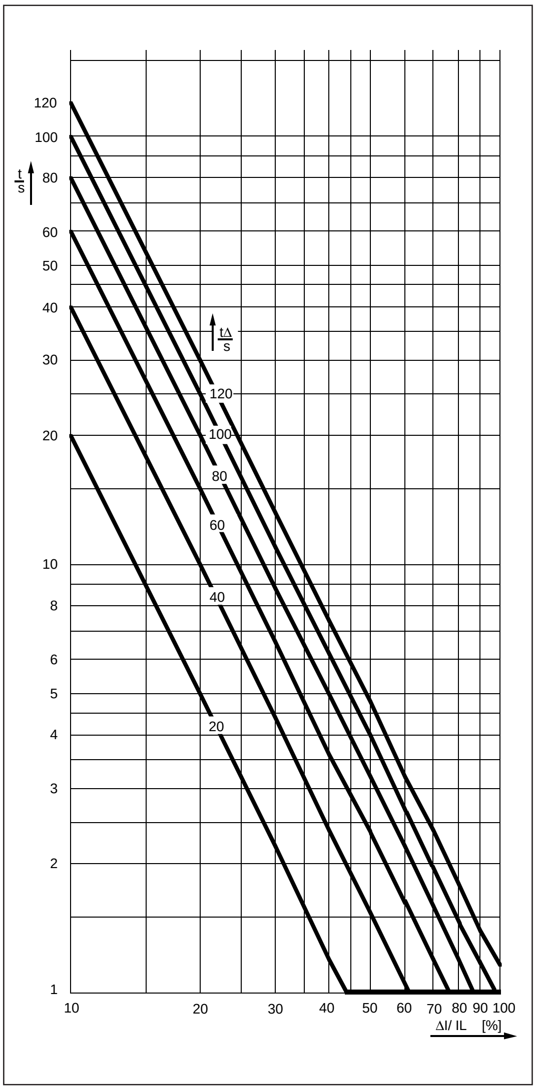
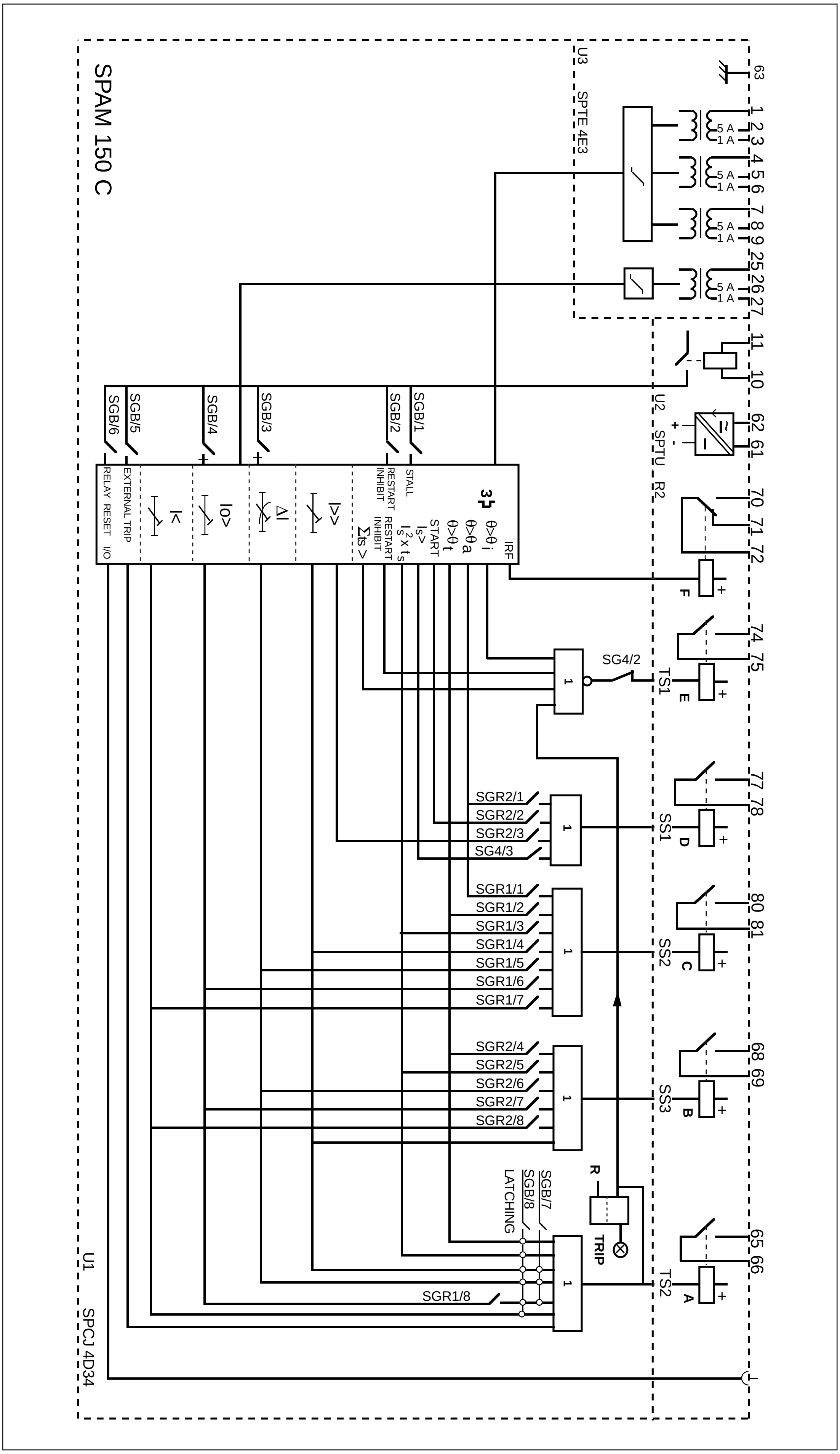


Figure. 12 The trip time diagram for the phase unbalance unit.

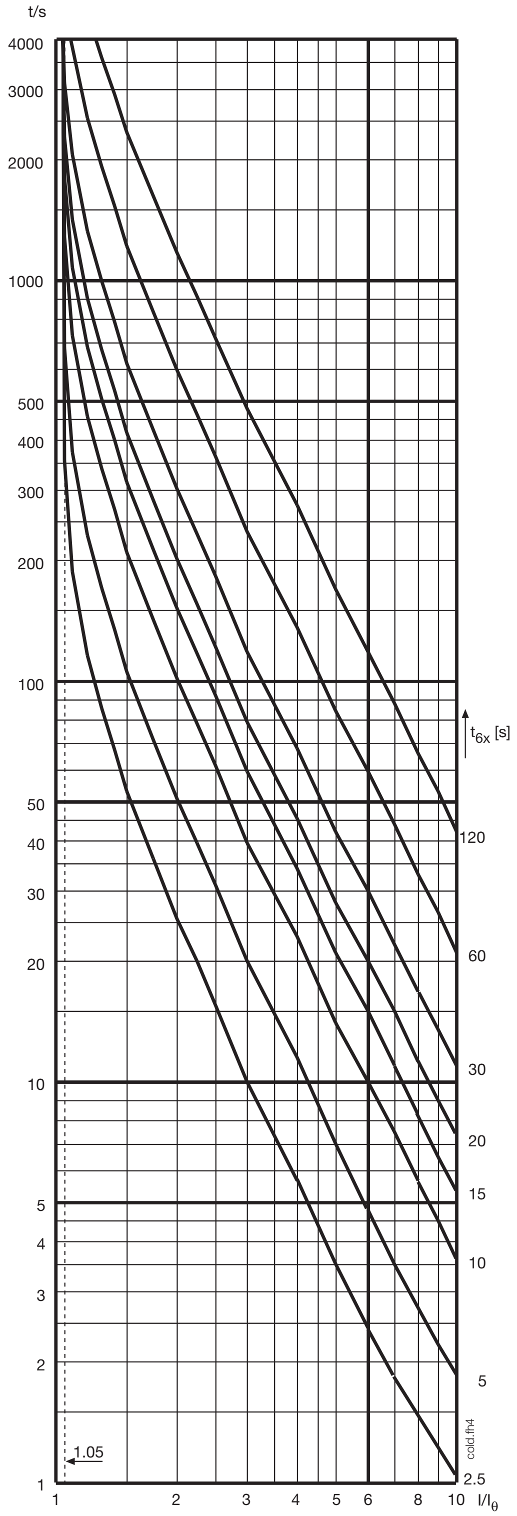
Appendix 1

The complete block diagram for SPAM 150 C with all SGR switches shown

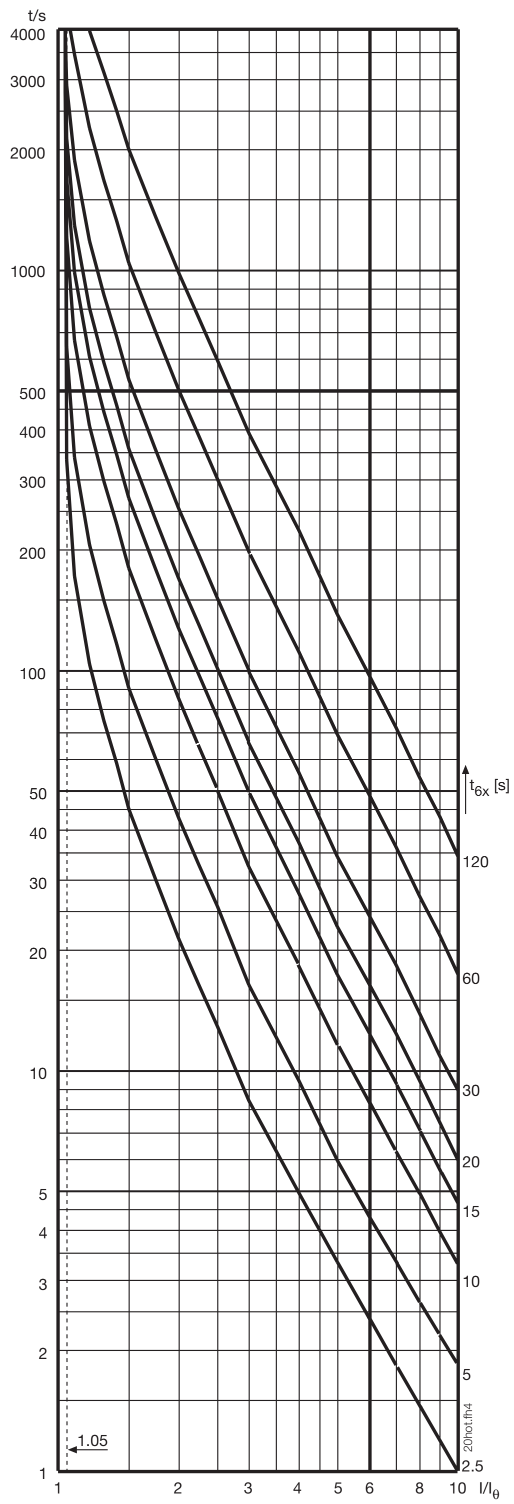


Appendix 2

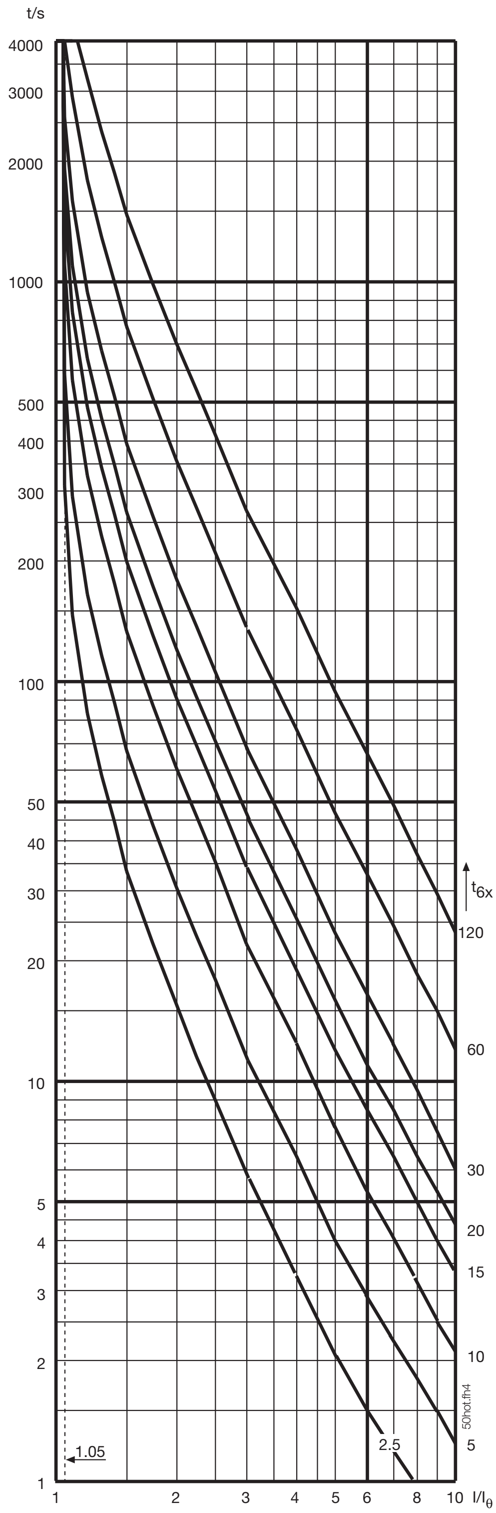
Trip characteristic diagrams for the thermal unit



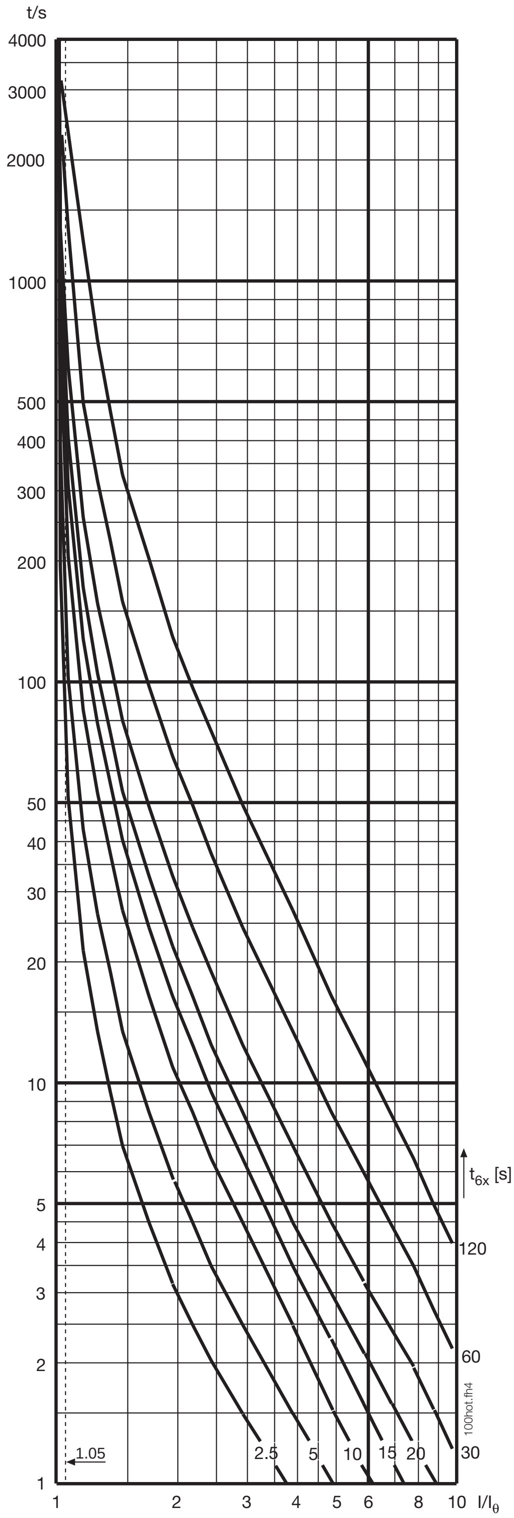
Trip diagram for a cold condition, i.e. without prior load. The cold curve is independent of the setting of the p-value



Trip diagram for a hot condition, i.e. with a prior load 1.0 x I_θ and weighting factor p set at 20%



Trip diagram for a hot condition, i.e. with a prior load 1.0 x I_θ and weighting factor p set at 50%



Trip diagram for a hot condition, i.e. with a prior load 1.0 x I_θ and weighting factor p set at 100 %

Appendix 3

Mathematical equations for the thermal unit

Heating up during an overload condition:

$\Theta_A = (I / (1.05 \times I_\theta))^2 \times (1\text{-}e^{-t/\tau}) \times 100\%$

$\Theta_B = (I / (1.05 \times I_\theta))^2 \times (1\text{-}e^{-t/\tau}) \times p\%$

Cooling at normal load or in a standstill condition:

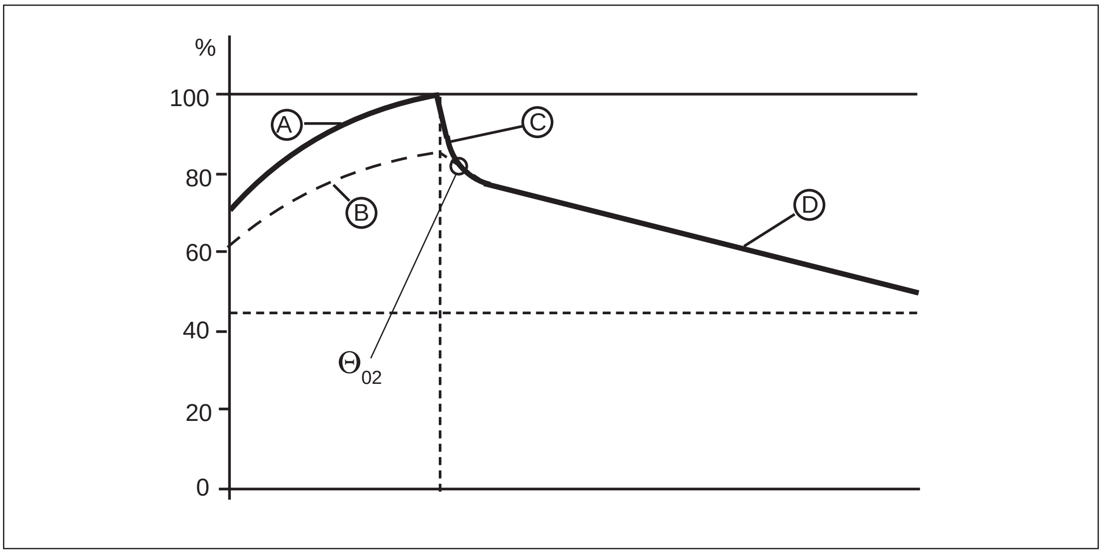
When the current decreases below 1.0 x I_θ, the thermal curve A is linearly brought down to the level of the thermal history curve B as shown in curve part C. This corresponds to the levelling out of the hot spots in the motor.

Thereafter the cooling follows the lower curve with a time constant equal to the heating time constant as long as the motor is running at normal load or idling.

For a motor at standstill, i.e. when the current is below 12% of I_θ, the cooling can be expressed as:

$\Theta = \Theta_{02} \times e^{-t/kc \times \tau}$

where Θ_{02} is the initial thermal level and kc is the cooling time multiplier according to the set value 1...64.



Estimated trip time
(modified 2003-04)

Solving the equation for heating up with reference to trip time gives:

$$t \approx 32.15 \times t_{6x} \times \ln \left\{ \frac{(I/I_\theta)^2 - p/100 \times (I_p/I_\theta)^2}{(I/I_\theta)^2 - I_t/I_\theta)^2} \right\}$$

In the above expression I_t is the trip current level, which is always 1.05 x I_θ, i.e.:

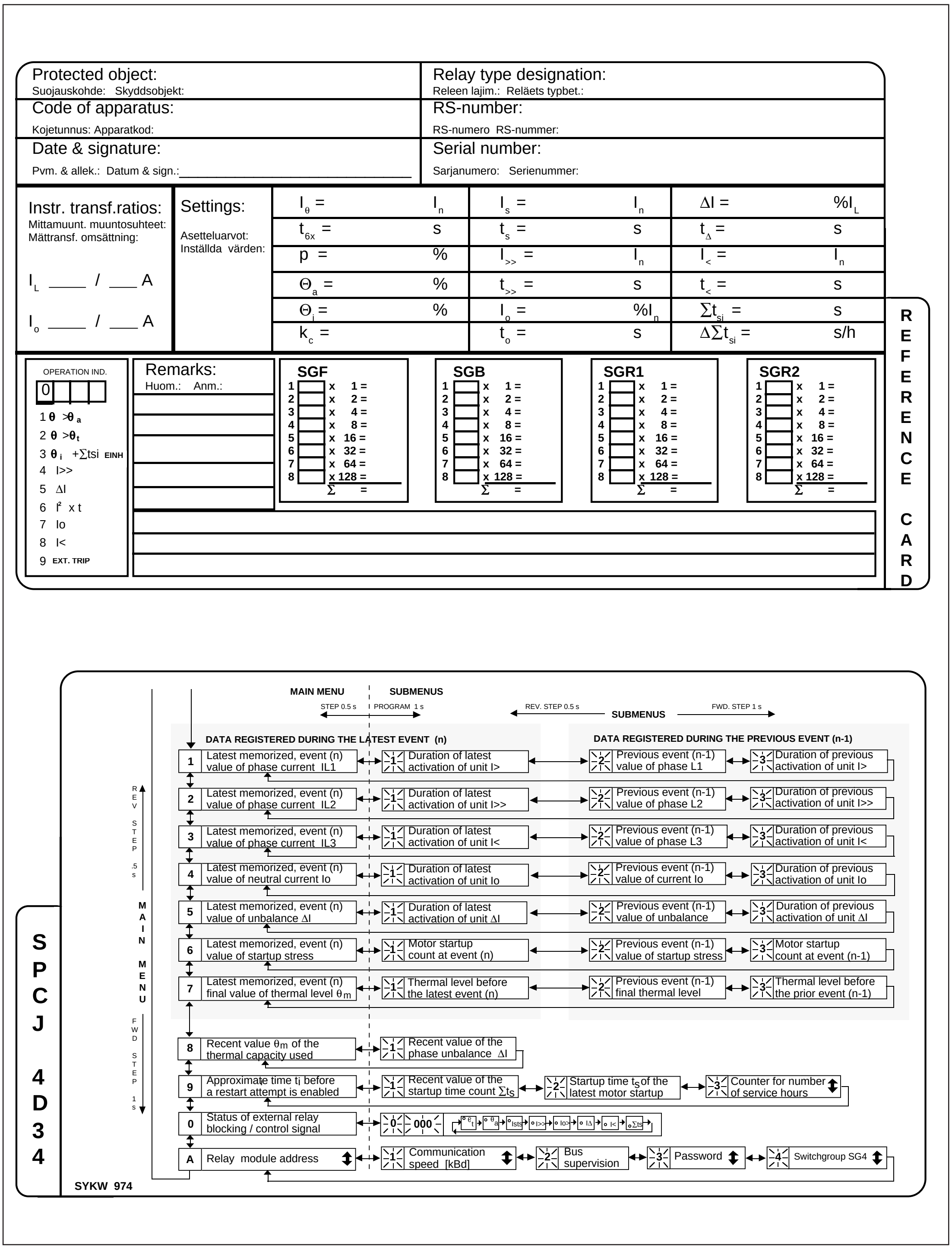
$$t \approx 32.15 \times t_{6x} \times \ln \left\{ \frac{(I/I_\theta)^2 - p/100 \times (I_p/I_\theta)^2}{(I/I_\theta)^2 - 1.1025} \right\}$$

The parameters I_θ, t6x and p are the relay settings, I_p is the long term prior load and finally I is the overload current which is finally going to cause a trip. The operand ln is the natural logarithm ($\log_e$).

The thermal level is handled twice a second in the relay, giving a best trip time resolution of 0.5 s.

Appendix 4

Reference card for the motor protection relay module SPCJ 4D34



A reference card similar to the one shown above is delivered with each relay. The reference card is the best place to store all information about the relay settings etc. Please fill in the card thorougly and keep it together with the protective relay for quick reference.

Data needed to determine motor protection settings

Motor data

Type or construction of motor...........
....

Rated power P_{nm} = kW
Rated voltage U_{nm} = V
Rated current I_{nm} = A

Start-up arrangement:
☐ direct on line ☐ transformer
☐ reactance

Starting current I_s = x I_{nm}
Actual starting time t_s = s

Max. start/stall time permitted
- from a cold condition = s
- from a hot condition = s

Required number of cold / hot starts ___/___

System data

Ambient temperature t_{amb} = °C

Cooling arrangements & systems:
☐ totally enclosed (rib cooling)
☐ heat exchanger
☐ ....

Cooling time coefficient k_c =

CT current ratio / A
Block transformer ratio / kV
Note! If a block transformer is used, the ratio of this transformer must also be noted!

Network earth-fault current when fully developed (100%) A

Type of load.....................................
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Special remarks & requirements
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The items marked with **bold** letters are completely essential to make it possible to work out settings for the motor thermal and start-up protection.

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