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Multifunction Relay
Types MCX 912 and MCX 913

Operating Instructions

Home

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Warning

This is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

This document has been carefully prepared and reviewed, however should in spite of this the reader find an error, he is requested to inform us at his earliest convenience.

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Contents

1. APPLICATION

The micro-processor controlled relays of the MCX91. series are intended for the protection of electrical plant in three-phase MV and HV power systems.

- MCX913 for connection to all three phases
- MCX912 for connection to two phases and, via a sensitive I_0 input transformer, to neutral.

The relays embody a large number of protection functions in a single unit, not only for the detection of faults (phase and earth faults), but also of inadmissible operating conditions (thermal overload). In both cases the necessary information is derived from the measurement of the phase currents flowing in the protected unit.

The combination of different protection functions enables several conventional loose relays to be replaced by a single one. The following faults and conditions can be detected:

- phase faults and overcurrents
- earth faults (neutral current derived either internally or externally by a core-balance c.t.)
- negative phase sequence (NPS)
- no load check
- thermal overload by thermal replica which records load changes and is a thermal model of the protected unit
- inadmissible stressing of machines, especially induction motors, whilst starting and running up (running up time too long, too many start attempts and blocked rotor (stalled)).

These relays are thus suited for the general protection against faults and for the preventative protection of three-phase machines, power transformers and feeders.

The relays are supplied in a standard ABB Size 1 relay casing.

The relay versions MCX91.-x-x-1 and MCX91.-x-x-0 differ merely in the auxiliary voltage supply (see Section 6.7.).

A description of the operation and the technical data of the multipurpose motor, overcurrent and overload relays MCX913(912) is contained in the Data Sheet 1MRB520124-Ben.

2. DETERMINING THE SETTINGS

2.1. What settings are necessary?

All the settings and the measured values of the MCX91. relays have an address (mode) by which they are retrieved and displayed.
The addresses are divided into five groups (see Table 2.1). Table 9.1 to Table 9.4 in the appendicies give all the possible settings and measured values together with the corresponding addresses, symbols, setting ranges, units and default values (basic settings as supplied from the works).

Mode	Purpose	Note
0 to 49	protection settings	see Table 9.1
50 to 99	display of load values	see Table 9.2
100 to 149	tripping logics	see Table 9.3
150 to 199	tripping values and elapsed times	see Table 9.4
900 to 999	instructions	see Section 5.3.6.

Table 2.1 Groups of addresses (modes)

In the first four groups of addresses, ones belonging to a particular protection function are obtained by adding 50 to, or subtracting 50 from the mode already known.

Example:

$I>>_1$ setting	= mode 01;	$tI>>_1$ delay	= mode 02
load current I (display)	= mode 51 ;	$tI>>_1$ time (counter)	= mode 52
$I>>_1$ tripping logic	= mode 101		
$I>>_1$ tripping value	= mode 151;	$tI>>_1$ elapsed time	= mode 152

2.1.1. Protection function settings

In most cases a protection function will have two settings:

- a pick-up setting
- a time delay setting.

The corresponding values have to be entered during commissioning for those protection functions which are required. The others which are not required are made "inactive" by setting their pick-up and timer values to zero either one-by-one, or automatically using the function selection procedure (mode 47). Details of this are given in Section 5.3.3.

2.1.2. *Base current I_E*

None of the current settings are referred directly to the relay rated current (1 A or 5 A), but to what is called the base current I_E. This is in effect the secondary rated current of the protected unit, which is obtained from the primary rated current of the protected unit I_{NS} by applying the c.t. ratio K_I. The setting of I_E, however, is not made directly in amperes, but as a ratio to the relay rated current I_{NR}:

$$I_E = \frac{I_{NS}}{K_I} \qquad \text{mode 00 setting} = \frac{I_E}{I_{NR}}$$

The base current can be set in a range of 0.30 to 1.20 x I_{NR}. The mode 00 setting must be determined at the time of commissioning and should be the first setting entered. Once this has been done, the following relationship exists:

$$1 \times I_{NS} \triangleq 1 \times I_E$$

The actual I_E setting is divided into a coarse and a fine setting. The coarse setting is a plug-in link S1 on PCB 1 (Fig. 9.3) with which the setting range for the mode value can be selected (see Table 2.2).

Base current I_E setting range	Position of link S1	Default value
0,30...0,42 x I_{NR}	1 - 2	0,35 x I_{NR}
0,43...0,60 x I_{NR}	2 - 3	0,50 x I_{NR}
0,61...0,84 x I_{NR}	4 - 5	0,70 x I_{NR}
0,85...1,20 x I_{NR}	5 - 6	1,00 x I_{NR}

Table 2.2 Position of the plug-in link S1 and the default values for the four base current I_E setting ranges (I_{NR} = relay rated current)

Once the base current has been set, the position of the plug-in link is monitored in relation to it. Changing the base current setting range by moving S1 then causes "error" to be signalled and the stand-by monitor resets and blocks the relay. Upon pressing the reset button, the default value corresponding to the position of S1 appears in mode 00 (see also Section 6.5.).

Note: When changing the I_E range (plug-in jumper S1) all setting values (Mode 0 to 49 and 100 to 149) including their default values are written into the foreground memory!

2.1.3. *Tripping logic (software matrix)*

The user can select which of the auxiliary tripping and signalling relays are to be actuated by the starting and tripping signals generated by each of the protection functions (see tripping logic, Table 9.3). Auxiliary tripping and signalling relays are treated in the same manner by the tripping logic, the only difference between them being the ratings of their contacts. The tripping logic must be set when commissioning for each of the protection functions being used.

starting signals: Starting signals last for as long as the pick-up setting is being exceeded, or for as long as $\Delta\vartheta > \Delta\vartheta_1$ and $\Delta\vartheta > \Delta\vartheta_3$.

Exception: protection against too many start attempts, see Section 2.2.9.

tripping signals: Tripping signals are generated after the set time delay of the particular protection function has expired, or as soon as $\Delta\vartheta > \Delta\vartheta_2$; or the number of starts exceeds N_{cold} or N_{hot}. They reset as soon as the input value fails sufficiently below setting as determined by the reset ratio.

Exception: If tripping with latching (see Table 9.3) has been selected, the tripping signals do not reset until the reset button has been pressed.

The standard versions of the MCX91. relays are equipped with two auxiliary signalling relays (MRI and MRII) and two auxiliary tripping relays (ARI and ARII).

2.2. *Comments on the various protection functions*

2.2.1. *Phase fault protection I>>$_{1,2}$ (mode 01 and mode 41)*

The two time-overcurrent stages are independent in their operation and settings and are intended for the detection of high fault currents.

2.2.2. *No load check I< (mode 15)*

The no load check picks up for currents I equal or greater than 0.1 x I_E, but less than the setting of I<, whereby I is the peak value of the phase-to-neutral current.

2.2.3. *Overcurrent protection $I>_{1,2,3}$ (modes 03, 43 and 45)*

The three time-overcurrent stages $I>_{1,2,3}$ are also independent in operation and setting and can be precisely graded with the $I>>_{1,2}$ stages. They are not activated when a machine is being started, i.e. when the function I_{start} is picked up (see Section 2.2.4.).

2.2.4. *Run-up protection I_{start} (mode 13)*

The main purpose of the function I_{start} is to protect induction motors whilst running up.
The correct measure of the thermal stress to which the motor is subjected during the run-up sequence is provided by the integral I^2T derived from the phase-to-neutral current. The advantage of the I^2T principle is above all, that a longer starting time is automatically permitted when the motor voltage is low and in consequence also the starting current.

Operating principle

As soon as the input current (phase-to-neutral current) falls below 0.1 x I_E the relay expects the next action to be a motor start, i.e. the functions overcurrent $I>$ and no load $I<$ are inhibited.

A timer is started the instant the input current exceeds 0.1 x I_E :

- A motor start is assumed, if the input current rises above the setting of I_{start} within 100 ms. At the same time as I_{start} is reached, the time-current function I^2T is enabled.
  The starting sequence lasts until the current has fallen below the setting of I_{start} once again, at which instant the overcurrent and no load functions are reactivated.
- If the setting of I_{start} is not reached within 100 ms, the occurrence is not considered to be a normal starting sequence, the function I_{start} is terminated and the overcurrent and no load functions are re-activated.

The relay waits 500 ms after the I_{start} function resets before considering a starting sequence to be completed in order to take short voltage dips or interruptions into account.

Tripping takes place when I^2T exceeds the setting I^2T_{start}.The time-current function

$I^2T = \int i^2(t)dt$; i(t): phase-to-neutral current
is totalised every 15 ms.

The overcurrent (I>) and no load (I<) functions are in operation at all times when the I_{start} function is not.

Relay settings

The starting current I_A and the starting time t_A at rated voltage of a motor are normally known and typical settings are:

I_{Start} = 0.6 to 0.8 x I_A

I^2T_{Start} = I_A^2 x t_A

2.2.5. *Blocked rotor (stalled) operation $I_{bl.r.}$ (mode 11)*

The operating principle of the blocked rotor protection is basically that of an overcurrent fault protection in conjunction with a speed switch. Induction motors can be protected against the blocked rotor condition in this way, and it is an important kind of protection particularly for motors having a permissible stalled time which is shorter than the normal running up time.

Example

Auxiliary signalling relay MRI selected for $I_{bl.r.}$ tripping

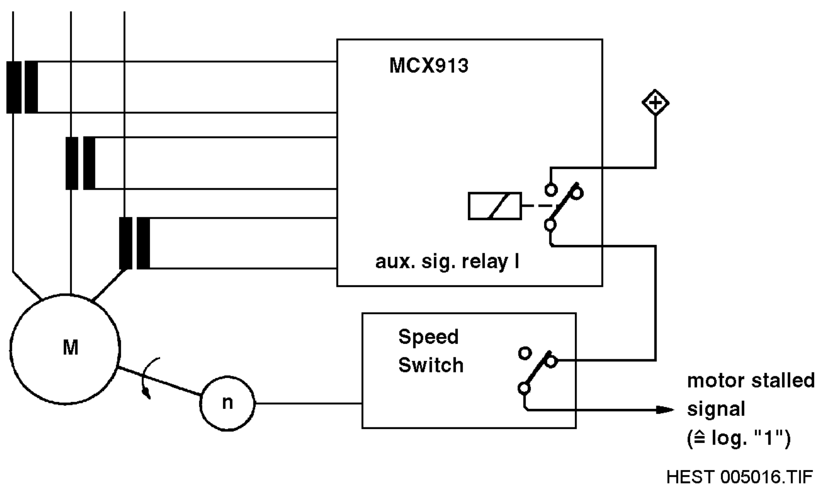


Fig. 2.1 MCX913 using aux. sig. relay MRI and speed switch

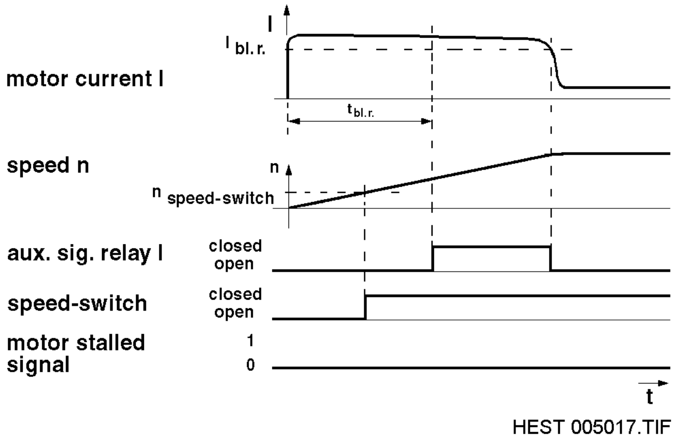


Fig. 2.2 Signals during a normal motor start

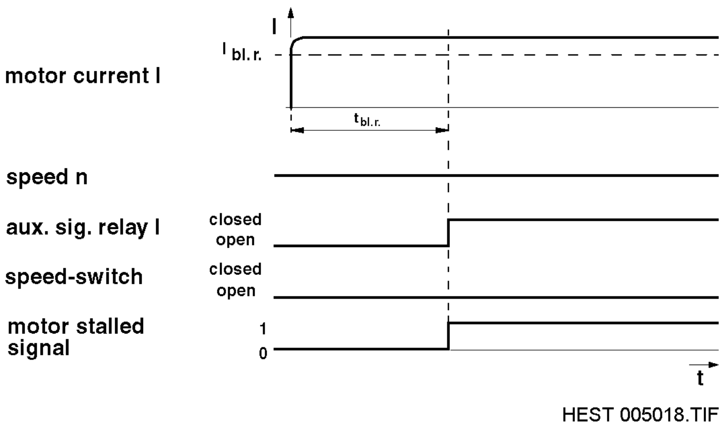


Fig. 2.3 Signals when starting with a blocked rotor

2.2.6. *Earth fault protection I_0 (modes 07 to 10)* *)

The earth fault current can be applied to the relay in one of two ways:

- Neutral current derived "internally" through vectorial addition of the three phase-to-neutral currents:

  $\underline{I}_0 = \underline{I}_R + \underline{I}_S + \underline{I}_T$

- Neutral current derived "externally" by a core-balance c.t. and applied to the input transformer normally used for S phase. There are two setting ranges available by positioning the plug-in link S3 (see Table 2.3).

The plug-in link S2 must also be positioned correctly to correspond to the "internal" or "external" method of obtaining the neutral current (see Table 2.3).
The one to which the relay is set can be viewed in mode 09:

Earth fault protection "internal" → 1 displayed

"external" → 0 displayed.

The I_0 (S phase) input of the MCX912-1 (i.e. 1 A rated current) is five times more sensitive than the phase inputs, whilst in the case of the MCX912-5 (i.e. 5 A rated current) it is twenty-five times greater.
For this reason the neutral current must always be derived "externally" for the MCX912 versions. If the plug-in link S2 is set to "internal" error 21 is displayed (see Section 6.5.).

Mode 10 shows the relevant I_0 (or S phase) input transformer ratio: k = 1 for MCX913, k = 5 for MCX912-1 and k = 25 for MCX912-5.

Neutral current		**E/F setting range**		
		MCX913	**MCX912-1**	**MCX912-5**
"internal":	S2 = 1 -2	0.2 ...1.0 x I_E (0.5 x I_E)	----------	----------
"external":	S2 = 2-3 S3 = 1-2	0.8 ...4.0 x I_E (2.0 x I_E)	0.16 ...0.8 x I_E (0.4 x I_E)	0.032 ...0.16 x I_E (0.08 x I_E)
"external":	S2 = 2-3 S3 = 2-3	0.2 ...1.0 x I_E (0.5 x I_E)	0.04 ...0.2 x I_E (0.1 x I_E)	0.008 ...0.04 x I_E (0.02 x I_E)

Table 2.3 Positions of the plug-in links S2 and S3 on PCB1 (Fig. 9.3) and the corresponding E/F setting ranges for internally and externally derived neutral currents. The default values in each case are given in brackets (see also Section 6.5.).

*) $I_0 = 3 \times I_0'$;

I_0' : zero-sequence current

The following should be observed when determining the settings:

- High E/F sensitivity is required on the one hand in order to detect faults at locations resulting in low E/F currents, whilst on the other spurious neutral currents can arise with the internal method during phase faults due to unequal c.t. behaviour. The probability of this happening is particularly great, if there is a d.c. component when switching a motor on.
- Wherever possible, core-balance c.t's should be used for E/F detection, because they are not subject to the above limitations. Providing c.t. performance (at low currents) and the power system capacitances to ground (neutral current during through faults) permit, the MCX912 is capable of detecting E/F currents down to 0.8% respectively 4% of I_E (see Table 2.3).
- The power system capacitances to ground can give rise to neutral currents on feeders not directly involved in the fault. Mal-operation can thus occur, if the relay setting is too sensitive.

The wiring diagrams for the various methods of obtaining the neutral current are given in Fig. 9.6, Fig. 9.7 and Fig. 9.8.

2.2.7. *Negative phase-sequence (NPS) protection I_2 (mode 05)*

The currents of the three phases are used to derive the negative-sequence component in relays set to form the neutral current internally.

$\underline{I}_2 = 1/3\ (\underline{I}_R + a^2\underline{I}_S + a\underline{I}_T)$; $\qquad a = e^{j2\pi/3}$

The following additional relationship applies for relays set to "external" neutral current (2ph + I_0):

$\underline{I}_R + \underline{I}_S + \underline{I}_T = 0$

If when set to external neutral current an E/F is measured which is greater than 0.25 times the E/F setting (i.e. the additional relationship no longer applies), the NPS protection is blocked (inactive).

Activation of the NPS protection with the relay set to external neutral current and inactive E/F protection (i.e. set to zero) causes error No. 70 to be displayed (see Section 6.5.).

2.2.8. *Thermal overload protection (modes 30 to 39)*

The temperature rise of a motor in steady-state operation follows an exponential function towards a steady-state final temperature. Since a motor is an inhomogeneous body, the exponential function is the resultant of several different time constants.
It has been found sufficient in practise to use a mean time constant.

Operating principle

The relative temperature rise $\Delta\vartheta$ in steady-state operation is given by:

$$\Delta\vartheta\,(t) = \Delta\vartheta\,(t = 0) \times e^{-\frac{t}{\tau}} + \left|\frac{I}{I_E}\right|^2 \times (1 - e^{-\frac{t}{\tau}}) \times 100\%$$

where I = maximum phase-to-neutral current (referred to I_E)
I_E = base current

The temperature rise of the thermal replica of the protected unit in the relay is based on the maximum of the three phase-to-neutral currents. Settings are provided for two time constants, one for the temperature rise $\tau\uparrow$ (mode 33) and one for cooling $\tau\downarrow$ (mode 34).

$\tau = \tau\uparrow$ for currents $0.1 \times I_E \leq I < 2 \times I_E$

$\tau = \tau\downarrow$ for currents $I < 0.1 \times I_E$

$\tau = \tau\uparrow \rightarrow \infty$ (adiabatical temperature rise) for currents $I \geq 2 \times I_E$

The steady-state temperature at a given current I ($< 2 \times I_E$) is:

$$\Delta\vartheta\,(t \rightarrow \infty) = \left(\frac{I}{I_E}\right)^2 \times 100\%$$

Temperature rise and cooling curves and operating characteristics for all operating conditions can be calculated using the above equation. Sets of these curves are to be found in Fig. 9.9 to Fig. 9.13 and Table 9.7 lists the formula for calculating the maximum temperature rise for different motor operating modes.

Relay settings

The mean temperature rise time constant is frequently unknown. Where this is the case, Table 9.8 gives typical relationships between time constant, motor frame size and method of cooling. The information was obtained from measurements on BBC motors, but will apply equally to motors of other manufacture having the same frame size and cooling system.

The relay has two thermal overload stages ($\Delta\vartheta_1$, $\Delta\vartheta_2$). Stage $\Delta\vartheta_1$ has a reset ratio of 95% and is intended to give alarm of impending inadmissible temperature rise to enable corrective measures to be taken, whilst stage $\Delta\vartheta_2$ is intended for tripping when the permissible limit is reached. The tripping signal is maintained for as long as the temperature has not fallen below the value determined by the setting $H\Delta\vartheta$ in relation to the $\Delta\vartheta_2$ setting. (Settings of $H\Delta\vartheta_2$ - $H\Delta\vartheta$ < 45% result in the minimum reset value of 45%).

Stage $\Delta\vartheta_1$ is normally set between 95% and 110% of the temperature rise corresponding to continuous operation at the (secondary) rated current I_N. Since the base current of the relay is set such that $I_{NS} \triangleq I_E$ (see Section 2.1.2.), the following relationship applies:

$$\Delta\vartheta_1 = 95...110\% \times \left| \frac{I_{NS}}{K_I \times I_E} \right|^2 = 95...110\%$$

Stage $\Delta\vartheta_2$ is set between 95% and 105% of the temperature rise corresponding to continuous operation at the maximum permissible continuous rating $I_{max\ th}$:

$$\Delta\vartheta_2 = 95...105\% \ \left| \frac{I_{max\,th}}{I_{NS}} \right|^2$$

Facility is provided in mode 39 ($\Delta\vartheta_{0\ manual}$) for changing the state of the thermal replica $\Delta\vartheta$ during operation. Providing a value less than 201 is set in mode 39, the thermal replica will be set to that value upon giving the instruction to implement the settings (instruction ①, see Section 5.3.6.). Once this has been done, the setting of mode 39 in the operating memory is returned to 201 to avoid the state of the thermal replica $\Delta\vartheta$ from being involuntarily changed the next time the instruction to implement settings is given. The setting 201 prevents mode 39 from having any influence.

The status of the thermal replica is maintained in the event of an interruption of the auxiliary supply for approximately ten minutes. The thermal replica is then initialised at this value, should the auxiliary supply regain its normal range before the ten minutes expire. After this time, the value in mode 38 ($\Delta\vartheta_{0\ automatic}$) is used.

As a rule $\Delta\vartheta_{0\ \text{automatic}}$ is set to 0%. For auxiliary supply interruptions longer than 1 min., but shorter than the time constant $\tau\downarrow$, the pre-loading of the motor can be approximated using the following:

$$\Delta\vartheta_{0\ \text{automatic}} \approx \Delta\vartheta_1 \times \frac{\tau\downarrow - t_{out}}{\tau\downarrow}$$

(t_{out} = duration of the aux. supply interruption).

Example

Thermal time constants are often unknown, particularly where small motors are concerned. The following information is usually provided:

- rated current I_N
- maximum continuous rating $I_{max\ th}$
- maximum permissible tripping time t_6 at I_{start} starting from cold (t_6 is usually given for $I_6 = 6 \times I_N$).

This information enables the setting of $\tau\uparrow$ to be determined.

The base current I_E is set in the normal manner such that $1 \times I_E \triangleq 1 \times I_N$ (see Section 2.1.2.). The setting thus becomes:

$$\Delta\vartheta_2 = \left|\frac{I_{max\ th}}{I_N}\right|^2 \times 100\%$$

The adiabatic temperature rise at currents greater than $2 \times I_E$ is:

$$\Delta\vartheta = \left(\frac{I}{I_E}\right)^2 \times \frac{t}{\tau\uparrow} \times 100\%$$

The operating time of the relay at I_6 should correspond to t_6:

$$\Delta\vartheta_2 = \left|\frac{I_6}{I_N}\right|^2 \times \frac{t_6}{\tau\uparrow} \times 100\% = \left(\frac{I_{max\ th}}{I_N}\right)^2 \times 100\%$$

From which follows

$$\tau\uparrow = \left|\frac{I_6}{I_{max\ th}}\right|^2 \times t_6$$

2.2.9. *Protection against too many starts (modes 17 to 21)*

The number of motor start attempts can only be counted, if the motor start protection is activated. Counting is performed according to the following method:

The timer t_{N-1} is started each time an attempt is made to start the motor.

The counter N_{cold} is incremented, providing the temperature rise is below $\Delta\vartheta_3$ or the $\Delta\vartheta_3$ stage is inactive, otherwise both N_{hot} and N_{cold} are incremented excepting when the latter is at zero. Both counters are decremented when the timer t_{N-1} times out after which the timer is re-started, providing the counters have not reached zero.

A starting signal is generated by the protection as soon either the counter N_{cold} or N_{hot} equals its setting after a start attempt (i.e. the current has fallen bellow I_{start}). This starting signal can be used for motor start interlocking.

The relay trips to inhibit further start attempts as soon as the last start attempt increases the count of either N_{cold} or N_{hot} exceeds its settings. The start attempt which caused tripping to take place is not counted, i.e. the counters are immediately decremented again.

Protection starting and tripping signals are maintained until a motor start is permissible again, i.e. until the blocking time t_{N-1} has timed out at least once or until both counters have fallen below their settings.

The tripping logic (see Table 9.3) provides facility for signalling whether the temperature rise $\Delta\vartheta$ has exceeded the setting of $\Delta\vartheta_3$ or not. The reset ratio of the $\Delta\vartheta_3$ stage is 95%.

Permissibly higher temperature rise when starting (mode 21)

Some drives, primarily those which have to start on load, are designed to withstand a briefly excessive temperature rise whilst running up. Where the manufacturer provides information in this respect, mode 21 enables corresponding settings to be made.

- Mode 21 set to 0: This is the normal setting for which the temperature rise of each and every start attempt is recorded by the thermal replica.
- Mode 21 set to 1 or 2: The temperature rise of the last respectively the last two start attempts is not recorded by the thermal replica.

2.2.10. *Display of mean value and maximum mean value (mode 40, 89, 90)*

Mode 90 shows the mean value of the phase current (highest of the three phase currents [R.M.S. value] resp. highest of the phase currents R and T for "external" earth faults) with a selectable setting time (see Table 2.4). After the setting time the mean value has reached more than 99% of the final value at a constant phase current.

Mode 89 shows the maximum mean value (of mode 90). Thus, this corresponds with the trailing pointer of the respective instruments. This display may be reset if required. Resetting is accomplished with mode 996 and the value 0000 (see also Section 5.3.6.).

Value of mode 40	Setting time in minutes
0	8 min.
1	15 min. (default value)
2	30 min.

Table 2.4 Setting times for the mean value display

2.2.11. *Operating hours counter (mode 98)*

The time that the protected unit is in operation is counted, i.e. the load current is greater than 0.1 x I_E, providing the relay is operational (standing by).

2.3. *Data of the protected unit required for setting the relay*

What data relating to the protected unit have to be known before the relay settings can be determined depends on the application. Some protection functions require only little information (mainly the rated phase-to-neutral current), but even more comprehensive schemes can manage with the following:

- rated current
- c.t. ratio
- max. permissible continuous rating
- thermal time constant or tripping time at a given I/I_N.

In special cases, the following supplementary information may be required:

- permissible starting time and current of motors
- cooling time constant when stationary
- No. of permissible start attempts from cold and when warm
- kind of grounding.

2.4. *Setting examples*

Examples are given below of determining the settings for three different kinds of protected unit, a typical small motor, an HV induction motor and a power transformer. The value to be entered and the corresponding mode are given in each case on the right of the page. The settings of each example are compiled once again in setting tables at the end of the respective example (see also Figure 9.14).

2.4.1. *Small motor*

Motor data

• rated power	S_N	= 38.5 kVA
• rated voltage	U_N	= 380 V
• rated current	I_N	= 58.5 A (= I_{NS})
• max. E/F current	I_{0p}	= I_N
• c.t. ratio	K_I	= 100 A/5 A = 20

The following were assumed:

• max. permissible continuous rating	$I_{max\ th}$	= 1.15 x I_N
• starting current	I_A	= 6 x I_N
• max. starting time (at rated voltage)	t_A	= 8 s
• max . tripping for I_6 = 6 x I_N (inverse characteristic)	t_6	= 25 s
• cooling time constant	$\tau\downarrow$	= 2 x $\tau\uparrow$

Base current I_E

Since the relay rated current is I_{NR} = 5 A, the base current becomes:

$$I_E = \frac{I_{NS}}{K_I \times I_{NR}} \times I_{NR} = \frac{58.5A}{20 \times 5A} \times I_{NR} = 0.585 \times I_{NR}$$ Mode 00 = 0.58

and 1 x $I_{NS} \triangleq$ 1 x I_E (see also Section 2.1.2.)

The following plug-in link position is obtained from Table 2.2: S1 = 2-3

Selected protection functions

Only the protection functions $I>>_1$, $I>_1$, I_2, I_0, $\Delta\vartheta_1$ and $\Delta\vartheta_2$ are activated.
The quickest and most logical setting procedure is to enter the value of the combination of functions immediately after setting I_E. This automatically inactivates those protection functions not being used and they do not appear on the display.
Not to follow this procedure means that the unwanted protection functions have to be inactivated one by one.

The selection from Table 9.5 for this example is Mode 47 = 4

Phase fault protection $I>>_1$

The setting should be at 30% to 50% higher than the maximum starting current I_A; 40% is chosen.

$I>>_1$ = 1.3 x I_A = 1.3 x 6 x $I_N \triangleq$ 7.8 x I_{NS} = 7.8 x I_E

Mode 01 = 7.8

Standard time delay: $tI>>_1$ = 0.05 to 1 s

chosen $tI>>_1$ = 0.05 s Mode 02 = 0.05

Overcurrent protection $I>_1$

The setting is typically 30% to 60% higher than the maximum permissible continuous rating; 30% is chosen.

$I>_1 = 1.3 \times I_{max\ th} = 1.3 \times 1.15 \times I_N \triangleq 1.495 \times I_{NS}$

$\triangleq 1.495 \times I_E$ (rounded to 1.5) Mode 03 = 1.5

Standard time delay: $tI>_1$ = 30 to 60 s

chosen $tI>_1$ = 30 s Mode 04 = 30.0

NPS I_2

Typical setting: I_2 = 0.2 to 0.4 x I_N

chosen I_2 = 0.3 x I_N

$\triangleq$ 0.3 x I_E Mode 05 = 0.30

Standard time delay: tI_2 = 1 to 5 s

chosen tI_2 = 4 s Mode 06 = 4.0

E/F protection I_0

The neutral current I_0 is to be derived internally through vectorial addition. Therefore a relay type MCX913 should be used.

From Section 2.2.6., the plug-in link positions are:

Plug-in link S2 in position 1-2 S2 = 1-2
Plug-in link S3 in position 1-2 S3 = 1-2
(Since S3 has no effect in this case, its position is of no consequence.)

Typical setting: I_0 = 0.4 to 0.8 x I_N

chosen I_0 = 0.4 x I_N

$\triangleq$ 0.4 x I_E Mode 07 = 0.40

Standard time delay: tI_0 = 0.2 to 1 s

chosen tI_0 = 0.2 s Mode 08 = 0.20

"Internal E/F protection causes 1 to be displayed in mode 09 Mode 09 = 1

I_0 (resp. S) input transformer ratio Mode 10 = 1

Motor starting protection I_{start}

Typical setting: I_{start} = 0.6 to 0.8 x I_A

chosen $I_{start} = 0.6 \times I_A$

$I_{start} = 0.6 \times 6 \times I_N \triangleq 3.6 \times I_E$ Mode 13 = 3.6

$$\left.\begin{array}{l} I_A \triangleq 6 \times I_E \\ t_A = 8\ s \end{array}\right\} \Rightarrow I^2T_{Start} = 6^2 \times 8 = 288$$ Mode 14 = 288

Thermal overload protection $\Delta\vartheta$

Typical setting: $\Delta\vartheta_1 = 95 \text{ to } 110\% \times \left|\frac{I_{NS}}{K_I \times I_E}\right|^2$

chosen $\Delta\vartheta_1 = 105\%$ Mode 30 = 105

Typical setting: $\Delta\vartheta_2 = 95 \text{ to } 105\% \times \left|\frac{I_{max\,th}}{I_{NS}}\right|^2$

chosen 100%

$\Delta\vartheta_2 = 100\% \times 1.15^2 = 132\%$ Mode 31 = 132

assumed $H\Delta\vartheta = 40\%$ Mode 32 = 40

Temperature rise time constant (see example in Section 2.2.8.)

$$\tau\uparrow = \left|\frac{I_6}{I_{max\,th}}\right|^2 \times t_6 = \left|\frac{6}{1.15}\right|^2 \times 25\ s = 11.3\ min$$ Mode 33 = 11

Cooling time constant

$\tau\downarrow = 2 \times \tau\uparrow$ (assumed) Mode 34 = 22

The protection against too many motor starts and therefore $\Delta\vartheta_3$ are not required. Mode 20 = 0

Initial temperature $\Delta\vartheta_0$

$\Delta\vartheta_0$ = 0 to 200% chosen $\Delta\vartheta_0$ = 0% Mode 38 = 0

Note:
$\Delta\vartheta_0$ = x% means that the thermal replica of the protected unit in the relay is set to x% following an interruption of the relay's auxiliary supply lasting longer than ten minutes.

Tripping logic

Tripping of $I>>_1$ is required to energise the auxiliary tripping relay ARII, the alarm stage $\Delta\vartheta_1$ the auxiliary signalling relay MRI and pick-up of $I>_1$ the auxiliary signalling relay MRII.
All the other protection functions must trip via auxiliary relay ARI, but latching is required for E/F's (I_0).

From Table 9.3 the settings are thus:

Phase faults	$I>>_1$	Mode 101 = 0002
Overcurrent	$I>_1$	Mode 103 = 0120
NPS	I_2	Mode 105 = 0020
E/F	I_0	Mode 107 = 0030
Run-up	I_{Start}	Mode 113 = 0020
Signalling	$\Delta\vartheta_3$	Mode 120 = 0000
Thermal overload	$\Delta\vartheta_1$, $\Delta\vartheta_2$	Mode 130 = 1020

Blocking logic

A signal applied to the blocking input should only block the auxiliary tripping relay ARI. The settings according to Section 6.6. are therefore:

Plug-in link: S4 = 1-2

DIL switch S65
MRI = open
MRII = open
ARI = closed
ARII = open

ABB Setting Table

STATION: FEEDER:

96-03

Multifunction relay types MCX 912 and MCX 913

Relay datas: ☐ MCX912-.......... ☐ 1 A ☒ 50 Hz ....

☒ MCX913-.......... ☒ 5 A ☐ 60 Hz ***- small motor -***......................................

Protected object:

S_N ....***38.5*** kVA U_N ....***380*** kV I_N ....***58.5*** A Main C.T. ratio .... A / ..... A

Mode	Symbol	Value	Remarks
00	I_E	***0.58***	
01	$I>>_1$	***7.8***	
02	$tI>>_1$	***0.05***	
03	$I>_1$	***1.5***	
04	$tI>_1$	***30.0***	
05	I_2	***0.30***	
06	tI_2	***4.0***	
07	I_0	***0.40***	
08	tI_0	***0.20***	
11	$I_{bl.r.}$		
12	$tI_{bl.r.}$		
13	I_{start}	***3.6***	
14	I^2T_{start}	***288***	
15	$I<$		
16	$tI<$		
17	N_{cold}		
18	N_{hot}		
19	t_{N-1}		
20	$\Delta\vartheta_3$	***0***	
21	N_S		
30	$\Delta\vartheta_1$	***105***	
31	$\Delta\vartheta_2$	***132***	
32	$H\Delta\vartheta$	***40***	
33	$\tau\uparrow$	***11***	
34	$\tau\downarrow$	***22***	
38	$\Delta\vartheta_0$	***0***	
40	k_{TE}	***1***	
41	$I>>_2$		
42	$tI>>_2$		
43	$I>_2$		
44	$tI>_2$		
45	$I>_3$		
46	$tI>_3$		
47	CTRL 1	***4***	

Matrix Mode	Symbol	Value				Value			
		MRI	MRII	ARI	ARII	MRI	MRII	ARI	ARII
101	$I>>_1$	***0***	***0***	***0***	***2***				
103	$I>_1$	***0***	***1***	***2***	***0***				
105	I_2	***0***	***0***	***2***	***0***				
107	I_0	***0***	***0***	***3***	***0***				
111	$I_{bl.r.}$								
113	I_{start}	***0***	***0***	***2***	***0***				
115	$I<$								
117	N_c,N_h								
120	$\Delta\vartheta_3$	***0***	***0***	***0***	***0***				
130	$\Delta\vartheta_{1,2}$	***1***	***0***	***2***	***0***				
141	$I>>_2$								
143	$I>_2$								
145	$I>_3$								

Tripping matrix:
- value 0 blocked
- value 1 Starting
- value 2 Tripping unlatched
- value 3 Tripping latched

S4: Blocking of relay		
S4		
1-2	selective blocking	☒
2-3	all functions blocked	☐

S2,S3: Neutral current I_0					
Relay type MCX913					
S2	S3	I_0			
2-3	1-2	external	0,8...4,0 x I_E	☐	
2-3	2-3		0,2...1,0 x I_E	☐	
1-2	-	internal	0,2...1,0 x I_E	☒	
Relay type MCX 912					
S2	S3	I_0			
2-3	1-2	external	0,16...0,8 x I_E	☐	MCX912-1
2-3	2-3		0,04...0,2 x I_E	☐	
2-3	1-2	external	0,032...0,16 x I_E	☐	MCX912-5
2-3	2-3		0,008...0,04 x I_E	☐	

S1: Base current I_E		
S1	Range	
1-2	0.300...0.424 * I_{NR}	☐
2-3	0.425...0.600 * I_{NR}	☒
4-5	0.601...0.848 * I_{NR}	☐
5-6	0.849...1.200 * I_{NR}	☐

S65: Selective blocking			
	switch		
Relay	open	closed	
MR I	☒	☐	Signal relay I
MR II	☒	☐	Signal relay II
AR I	☐	☒	Tripping relay I
AR II	☒	☐	Tripping relay II

Switch "open": no influence at blocking

	Client
Date: Signature:	Date: Signature:

2.4.2. *HV induction motor*

Motor data

• rated power	S_N	= 2.44 MVA
• rated voltage	U_N	= 6 kV
• rated current	I_N	= 235 A (= I_{NS})
• rated frequency	f_N	= 50 Hz
• max. permissible continuous rating	$I_{max\ th}$	= 1.2 x I_N
• starting current	I_A	= 5.5 x I_N
• max. permissible starting time (at rated voltage)	t_A	= 12 s
• max. blocked rotor time	t_E	= 20 s ($t_E > t_A$)
• heating time constant	$\tau\uparrow$	= 45 min
• cooling time constant	$\tau\downarrow$	= 120 min (stationary)
• permissible No. of consecutive starts	N_{cold}	= 3 (from cold)
	N_{hot}	= 2 (when hot)

Power system data

• grounding	high resistance	
• max. E/F current	I_{0p}	= I_N
• c.t. ratio	K_I	= 300 A/1 A = 300
• ratio of core-balance c.t. for E/F's	K_{I_0}	= 250 A/1 A = 250

Base current I_E

The base current for a relay rated current of I_{NR} =1 A is:

$$I_E = \frac{I_{NS}}{K_I \times I_{NR}} \times I_{NR} = \frac{235A}{300 \times 1A} \times I_{NR} = 0.783 \times I_{NR}$$

Mode 00 = 0.78

From Table 2.2, the plug-in link position is: S1 = 4-5

and 1 x I_{NS} ≙ 1 x I_E (see also Section 2.1.2.)

Phase fault protection $I>>_1$

The setting is typically 30% to 50% higher than the maximum starting current I_A; 40% is chosen.

$I>>_1$ = 1.4 x I_A = 1.4 x 5.5 x I_N ≙ 7.7 x I_{NS} ≙ 7.7 x I_E

Mode 01 = 7.7

The transient surge current when starting the motor is usually overcome by setting a short time delay:

$tI>>_1$ = 50 ms . Mode 02 = 0.05

Nevertheless the amplitude and duration of the starting current should be checked as part of commissioning and the corresponding settings modified as necessary.

Overcurrent protection $I>_1$

The setting is typically 30% to 60% higher than the maximum permissible continuous rating; 30 % is chosen.

$I>_1$ = 1.3 x $I_{max\ th}$ = 1.3 x 1.2 x I_N ≙ 1.56 x I_E

(rounded to 1.6) Mode 03 = 1.6

The time delay $tI>_1$ is set 50% higher than the maximum permissible blocked rotor time (t_E). Mode 04 = 30.0

NPS I_2

This is in particular a protection for the rotor, if the phase currents become severely asymmetrical or in the event of single phasing.

Typical setting:

$I_2 = 0.3 \times I_E$	Mode 05 =0.30
$tI_2 = 4$ s	Mode 06 = 4.0

With the exception of some special cases, this setting ensures correct tripping in the event of single phasing or wrong phase sequence.

E/F protection I_0

A core-balance c.t. will be used in accordance with Section 2.2.6. and a setting of $I_0 = 0.1 \times I_N$ chosen.

The relay setting is thus:

$$\frac{I_0}{I_E} = 0.1 \times \frac{K_I}{K_{I_0}} = 0.1 \times \frac{300}{250} = 0.12$$ Mode 07 = 0.12

It is not possible to achieve this sensitivity with the MCX913 (not even with "external" I_0 , see Section 2.2.6.).

An MCX912-1 must therefore be used.

The plug-in link positions become:

position of plug-in link S2	S2 = 2-3
position of plug-in link S3	S3 = 2-3
Time delay $tI_0 = 0.15$ s	Mode 08 = 0.15
External neutral current	Mode 09 = 0
Core-balance c.t. ratio	Mode 10 = 5

Blocked rotor (stalled) protection $I_{bl.r.}$

The setting should lie between 0.4 and 0.8 x I_A for the motor in question.

$I_{bl.r.}$ = 0.5 x I_A = 0.5 x 5.5 x I_E = 2.75 x I_E Mode 11 = 2.7

The delay is set the same as t_E Mode 12 = 20.0

Motor starting protection I_{start}

Typical setting: I_{start} = 0.6 to 0.8 x I_A

The setting in this particular case is chosen to be:

I_{start} =- 0.7 x I_A = 0.7 x 5.5 x I_E = 3.85 x I_E Mode 13 = 3.8

$$\left.\begin{array}{l} I_A \mathrel{\hat{=}} 5.5 \times I_E \\ t_A = 12\ s \end{array}\right\} \Rightarrow I^2T_{Start} = 5.5^2 \times 12 = 363$$ Mode 14 = 363

No load protection I<

A no-load check is not required for this induction motor. Mode 15 = 0

Protection against too many start attempts N_{cold}, N_{hot}

The permissible number of consecutive start attempts from cold, respectively when hot is given:

N_{cold} = 3 Mode 17 = 3

N_{hot} = 2 Mode 18 = 2

The blocking time for t_{N-1} for two starts an hour is:

t_{N-1} = 30 min = 1800 s Mode 19 = 1800

The temperature reached at 90% of I_N is defined as the dividing line between "cold" and "hot" starts, i.e. :

$$\Delta\vartheta_3 = \left|\frac{0.9 \times I_N}{I_N}\right|^2 \times 100\% = 0.9^2 \times 100\% = 81\%$$ Mode 20 = 81

The thermal replica of the protected unit should continue to follow the temperature rise during starting. Mode 21 = 0

Thermal overload protection $\Delta\vartheta$ (see Section 2.2.8.)

At a motor current I ($I_E = I_N$) the steady-state temperature rise represented by the thermal replica is:

$$\Delta\vartheta = \left|\frac{I}{I_N}\right|^2 \times 100\%$$

from which follows that

when $I = I_N$

$\Delta\vartheta_N = 1^2 \times 100\% = 100\%$

The max. permissible continuous current $I_{max\,th} = 1.2 \times I_N$

$$\Delta\vartheta_{max} = \left|\frac{I_{max\,th}}{I_N}\right|^2 \times 100\% = 1.2^2 \times 100\% = 144\%$$

Typical settings for the alarm stage $\Delta\vartheta_1$ lie between 95% and 110% of $\Delta\vartheta_N$ (setting range 50 to 200%). Chosen:

$\Delta\vartheta_1 = 100\%$ Mode 30 = 100

The tripping stage $\Delta\vartheta_2$ is set between 90% and 110% of $\Delta\vartheta_{max}$.

$\Delta\vartheta_2 = 135\%$ Mode 31 = 135

$\Delta\vartheta_2$ must reset at a value lower than $\Delta\vartheta_1$, so that :

$H\Delta\vartheta = 40\%$ Mode 32 = 40

Temperature rise and cooling time constants are given: Mode 33 = 45
Mode 34 = 120

Checking the temperature rise following consecutive starts

It is necessary to check that with these settings the MCX912 allows the permissible number of start attempts.

For this purpose the starting time t_A and current are considered to be a maximum for each attempt, providing t_A is less than $\tau\uparrow$. The intervals between each attempt are neglected. In practice the temperature rise simulated by the relay will be lower, because at the maximum starting current I_A the starting time are less than t_A.

- Temperature rise from cold (3 starts):

$$\Delta\vartheta = N_{cold} \times \left(\frac{I_A}{I_N}\right)^2 \times \frac{t_A}{\tau\uparrow} \times 100\%$$

$$\Delta\vartheta = 3 \times 5.5^2 \times \frac{12}{45 \times 60} \times 100 = 40\%$$

- Temperature rise when hot (2 starts):

A temperature rise of $\Delta\vartheta \geq \Delta\vartheta_3$ is defined as hot:

$$\Delta\vartheta = \Delta\vartheta_1 + N_{hot} \times \left(\frac{I_A}{I_N}\right)^2 \times \frac{t_A}{\tau\uparrow} \times 100\%$$

$$\Delta\vartheta = 100 + 2 \times 5.5^2 \times \frac{12}{45 \times 60} \times 100 = 127\%$$

Thus the overload protection does not pick-up at a $\Delta\vartheta_2$ setting of 135% even with two consecutive starts when hot with $\Delta\vartheta = \Delta\vartheta_1$.

Initial temperature $\Delta\vartheta_0$

For this particular example, $\Delta\vartheta_{0\ automatic} = 0$ is chosen (see Section 2.2.8.). This means that the thermal replica will be set to zero following an auxiliary supply interruption lasting longer than ten minutes.

Mode 38 = 0

Selected protection functions

The protection functions required in this HV induction motor are $I{>>}_1$, $I{>}_1$, I_2, I_0, $I_{bl.r.}$, I_{start}, No. of motor starts and $\Delta\vartheta$ and according to Table 9.5 the combination 1 can be used.

Mode 47 = 1

The function I< is not required and must be set to zero. Mode 15 = 0

Tripping logic

The alarm stage $\Delta\vartheta_1$ has to actuate the auxiliary signalling relay MRI. The signalling relay MRII is used for the closing interlock and therefore is actuated by the starting signal N_{cold} or N_{hot}. A trip of $\Delta\vartheta_2$ shall be performed by the tripping relay ARII.
All other tripping functions are actuated by the auxiliary tripping relay ARI.

The corresponding settings from Table 9.3 are:

Phase faults	$I>>_1$	Mode 101 = 0020
Overcurrent	$I>_1$	Mode 103 = 0020
NPS	I_2	Mode 105 = 0020
E/F	I_0	Mode 107 = 0020
Blocked rotor	$I_{bl.r.}$	Mode 111 = 0020
Motor starting	I_{start}	Mode 113 = 0020
Too many starts	N_{cold}, N_{hot}	Mode 117 = 0120
Temperature rise	$\Delta\vartheta_3$	Mode 120 = 0000
Thermal overload	$\Delta\vartheta_1$, $\Delta\vartheta_2$	Mode 130 = 1002

Blocking logic

When a signal is applied to the blocking input of the MCX912, the whole relay must be blocked and all the auxiliary relays reset. The corresponding settings according to Section 6.6. are:

Plug-in link:	S4 = 2-3
all DIL switches S65:	closed

Setting Table

STATION: FEEDER:

96-03

Multifunction relay types MCX 912 and MCX 913

Relay datas: ☒ MCX912-.......... ☒ 1 A ☒ 50 Hz ***- HV induction motor*** ....

☐ MCX913-.......... ☐ 5 A ☐ 60 Hz ....

Protected object:

S_N ....***2.44*** MVA U_N ....***6*** kV I_N ....***235*** A Main C.T. ratio .... A / ..... A

Mode	Symbol	Value	Remarks
00	I_E	***0.78***	
01	$I>>_1$	***7.7***	
02	$tI>>_1$	***0.05***	
03	$I>_1$	***1.6***	
04	$tI>_1$	***30.0***	
05	I_2	***0.30***	
06	tI_2	***4.0***	
07	I_0	***0.12***	
08	tI_0	***0.15***	
11	$I_{bl.r.}$	***2.7***	
12	$tI_{bl.r.}$	***20.0***	
13	I_{start}	***3.8***	
14	I^2T_{start}	***363***	
15	$I<$	***0***	
16	$tI<$		
17	N_{cold}	***3***	
18	N_{hot}	***2***	
19	t_{N-1}	***1800***	
20	$\Delta\vartheta_3$	***81***	
21	N_S	***0***	
30	$\Delta\vartheta_1$	***100***	
31	$\Delta\vartheta_2$	***135***	
32	$H\Delta\vartheta$	***40***	
33	$\tau\uparrow$	***45***	
34	$\tau\downarrow$	***120***	
38	$\Delta\vartheta_0$	***0***	
40	k_{TE}	***1***	
41	$I>>_2$		
42	$tI>>_2$		
43	$I>_2$		
44	$tI>_2$		
45	$I>_3$		
46	$tI>_3$		
47	CTRL 1	***1***	

Matrix Mode	Symbol	Value				Value			
		MRI	MRII	ARI	ARII	MRI	MRII	ARI	ARII
101	$I>>_1$	***0***	***0***	***2***	***0***				
103	$I>_1$	***0***	***0***	***2***	***0***				
105	I_2	***0***	***0***	***2***	***0***				
107	I_0	***0***	***0***	***2***	***0***				
111	$I_{bl.r.}$	***0***	***0***	***2***	***0***				
113	I_{start}	***0***	***0***	***2***	***0***				
115	$I<$	***0***	***0***	***0***	***0***				
117	N_c,N_h	***0***	***1***	***2***	***0***				
120	$\Delta\vartheta_3$	***0***	***0***	***0***	***0***				
130	$\Delta\vartheta_{1,2}$	***1***	***0***	***0***	***2***				
141	$I>>_2$								
143	$I>_2$								
145	$I>_3$								

Tripping matrix:

value 0	blocked
value 1	Starting
value 2	Tripping unlatched
value 3	Tripping latched

S4: Blocking of relay		
S4		
1-2	selective blocking	☐
2-3	all functions blocked	☒

S2,S3: Neutral current I_0					
Relay type MCX913					
S2	S3	I_0			
2-3	1-2	external	0,8...4,0 x I_E	☐	
2-3	2-3		0,2...1,0 x I_E	☐	
1-2	-	internal	0,2...1,0 x I_E	☐	
Relay type MCX 912					
S2	S3	I_0			
2-3	1-2	external	0,16...0,8 x I_E	☐	MCX912-1
2-3	2-3		0,04...0,2 x I_E	☒	
2-3	1-2	external	0,032...0,16 x I_E	☐	MCX912-5
2-3	2-3		0,008...0,04 x I_E	☐	

S1: Base current I_E		
S1	Range	
1-2	0.300...0.424 * I_{NR}	☐
2-3	0.425...0.600 * I_{NR}	☐
4-5	0.601...0.848 * I_{NR}	☒
5-6	0.849...1.200 * I_{NR}	☐

S65: Selective blocking			
	switch		
Relay	open	closed	
MR I	☐	☒	Signal relay I
MR II	☐	☒	Signal relay II
AR I	☐	☒	Tripping relay I
AR II	☐	☒	Tripping relay II

Switch "open": no influence at blocking

	Client
Date: Signature:	Date: Signature:

2.4.3. *Power transformer*

Power transformer data

• rated power	S_N	= 3670 kVA
• rated voltage	U_N	= 10 kV
• rated current	I_N	= 212 A (= I_{NS})
• max. permissible continuous rating	$I_{max\ th}$	= 1.1 x I_N
• inrush current	I_A	= 13 x I_N
• heating time constant	$\tau\uparrow$	= 70 min
• cooling time constant	$\tau\downarrow$	= 200 min

Power system data

• grounding	high resistance	
• max. E/F current (fault at the terminals)	I_{0p}	= I_N
• c.t. ratio	K_I	= 400 A/1 A = 400

Basic considerations

The relay uses an exponential function (typical 40 ms time constant) approximate the curve of the inrush current.

A graded phase fault protection is achieved by combining the protection functions $I{>>}_1$, $I{>>}_2$ and $I_{bl.r.}$. The motor start protection is used to prevent the inrush current from causing the overcurrent functions to pick-up. The overcurrent functions $I{>}_1$, $I{>}_2$ and I_3 are, however, also time-graded.

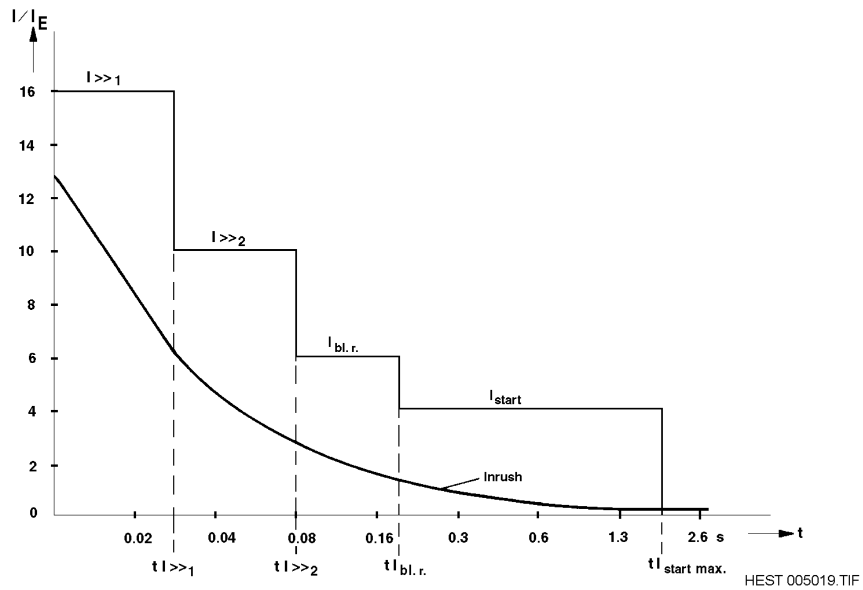


Fig. 2.4 Grading of functions or phase fault protection

Base current I_E

For a relay rated current of I_{NR} = 1 A the base current is:

$$I_E = \frac{I_{NS}}{K_I \times I_{NR}} \times I_{NR} = \frac{212\,A}{400 \times 1A} \times I_{NR} = 0.53 \times I_{NR}$$

Mode 00 = 0.53

Thus 1 x I_{NS} ≙ 1 x I_E (see also Section 2.1.2.)

The plug-in link position from Table 2.1 is: S1 = 2-3

Phase fault protection $I>>_1$, $I>>_2$, $I_{bl.r.}$

$I>>_1$	= 16 x I_E	Mode 01 = 16.0
$tI>>_1$	= 0.03 s	Mode 02 = 0.03
$I>>_2$	= 10 x I_E	Mode 41 = 10.0
$tI>>_2$	= 0.08 s	Mode 42 = 0.08
$I_{bl.r}$	= 6 x I_E	Mode 11 = 6.0
$tI_{bl.r.}$	= 0.2 s	Mode 12 = 0.2

Overcurrent protection $I>_1$, $I>_2$, $I>_3$

$I>_1$	= 3 x I_E	Mode 03 = 3.0
$tI>_1$	= 10 s	Mode 04 = 10.0
$I>_2$	= 2 x I_E	Mode 43 = 2.0
$tI>_2$	= 30 s	Mode 44 = 30.0
$I>_3$	= 1.4 x I_E	Mode 45 = 1.4
$tI>_3$	= 60 s	Mode 46 = 60.0

NPS I_2

This protection function is not required Mode 05 = 0

E/F protection I_0

The neutral current I_0 is to be derived internally.
For this reason an MCX913 relay is chosen.

The plug-in link positions from Section 2.2.6. are:

Plug-in link S2 in position 1-2	S2 = 1-2
Plug-in link S3, for example, in position 1-2 (S3 has no effect in this application and may be in any position.)	S3 = 1-2
Typical setting: I_0 = 0.4 to 0.8 x I_N	
chosen I0 = 0.4 x $I_N \triangleq$ 0.4 I_E	Mode 07 = 0.40
Typical time delay : tI_0 = 0.2 to 1 s	
chosen tI_0 = 0.2 s	Mode 08 = 0.20
"Internal" neutral current displays 1 in mode 09	Mode 09 = 1
I_0 (resp. S) input c.t. ratio	Mode 10 = 1

"Motor starting" protection I_{start}

I_{start} = 4 x I_E	Mode 13 = 4.0
I^2T_{start} = 32 $I_E{}^2$s	Mode 14 = 32

From this results a maximum operating time

$$t_{start\ max} = \frac{32}{4^2} = 2\ s$$

Thermal overload protection $\Delta\vartheta$

$\Delta\vartheta_1$ = 95...100% x ($I_{NS} \triangleq I_E$)

chosen $\Delta\vartheta_1$ = 105% Mode 30 = 105

$$\Delta\vartheta_2 = 85...105\% \times \left(\frac{I_{max\ th}}{I_{NS}}\right)^2$$

$$\text{chosen } \Delta\vartheta_2 = 100\% \times \left|\frac{I_{max\ th}}{I_{NS}}\right|^2$$

$\Delta\vartheta_2$ = 100% x 1.1^2 = 121%	Mode 31 = 121
assumed $H\Delta\vartheta$ = 20%	Mode 32 = 20
heating time constant $\tau\uparrow$ = 70 min	Mode 33 = 70
cooling time constant $\tau\downarrow$ = 200 min	Mode 34 = 200

Selected protection functions

Only the protection functions given above are to be activated for the example of protecting a power transformer ($I{>>}_1$, $I{>>}_2$, $I_{bl.r.}$, $I{>}_1$, $I{>}_2$, $I{>}_3$, I_{start}, I_0 and $\Delta\vartheta$.

From Table 9.5 the value 11 has to be set — Mode 47 = 11

This combination also includes the NPS protection I_2, which must then be made inactive (see above): — Mode 05 = 0

Tripping logic

Tripping of $I{>>}_{1,2}$ is to be latched and made via auxiliary tripping relay ARII; this also applies to tripping of I_{start} and $I_{bl.r.}$.
Tripping of $I{>}_{1,2,3}$ and $\Delta\vartheta$ should actuate auxiliary tripping relay ARI.
$I{>}_3$ picking up should be signalled by the auxiliary signalling relay MRI and an I_0 trip by auxiliary signalling relay MRII.

The corresponding settings according to Table 9.3 are:

Phase faults	$I{>>}_1$	Mode 101 = 0003
Overcurrent	$I{>}_1$	Mode 103 = 0020
E/F	I_0	Mode 107 = 0200
Blocked rotor	$I_{bl.r.}$	Mode 111 = 0002
Motor starting	I_{start}	Mode 113 = 0002
Thermal overload	$\Delta\vartheta_1$, $\Delta\vartheta_2$	Mode 130 = 0020
Phase faults	$I{>>}_2$	Mode 141 = 0003
Overcurrent	$I{>}_2$	Mode 143 = 0020
Overcurrent	$I{>}_3$	Mode 145 = 1020

Blocking logic

When a signal is applied to the blocking input of the MCX913, the whole relay must be blocked and all the auxiliary relays reset.
The corresponding settings according to Section 6.6. are:

Plug-in link S4 in position 2-3	S4 = 2-3
all DIL switches S65:	closed

ABB Setting Table

STATION: FEEDER:

96-03

Multifunction relay types MCX 912 and MCX 913

Relay datas: ☐ MCX912-.......... ☒ 1 A ☒ 50 Hz ....
☒ MCX913-.......... ☐ 5 A ☐ 60 Hz ***- Transformator -*** ....

Protected object:

S_N ....***3670*** kVA U_N ....***10*** kV I_N ....***212*** A Main C.T. ratio .... A / ..... A

Mode	Symbol	Value	Remarks
00	I_E	***0.53***	
01	$I{>>}_1$	***16.0***	
02	$tI{>>}_1$	***0.03***	
03	$I{>}_1$	***3.0***	
04	$tI{>}_1$	***10.0***	
05	I_2	***0***	
06	tI_2		
07	I_0	***0.40***	
08	tI_0	***0.20***	
11	$I_{bl.r.}$	***6.0***	
12	$tI_{bl.r.}$	***0.2***	
13	I_{start}	***4.0***	
14	I^2T_{start}	***32***	
15	I<		
16	tI<		
17	N_{cold}		
18	N_{hot}		
19	t_{N-1}		
20	$\Delta\vartheta_3$	***0***	
21	N_S		
30	$\Delta\vartheta_1$	***105***	
31	$\Delta\vartheta_2$	***121***	
32	$H\Delta\vartheta$	***20***	
33	$\tau\uparrow$	***70***	
34	$\tau\downarrow$	***200***	
38	$\Delta\vartheta_0$	***0***	
40	k_{TE}	***1***	
41	$I{>>}_2$	***10.0***	
42	$tI{>>}_2$	***0.08***	
43	$I{>}_2$	***2.0***	
44	$tI{>}_2$	***30.0***	
45	$I{>}_3$	***1.4***	
46	$tI{>}_3$	***60.0***	
47	CTRL 1	***7***	

Matrix Mode	Symbol	Value MRI	Value MRII	Value ARI	Value ARII	Value MRI	Value MRII	Value ARI	Value ARII
101	$I{>>}_1$	***0***	***0***	***0***	***2***				
103	$I{>}_1$	***0***	***1***	***2***	***0***				
105	I_2	***0***	***0***	***0***	***0***				
107	I_0	***0***	***2***	***0***	***0***				
111	$I_{bl.r.}$	***0***	***0***	***0***	***2***				
113	I_{start}	***0***	***0***	***0***	***2***				
115	I<								
117	N_c,N_h								
120	$\Delta\vartheta_3$	***0***	***0***	***0***	***0***				
130	$\Delta\vartheta_{1,2}$	***0***	***0***	***2***	***0***				
141	$I{>>}_2$	***0***	***0***	***0***	***3***				
143	$I{>}_2$	***0***	***0***	***2***	***0***				
145	$I{>}_3$	***1***	***0***	***2***	***0***				

Tripping matrix:
- value 0 blocked
- value 1 Starting
- value 2 Tripping unlatched
- value 3 Tripping latched

S4: Blocking of relay		
S4		
1-2	selective blocking	☐
2-3	all functions blocked	☒

S2,S3: Neutral current I_0					
Relay type MCX913					
S2	S3	I_0			
2-3	1-2	external	0,8...4,0 x I_E	☐	
2-3	2-3		0,2...1,0 x I_E	☐	
1-2	-	internal	0,2...1,0 x I_E	☒	
Relay type MCX 912					
S2	S3	I_0			
2-3	1-2	external	0,16...0,8 x I_E	☐	MCX912-1
2-3	2-3		0,04...0,2 x I_E	☐	
2-3	1-2	external	0,032...0,16 x I_E	☐	MCX912-5
2-3	2-3		0,008...0,04 x I_E	☐	

S1: Base current I_E		
S1	Range	
1-2	0.300...0.424 * I_{NR}	☐
2-3	0.425...0.600 * I_{NR}	☒
4-5	0.601...0.848 * I_{NR}	☐
5-6	0.849...1.200 * I_{NR}	☐

S65: Selective blocking			
Relay	switch open	switch closed	
MR I	☐	☒	Signal relay I
MR II	☐	☒	Signal relay II
AR I	☐	☒	Tripping relay I
AR II	☐	☒	Tripping relay II

Switch "open": no influence at blocking

Date: Signature:

Client
Date: Signature:

3. CHECKING THE SHIPMENT

Unpacking, visual inspection

Should the shipment be found to be damaged upon receipt, a claim must be lodged immediately in writing with the last carrier and the facts notified to ABB Power Automation Ltd, Department NAP, CH-5401 Baden, Switzerland.

The data on the adhesive rating plate on the plug-in relay unit (Fig. 9.1) must agree with the corresponding data on the order and on the delivery note.

4. INSTALLATION AND WIRING

The relay is supplied in a standard size 1 BBC relay casing which can be adapted on site for either surface or semi-flush switchpanel mounting. The plug-in relay unit is not mechanically latched in the casing. The casing is equipped with shorting links which automatically short-circuit the c.t. connections when the relay is withdrawn.

4.1. Relay location and ambient conditions

Since every piece of technical equipment can be damaged or destroyed by inadmissible ambient conditions,

- the relay location should not be exposed to excessive air pollution (dust, aggressive substances)
- severe vibration, extreme changes of temperature, high levels of humidity, surge voltages of high amplitude and short rise time and powerful induced magnetic fields should be avoided as far as possible
- air should be permitted to circulate freely around the unit.

4.2. Checking the wiring (see Fig. 9.5 for wiring diagram)

The relay wiring must be checked against the corresponding wiring diagram.

The c.t. data must agree with the input data of the relay.

The relay is connected to three c.t's having a secondary rated current of either 1 A or 5 A.

Generally the c.t's are wound in the sense and have the terminal designations shown in Fig. 4.1. With the normal arrangement of K connected towards the busbar and L towards the line, the secondary terminals k and l are connected in strict accordance with the circuit diagram. Should the primary of a winding be connected in the reverse sense, i.e. L towards the busbar and K towards the line, the secondary connections to the terminals k and 1 must also be reversed. The phase-sequence and the energy direction have to be correct, otherwise the NPS I_2 measurement cannot function.

Should there be any doubt as to the sense of any of the windings, the following method can be used to determine the polarity of the secondaries. Terminals K and L are connected to a d.c.

source of about 4 V and k and l to a polarised voltmeter as shown in Fig. 4.1. The polarity is correct, if there is a positive deflection when the switch S is closed.

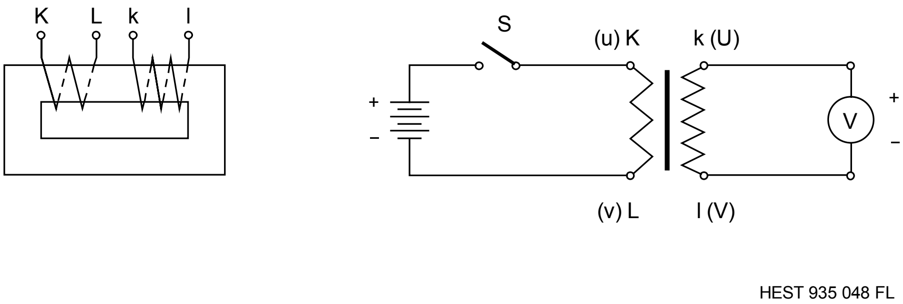


Fig. 4.1 Instrument transformer terminals and polarity check (U, u, V and v apply to p.t's)

The auxiliary supply and the blocking signals must be within the ranges of permissible variation given in the Data Sheet.

The maximum data stated in the Data Sheet for the signalling and tripping contacts may not be exceeded.

For correct operation it is essential that the frequency marked on the rating plate of the relay (50 or 60 Hz) be the same as the power system frequency. If this is not the case, the relay can be provisionally re-calibrated to the corresponding frequency on site (see Section 6.9.).

4.3. Earthing and Wiring of Protection Units of the 900 Family

Switching operations in HV installations generate transient overvoltages in measurement and control cables. Electrostatic or magnetic RF fields either of a latent nature or caused by various operations are also induced in the devices themselves or in the cables connected to them.

Interference of this kind can impair the operation of electronic equipment.

On the other hand, electronic equipment itself can transmit electromagnetic waves that interfere with other electronic equipment.

To keep this interference within acceptable limits, the grounding, wiring and screening of the equipment must fulfil certain minimum standards.

For these precautions to have the desired effect, the station ground must be of good quality.

4.3.1. Cubicle

4.3.1.1. Mechanical design

The cubicle must be designed and fitted out such that the impedance for RF interference of the ground path from the electronic device to the cubicle ground terminal is as low as possible.

Metal accessories such as side plates, blanking plates etc., must be effectively connected surface-to-surface to the grounded frame to ensure a low-impedance path to ground for RF interference. The contact surfaces must no only conduct well, they must also be non-corroding.

If the above conditions are not fulfilled, there is a possibility of the cubicle or parts of it forming a resonant circuit at certain frequencies that would amplify the transmission of interference by the devices installed and also reduce their immunity to induced interference.

4.3.1.2. Grounding system

4.3.1.2.1. Grounding a single cubicle

Movable parts of the cubicle such as doors (front and back) or hinged equipment frames must be effectively grounded to the frame by three braided copper strips (see Fig. 4.2).

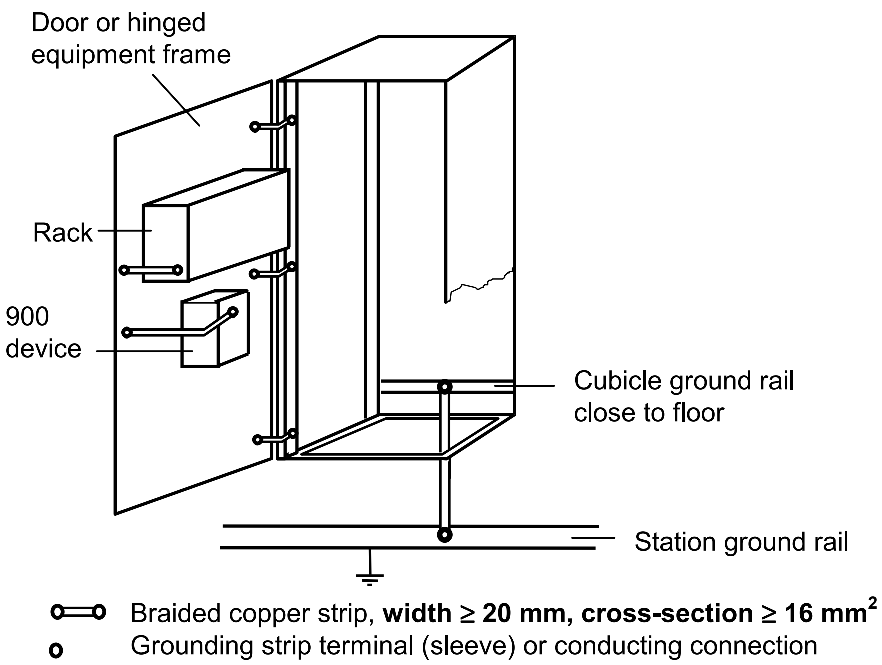


Fig. 4.2 Cubicle grounding system (schematic representation)

The cubicle ground rail must be effectively connected to the station ground rail by a grounding strip (braided copper, see Section 4.3.4.).

Where the two ground rails are more than 5 m apart, two grounding strips must be run parallel and as close as possible to each other.

4.3.1.2.2. *Grounding system for adjacent cubicles*

Where cubicles are placed next to each other (≤ 1 m apart), the requirements of Fig. 4.3 (example with two cubicles) must be observed in addition to those of Fig. 4.2.

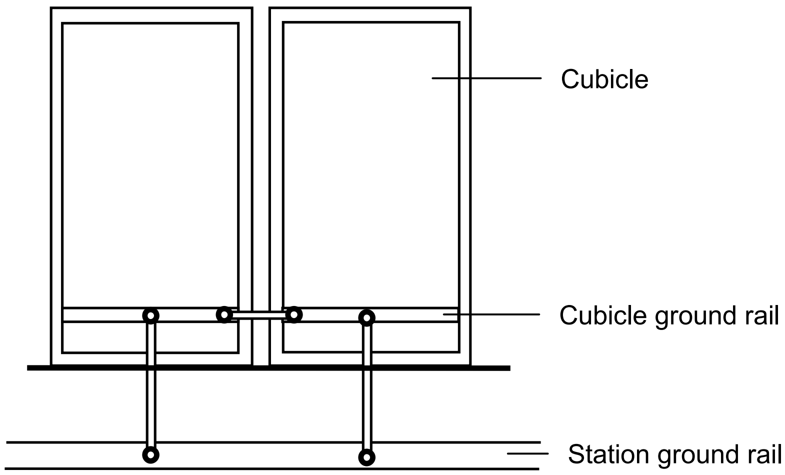


Fig. 4.3 Cubicle grounding system in the case of several cubicles next to each other (schematic representation)

The cubicle ground rails are linked together and each one individually connected to the station ground rail. If the cubicles are further than 1 m apart, they do not have to be interconnected.

In the case of cubicles with several compartments, the ground rails of the compartments are linked together and each one connected to the station ground rail.

4.3.1.2.3. *Grounding system for equipment*

Grounding strips may be attached to the left (as in Fig. 4.2) or to the right of racks and devices (see Fig. 4.4a). Take care that the grounding strip is always as short as possible.

Note the admissible and inadmissible arrangements illustrated in Fig. 4.4.

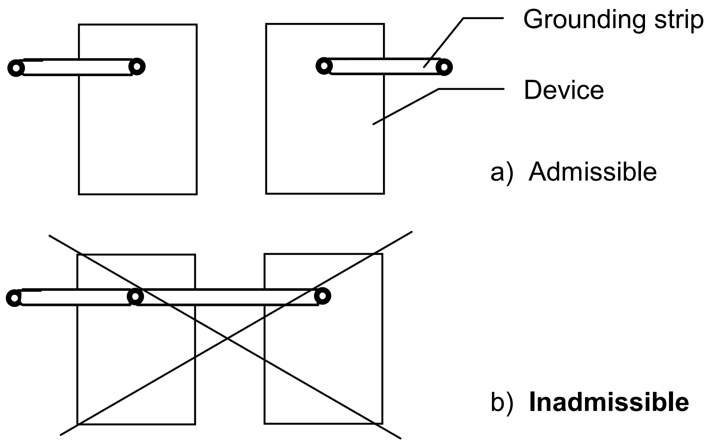


Fig. 4.4 Grounding system for two devices installed next to each other (schematic representation)

4.3.2. *Open equipment racks*

Open equipment racks must be electrically conducting and non-corroding and must be effectively connected to the station ground rail (see Fig. 4.5).

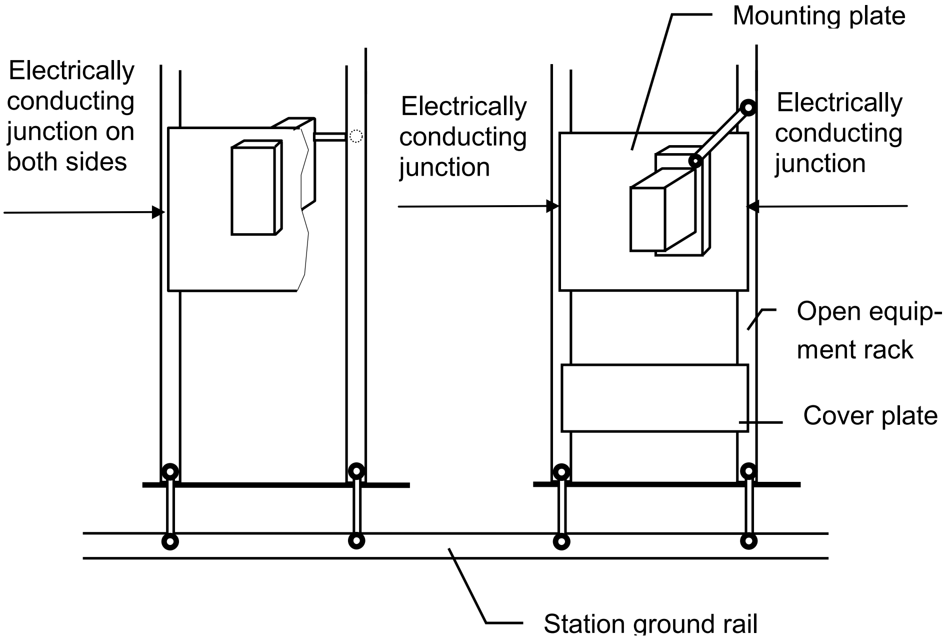


Fig. 4.5 Grounding system for open equipment racks (schematic representation of the flush and surface mounting methods with front view)

Metal interface modules not having their own grounding strips, mounting plates and all kinds of cover plates must have an electrically conducting connection to the equipment rack, i.e. neither contact surface may be painted and yet must be non-corroding (e.g. galvanised).

Devices and 19" racks must be grounded as shown in Fig. 4.5 or Fig. 4.8 in Section 4.3.5.2. The difference lies in another surface treatment of the mounting plates.

Always take care to keep the grounding strips as short as possible.

As stipulated in Section 4.3.1.2.1., a second grounding strip must be run parallel and as close as possible to the first, if the station ground rail is more than 5 m away.

4.3.3. *Grounding strips (braided copper) and their installation*

High frequency currents are produced by interference in the ground connections and because of skin effect at these frequencies, only the surface region of the grounding strips is of consequence.

The grounding strips must therefore be of tinned braided copper and not round copper conductors, as the cross-section of round copper would have to be excessively large.

Data of braided copper strip: Width ≥ 20 mm,
Cross-section ≥ 16 mm^2
(protection ground)

Proper terminations must be fitted to both ends (press/pinch fit) with a hole for bolting them firmly to the items to be connected.

Each device is accompanied by a mounting set and an installation drawing for mounting the grounding strip on the device.

The surfaces (cubicle or open equipment rack) to which the other end of the grounding strips are bolted must be electrically conducting and non-corroding (Fig. 4.6).

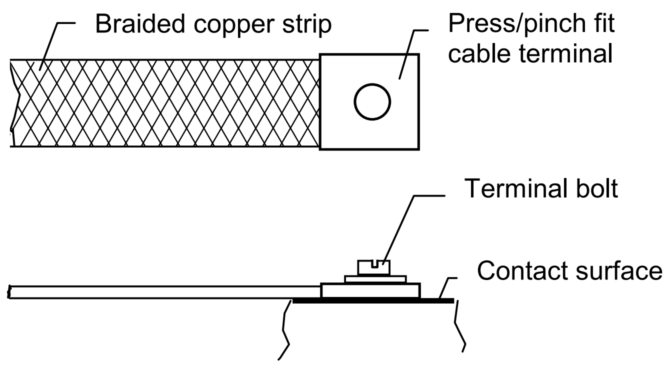


Fig. 4.6 Ground strip and termination

If the contact surface is aluminium, a *Cupal* (copper plated aluminium) washer must be inserted between the grounding strip and the aluminium to prevent corrosion.

4.3.4. *Wiring*

4.3.4.1. *External wiring*

The external wiring includes all the connections from the primary plant to the cubicle or open equipment rack terminals or directly to the device terminals.

This cables are run in metal ducts that are connected to the station ground at several places.

The external wiring is of the following types:

- instrument transformer leads
- auxiliary supply cables
- binary inputs and outputs.

Since experience has shown that the main source of interference is the c.t. and v.t. leads, these should be run in different cable ducts separately from the other cables.

In the case of GIS installations, the c.t. and v.t. leads must be screened (see Section 4.3.5.).

Screened c.t. and v.t. leads are recommended for other types of installation.

4.3.5. *Screening*

4.3.5.1. *Cable shields*

The cable shields shall be braided and have a cover factor of at least 80 %.

4.3.5.2. *Grounding the ends of cable shields*

The ground connection to a cable shield must extend around the entire circumference.

Grounding a shield by soldering a wire to it achieves only an inadequate screening effect in industrial installations.

Cable shields must be grounded at both ends.

The best screening effect is achieved when the cable enters the cubicle via a screwed cable gland. If a cable gland of this type is not provided, the cable must be grounded as shown in Fig. 4.8 on the inside of the cubicle ***immediately adjacent to the cable inlet***.

To ground the cable, remove a suitable length of the insulation and push the braiding of the shield back over the end of the insulation. Secure the end of the cable to the grounded surface by means of a metal cleat (Fig. 4.7). The cleat and the contact surface must be electrically conducting and non-corroding.

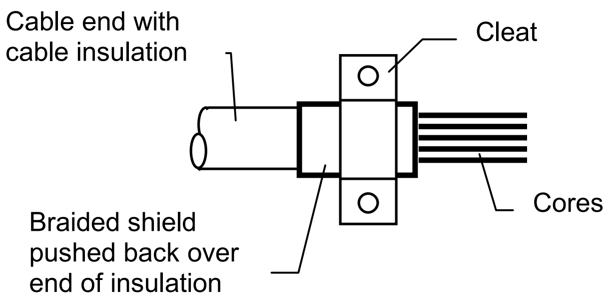


Fig. 4.7 All-round grounding of the end of the cable shield (schematic representation)

The shield must be pushed back over the insulation to prevent it from fraying with time and the quality of the ground contact diminishing. It also reduces the risk of pinching the shield and the cores.

The grounding system in the case of open equipment racks is executed as shown in Fig. 4.7 and Fig. 4.8.

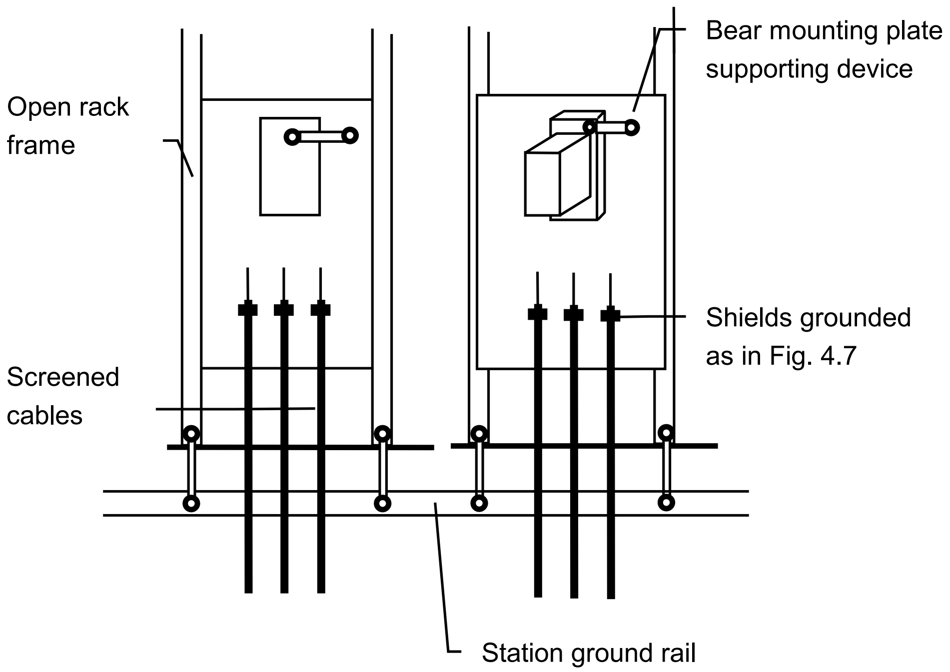


Fig. 4.8 Grounding cable shields in the case of an open equipment rack
(schematic representation of the flush and surface mounting method),
(Flush mounting: rear view
Surface mounting: front view)

The rear of the mounting plate must not be painted and the surface must be a good conductor and non-corroding.

As shown in Fig. 4.5 and explained in Section 4.3.4., the mounting plate must be in good electrical contact with the frame of the open rack. Therefore we recommend not to varnish both sides of the mounting plates.

The unscreened ends from the point of grounding to the device terminals must be kept as short as possible. Certain groups of cables must also be run separately as explained in Section 4.3.4.

4.3.5.3. Additional cable grounds between the ends

With the cable shields grounded at both ends, any potential differences between the both ground points will cause balancing currents to flow in the shields that can induce interference in the cables. This can interfere with the function of a device at cable lengths of 10 m and more.

A recommended solution is to run the cables along ground rails of the meshed station ground system and grounding the shields at intervals of 5 to 10 m.

For this purpose, a suitable length of insulation is stripped from the shield and the exposed shield connected by a cable cleat to a grounded metal surface (Fig. 4.7). Both the cleat and the contact surface must be electrically conducting and non-corroding.

Choose a cleat that holds the shield firmly but does not pinch the shield or the cores.

5. COMMISSIONING

5.1. Pre-commissioning checks

- The wiring checks according to Section 4.2. must be concluded.
- The auxiliary supply must not be switched on.
- The plug-in links S1 to S4 and the DIL switches S65 must be set as required for the application (Fig. 9.2 and Fig. 9.3).

5.2. Inserting the relay and switching on the auxiliary supply

It is only permissible to insert or withdraw the relay with the auxiliary supply switched off!

It is only permissible to switch on the auxiliary supply after the relay has been inserted.
When this has been done, all the segments of the LED display are automatically tested, i.e. four rectangles, then four stars and then four dots appear on the mode and value displays; the number of firmware version is then displayed for about 1 s.
Providing the self-checking arrangements do not discover a defect, the display disappears, the green stand-by LED lights and the stand-by signalling contact closes.

Should on the other hand there be a defect, it is signalled on the display, the relay cannot assume the stand-by state and correspondingly the green LED does not light (see Section 6.5.).

5.3. Relay controls

5.3.1. General

Two memories are concerned with the relay settings (modes 0 to 49 and 100 to 149; see Table 9.1 and Table 9.3):

- Main memory (non-volatile; NOVRAM)
  The settings in this memory are the operational settings, i.e. **only settings in the main memory** determine relay behaviour.
- Operating memory (volatile)
  Whenever the relay is switched on or upon a special instruction (see Section 5.3.6.) the settings are copied from the main memory into the operating memory where it is possible to change them as necessary using the key-pad.

The value display shows only the values in the operating memory.

The changed and unchanged values in the operating memory can be written from the operating memory into the main memory, i.e. they become the new operational settings, by entering a corresponding instruction (see Section 5.3.6.).

As supplied the MCX91. relays have the settings (default values) listed in Table 9.1 and Table 9.3.

5.3.2. Frontplate displays, key-pad

On the frontplate (see Fig. 9.1) there are two LED displays, one for the address (mode) of a setting or measurement quantity, the other for its value. The same displays are used for signalling functions which have picked up or have tripped (selected automatically with flashing display).

Functions are selected and settings made using the key-pad, which apart from the digits 0 to 9 also includes keys for the following instructions:

[R]	reset:	for resetting the frontplate displays of protection signals and error indications and also latched trips (see also Section 6.1.)
[M]	mode:	for keying in a function address (e.g. pick-up, timer etc.; see also Section 5.3.4.)
[V]	value:	for keying in a setting (see also Section5.3.5.)
[E]	enter:	The action of selecting a mode or entering a setting is terminated by pressing the 'enter' key (see also Sections 5.3.4. and 5.3.5.).
[Cl]	clear:	erase key (see also Section 5.3.7.)
[↑/.]	increment mode / decimal point:	for going to next address or writing a decimal point when entering a setting (see also Section 5.3.7.).

5.3.3. *Making a protection function active or inactive*

In the protection function selection mode (mode 47), a combination of protection functions best suited to the application in hand can be chosen from an extensive number (see Table 9.5).
Once a combination has been selected in mode 47, only those functions contained in it can be made active (or inactive) and only they and their settings can be displayed.

Protection functions of a combination which are not required are made inactive individually by entering zero for its setting, regardless of whether a current setting, or $\Delta\vartheta_1$ and $\Delta\vartheta_2$ in the case of thermal overload protection, or N_{cold} and N_{hot} in the case of protection against too many motor starts.

An alternative is to enter 0000 for the tripping logic setting (see Table 9.3) of the unwanted functions, which blocks the function completely (no automatic selection and no signals; see Section 6.1.).

5.3.4. *Displaying settings and load values*

The procedure for displaying a setting or a load value is as follows:

Firstly press the mode key followed by the digits of the desired mode and terminate the entry with the enter key.
The 'value' display then shows the **corresponding setting in the operating memory** (see also Section 5.3.1.) or value of the chosen load quantity.

Example:

Display of the NPS current I_2 at the moment

Key sequence	'Mode' display	'Value' display
[M]	M _ _ _	_ _ _ _
[5]	M _ _ 5	_ _ _ _
[5]	M _ 5 5	_ _ _ _
[E]	_ _ 5 5	x x x x

where: _ = no display

x = digit or decimal point.

If an incorrect mode is entered, i.e. one which is not contained in Table 9.1 to Table 9.4 or was inactivated when selecting the combinations of functions, the signal "ERR" (error) appears on the 'value' display.

5.3.5. *Changing and saving settings*

The procedure for changing a setting is as follows:

Firstly select the mode as described in Section 5.3.4., press the value key, key in the new setting and terminate the entry by pressing the enter key.
The new setting is now in the operating memory.
It is only transferred to the main memory when Instruction ① (saving settings, see Section 5.3.6.) is given.

Note:	After their change, all setting values shall be saved commonly.

Settings can be changed in the same way when the relay is in operation and even when there is a flashing protection signal.

Example:

Changing the setting of I> (mode 15) in the operating memory from 0.6 to 0.5.

Key sequence	'Mode' display	'Value' display
[M]	M _ _ _	_ _ _ _
[1]	M _ _ 1	_ _ _ _
[5]	M _ 1 5	_ _ _ _
[E]	_ _ 1 5	_ 0 . 6
[V]	V _ 1 5	_ _ _ _
[0]	V _ 1 5	_ _ _ 0
[+/.]	V _ 1 5	_ _ 0 _
[5]	V _ 1 5	_ 0 . 5
[E]	_ _ 1 5	_ 0 . 5

The firmware of the MCX91. will only accept settings in the permissible setting range. Entries outside this range are automatically modified upon pressing the [E] key to the lowest respectively the highest permissible value before being written into the operating memory.

Exception: The zero setting when inactivating a protection function (see Section 5.3.3.) is accepted.

5.3.6. *Instructions*

To prevent unauthorised interference with settings, it is only possible to change settings in the main memory with the aid of Instruction ① (save).
There are five further instructions which simplify and speed up the setting procedure and make the relay more convenient for the user.

The procedure for entering an instruction is the same as for entering a setting:
Each instruction is a digital code which has to be entered in the corresponding instruction mode (997, 998 or 999). An incorrect code is indicated on the 'value' display by "ERR" and in the case of mode 999 Instruction ③ (copy main memory) is automatically executed.

The six possible instructions and their purposes are as follows:

① **Save:** [M] 9 9 9 [E] [V] 4 3 2 1 [E]

Providing defect 70 is not present (see Section 6.5.), the contents of the operating memory are copied into the main memory, i.e. the corresponding values become the effective settings. When this is done, mode 80 automatically appears on the display.

② **Erase operating memory:** [M] 9 9 8 [E] [V] 1 1 1 1 [E]

The operating memory is erased, i.e. the settings and the tripping logic are set to zero, and the default values for time delays, combination of functions and I_E are written into it.
The contents of the main memory remain unchanged.

③ **Copy main memory:** [M] 9 9 8 [E] [V] 2 2 2 2 [E]

The contents of the main memory (the effective settings) are copied into the operating memory.

④ **Continuous display:** [M] 9 9 8 [E] [V] 3 3 3 3 [E]

The display is not automatically suppressed (see the Note below).
This instruction is cancelled by an auxiliary supply interruption lasting longer than 5 s or by pressing the [R] key.

⑤ **Erase tripping value and elapsed time memory:**

[M] 9 9 8 [E] [V] 4 4 4 4 [E]

The complete tripping value and elapsed time memory is set to zero.

⑥ **Set operating hours counter:** [M] 9 9 7 [E] [V] x x x x [E]

The operating hours counter is set to xxxx.

⑦ **Resetting the maximum mean value:**

[M] 9 9 6 [E] [V] 0 0 0 0 [E]

The maximum mean value (mode 89) is reset to the inst. mean value (mode 90).

Note: If the keys are not operated for at least 60 min., the display extinguishes (except for the green LED) and instruction ③ is carried out automatically.

5.3.7. *Operation of the keys [↑/.] and [Cl]*

These keys serve different purposes depending on the status of the display. The reactions of the relay when these keys are operated are as follows:

[↑/.] Increment mode / decimal point:

- If a mode has already been selected, then operation of this key selects the next higher activated mode (according to Table 9.1 to Table 9.4 and selected functions).
The increment key can not be used to go beyond mode 199, which is followed by mode 00 and the cycle starts again.

- If a setting is being entered, this key is used to write a decimal point.

[Cl] Clear:

- As long as a mode entry has not been terminated by pressing the [E] key, pressing [Cl] erases everything which has been already entered on the 'mode' display.
If no digit was keyed in after pressing the [M] key, the complete display is switched off.

- As long as the entry of a setting has not been terminated by pressing the [E] key , pressing [Cl] erases everything which has already been entered on the 'value' display.

If no digit was keyed in after pressing the V key, the value of the corresponding setting in the operating memory is displayed again.

- If the display of a measured value (modes 50 to 99 and 150 to 199) was selected, pressing Cl causes the first value of the FIFO (first in, first out memory) to be displayed (see Section 6.1.) or the complete display is switched off.
- If the display of a setting (modes 0 to 49 and 100 to 149) was selected, pressing Cl causes the effective setting to be copied from the main memory into the operating memory and displayed. Should the values of both memories be the same, then the first value of the FIFO is displayed (see Section 6.1.) or the complete display is switched off.

6. OPERATION AND MAINTENANCE

6.1. Tripping and starting signals and resetting

Providing the corresponding tripping logic setting is not at 0000 (see Table 9.3), every activated protection function generates a flashing signal on the frontplate display ("mode" and "value") whenever it trips or picks up.

In the case of a pick-up, the corresponding time delay counter (or I^2T) is displayed and decremented. If the protection function concerned resets before the timer has reached zero, the display reverts to the non-flashing display of the mode selected prior to the pick-up.
Otherwise the display shows the setting of the corresponding protection function when tripping takes place at the end of the time delay.
Regardless of any mode which may be selected at the time, the first starting or tripping event to occur is immediately displayed.

Up to ten events are recorded in sequence in a FIFO (first in, first out) memory.

If the tripping logic is set to zero for a particular protection function, then its operation is blocked, as are auxiliary signalling and tripping relays, and selection of timer and pick-up value, flashing display and registration by the FIFO do not take place.

A flashing display is maintained until reset by the [R] key. Resetting, however, is only possible providing the timer is not running and a tripping command is not actually being generated.

When a pick-up or tripping signal is reset, its value flashes three times with a 'C' (cleared) on the 'mode' display, it is erased from the FIFO and any latching is cancelled.
This is followed by the display of the next value in the FIFO or of the mode prior to the signalled occurrence.
Pressing the [R] key when the FIFO is empty starts the LED testing routine which finally displays the version of the firmware before reverting to the display of the previous mode.

Exceptions:

- $\Delta\vartheta_1$ and $\Delta\vartheta_3$ pick-ups are processed in the same way as tripping commands (recorded by the FIFO) providing the tripping logic has at least one digit set to one for these functions (130 or 120), i.e. no one means the function is simply not processed.

- A single digit set to one in mode 117 means that when there is an N_{cold} or N_{hot} pick-up (see Section 2.2.9.), the value of the reverse counting timer t_{N-1} flashes on the display (no operation without a one in mode 117). After this timer has timed out and the pick-up signal has been reset, the display reverts to the non-flashing display of the mode selected prior to the occurrence.
  At least one digit set to 2 in mode 117 will cause the pick-up setting of the corresponding counter to be displayed when it is reached. Tripping and pick-up signals only disappear and the display can only be reset after both counters have fallen below their settings once again.

  Tripping of N_{cold} or N_{hot} is recorded by the FIFO.

- Operation of the blocked rotor (stalled) protection is not signalled (no automatic selection upon pick-up or tripping and not recorded by the FIFO) regardless of the tripping logic settings.
  This is to prevent a blocked rotor scheme with a speed switch (see Section 2.2.5.) from generating a continuously flashing display in normal operation.

Events recorded by the FIFO are maintained for an unlimited period after the auxiliary supply has been switched off, but the contents can only be displayed, of course, when it is switched on.

New settings can be keyed in and entered regardless of whether a signal is being generated at the time, however, the display flashes to indicate the simultaneously presence of a signal. Pressing [Cl] after the entry has been finished causes the first value of the FIFO to re-appear.

The discovery of a defect by the self-monitoring system is signalled by the fact that the green stand-by LED extinguishes. In this case, the display shows the corresponding defect code (see Section 6.5.).

6.2. *Displaying load values*

Under normal system conditions, the r.m.s. values of various load quantities can be displayed. (Caution! All current values are referred to the base current I_E). It will be seen that the same value is displayed for a number of protection functions. This is because they use the same input quantity, the phase-to-neutral current (see Table 9.2).

Zero is displayed when a timer is selected during normal load conditions, but if this is done after a protection function has picked up, the progress of the time delay can be observed (or of I^2T).

Mode 51 displays the highest of the phase-to-neutral currents. This can also be measured at the terminals of the protection equipment, paying attention, of course, that the secondary circuits of the c.t's are never opened.

There are upper limits to the measuring ranges for currents, $\Delta\vartheta$ and the counters N_{cold} and N_{hot}.
The measuring ranges are independent of the I_E setting and the setting range with an externally derived neutral current I_0.
The upper limits of the measuring ranges are given in Table 6.1. All the lower limits are zero.

Load value	Measuring range MCX913	Measuring range MCX912-1	Measuring range MCX912-5
phase current	≥ 20 x I_E	≥ 20 x I_E	≥ 20 x I_E
internal I_0	≥ 1 x I_E	---	---
external I_0	≥ 1 x I_E resp. 4 x I_E	≥ 0.2 x I_E resp. 0.8 x I_E	≥ 0.04 x I_E resp. 0.16 x I_E
I_2	≥ 0.5 x I_E	≥ 0.5 x I_E	≥ 0.5 x I_E
$\Delta\vartheta$	999%	999%	999%
N_{cold}, N_{hot}	99	99	99

Table 6.1 Upper limits of the measuring ranges

The value of load quantity which is higher than the upper limit of its measuring range (overflow) is indicated by an asterisk (*) on the mode display when it is visible on the value display. The overflow asterisk disappears as soon as the value is within the measuring range again.

Overflowing of tripping values and elapsed times (see Section 6.3.) are indicated in the same way.

A supply voltage failure causes the mean value of the phase current (mode 90) to reset to 0.0. The maximum mean value (mode 89), however, is saved in the non volatile memory and is again present on return of the supply voltage.

Load values, including $\Delta\vartheta$, and the tripping and elapsed time memory cannot be read, if there is any defect with the exception of defect 80 (RST, see Section 6.5.).
In this case - - - - appears on the 'value' display.
The 'value' display also shows - - - - in a scheme with external neutral current I_0 and blocked I_2 when mode 55 is selected, i.e. the E/F current at the time is greater than 0.25 x I_0 (see Section 2.2.7.).

6.3. *Tripping value and elapsed time memory*

The tripping value and elapsed time memory contains the value of the current and the delay time of a protection function at the instant of its **last tripping**. If tripping did not take place, the last elapsed time (or remaining I^2T) is registered.
The registered current value in this case does not originate from this start, but from the **last tripping**. The tripping value and elapsed time memory is independent of the tripping logic, i.e. the corresponding values of a pickup or a trip are registered even if a function's tripping logic setting is 0000.
The contents of this memory are lost, if there is an interruption to the auxiliary supply.
The contents of the memory can be erased (display 0) by Instruction ⑤ (erase tripping value and elapsed time memory, see Section 5.3.6.); it is also erased automatically when a new base current I_E is set . When a protection function is made inactive (by a zero setting or function selection) the corresponding values in the tripping value and elapsed time memory are automatically reset to zero.

6.4. *Self-monitoring system*

Any defects are immediately registered by the comprehensive self-monitoring system comprising a hardware monitoring circuit and test software. Thus periodic testing can take place much less frequently without reducing availability.

6.4.1. *Watchdog, auxiliary supply supervision*

The operation of the micro-processor is monitored by a "watchdog" circuit (see Fig. 9.2).

- The processor and with it the whole relay are blocked whenever the 5 V supply falls below 4.5 V.
- A reduction of the 24 V supply below 21 V causes an $\overline{INT0}$.

  An $\overline{INT0}$ does the following:
  - All auxiliary signalling and tripping relays, including that for signalling stand-by, are reset.
  - The green LED and the mode and value displays go out.
  - The states of the thermal replica, the FIFO for the operating signals and the operating hours counter are written into the non-volatile main memory.
- A single automatic hardware reset occurs following a transient micro-processor disturbance and after an $\overline{INT0}$, i.e. the system is restarted. If the restart is successful (all self-testing routines in order and auxiliary supplies within tolerances), the relay immediately resumes its normal operating state. A recurrence of a processor disturbance or an $\overline{INT0}$ within ten seconds will block the processor continuously.
  It is necessary to interrupt the auxiliary supply for about 5 s to restart the relay in this case.
  On the other hand, correct operation for a period longer than 10 s after a restart, means that another hardware reset will be permitted.
  This blocking time of 10 s must also be taken into account when an $\overline{INT0}$ is initiated by applying an external signal to a blocking input (see Section 6.6.).
  A successful restart following a disturbance and hardware reset is indicated by a flashing display:

  "mode" display: 99 (defect)
  "value" display: RST (restart)
  — see also Table 9.6

  These signals can be reset by pressing the $\boxed{R}$ key.

The restart procedure after an auxiliary supply interruption or an $\overline{INT0}$ takes about 5 s.

6.4.2. *Test software*

The control programme (EPROM) and settings are continuously monitored by check-sum techniques. The positions of plug-in links and setting ranges are checked periodically. The internal -15 V auxiliary supply and the A/D converter are monitored via channels Ch4 and Ch5 (see Fig. 9.2).

6.5. *Defect signals*

The relay's test software (Section 6.4.) causes any irregularities to be indicated by flashing signals in mode 99.

Providing a defect is being signalled for the first time, the relay will only respond to the [R] key.
All defects with the exception of RST and 80 result in the stand-by circuit resetting and blocking the relay.
Table 9.6 in the appendices lists the possible defect signals, the corresponding defect display codes and the response when the [R] key is pressed.

Corresponding defect signals are generated when the coarse I_E setting range is changed (moving plug-in link S1) or the "external I_0" range (moving plug-in link S3). It is for this reason that new settings can be entered following acknowledgement of these defect signals (11/12/13/14 or 31/32 or 40/70) by pressing the [R] key. Once the new settings have been saved by giving Instruction ① (see Section 5.3.6.), the relay is operational once again.

Note:	All settings (modes 0 to 49 and 100 to 149) are automatically written into the operating memory when the I_E range is changed!

If the E/F protection I_Q is set to zero in a scheme with external neutral current and I_2 in operation, the error signal E70 appears in mode 999 after Instruction (save settings) has been given. Instruction ① is not executed (see Section 2.2.7.).

Defects 50, 60 and 61 concern the monitoring of the EPROM, A/D converter and the -15 V auxiliary supply. The auxiliary supply must be switched off for about 5 s should these signals not reset when the [R] key is pressed.

If this measure is also unsuccessful, the relay should be returned to the nearest ABB agent or to ABB Baden, Switzerland.

Providing the self-testing arrangements do not find a defect and the relay is operational, selecting mode 99 displays the value 0 (i.e. no defects found).

6.6. *Blocking (inhibiting) relay operation*

Applying a signal to the blocking input (E5/E4/E3-E2) enables either just the auxiliary signalling and tripping relays or operation of the whole relay to be inhibited. Which of these two possibilities is effective depends on the positions of the plug-in link S4 and the DIL switch S65 (both on PCB 1, Fig. 9.3).

Position of plug-in link S4	Function
1 - 2	selective blocking, see below
2 - 3	The micro-processor is blocked ($\overline{INT0}$, see Section 6.4.1.) and all aux. signalling and tripping relays, including the one for stand-by, reset.

Table 6.2 Function of plug-in link S4

Selective blocking:

A switch of S65 on PCB 1 is associated with each of the auxiliary signalling and tripping relays.

Marking: MRI = aux. signalling relay I
MRII = aux. signalling relay II
ARI = aux. tripping relay I
ARII = aux. tripping relay II

A signal applied to the blocking input has no influence on an auxiliary relay when its switch is in the "open" position, but the signal causes an auxiliary relay to reset, if its switch is in the "closed" position. This blocking arrangement is purely hardware, "unnoticed" by the processor and without a indication on the display. Blocking is maintained for as long as the signal is applied to the blocking input and is cancelled as soon as it disappears.

6.7. *Auxiliary supply*

The auxiliary supply must not be allowed to fall below the minimum permissible voltage and must already be within the permissible range when it is switched on (please refer to the Data Sheet).

For relay version MCX91x-x-x-1

- when supplied from the station battery : 36 to 312 V
- when supplied from the a.c. mains : 80 to 242 V, 50/60 Hz

The supply unit does contain a wet electrolytic capacitor (see Section 6.9.) which functions as a reservoir to some extent for bridging brief supply interruptions. At an ambient of 25°C and with two auxiliary signalling relays and one auxiliary tripping relay energised, the following bridging times may be considered typical:

- auxiliary supply voltage 110 V d.c. : 60 ms
- auxiliary supply voltage 220 V d.c. : 190 ms

For relay version MCX91x-x-x-0

- when supplied from the station battery : 18 to 36 V

The following bridging times may be expected:

- auxiliary voltage V d.c. : 20 ms

6.8. *Supply fuse*

There is one fuse at the upper edge of PCB 1 with the following data (see Fig. 9.3).

0.8 A slow, 5 mm diameter, 20 mm long
(1 A slow, 5 mm diameter, 20 mm long in the versions having an auxiliary supply range of 18 to 36 V d.c.)

6.9. *Maintenance*

The relay requires no special maintenance. However, as is usual with all safety systems, they should be tested at regular intervals (every one to two years). Above all care should be taken that the auxiliary supply voltage lies within the permissible range.

For relay version MCX91x-x-x-1

Since the electrolytic capacitor C155 (see Fig. 9.3) in the auxiliary supply circuit on PCB 1 will be subject to ageing, it is recommended that it be replaced about eight years after delivery of a relay. Replacement is only necessary, if:

- during this period an a.c. auxiliary supply was used,
- following up to eight year's supply from a battery the future supply will be a.c.,
- with a d.c. supply, interruptions are to be expected which could be bridged by a capacitor up to standard (see Section 6.7.).

The work of replacing the capacitor may only be performed by qualified personnel.

PCB 1, C155: 47 µF, 350 V   Order No. XN 400 272 P211

"Calibrating" the relay to the rated frequency (50 or 60 Hz)

As was pointed out in Section 4.2., the rated frequency of the relay must correspond to that of the power system. Should this not be the case, it is possible to provisionally recalibrate the relay on site.

In order to calibrate the relay, it must first be removed from its casing. The auxiliary supply must then be connected directly to terminals E20 and E19 and a calibration current from a single-phase a.c. source to the heavy current terminals.

Relay settings

Plug-in links:	S1	=	2 - 3
	S2	=	1 - 2 with MCX913 2 - 3 with MCX912
	S3	=	1 - 2

Mode settings:	Function selection:	M 47 = 16
	I_E:	M 00 = 0.50
		M103 = 0000
		M105 = 0000
		M107 = 0000

$I>_1$ check

MCX913: Inject 1 x I_{NR} (relay rated current) at R, S or T phase.

MCX912: Inject 1 x I_{NR} at R or T phase.

Mode 53 must be at 2.00 for all phases. A correction can be made with the corresponding trimmer R, S or T (Fig. 9.3), if the discrepancy exceeds ± 3%.

External I_0 check

MCX912-1 and -5: Inject 0.25 A at S phase (I_0).

Mode 57 must be at 0.50 for MCX912-1 or .100 for MCX912-5.

A correction can be made with trimmer S (Fig. 9.3), if the discrepancy exceeds ± 3%.

Calibrating the NPS (I_2) filter

MCX913: Inject 0.75 x I_{NR} at S phase.

MCX912: Inject 0.433 x I_{NR} at T phase.

Adjust trimmer I_2 (Fig. 9.3) such that the value display shows 0.50 for mode 55.

Important: It is possible for the accuracy of the pick-up values to have suffered somewhat as a result of recalibrating in this way. If it is considered essential for the accuracies given in the Data Sheet to be maintained, the relay must be returned to ABB Power Automation Ltd in Switzerland for frequency calibration.

6.10. Testing by current injection

6.10.1. General

The relay has a testing mode (see Section 6.10.3.) for testing those parts which are not covered by the self-monitoring system (see Section 6.4.).The testing mode enables the relay to be tested quickly and simply. The following components and functions can be checked using the test mode:

- the input transformers and signal conditioning circuits
- the auxiliary signalling and tripping relays
- the accuracy of the settings
- the accuracy of the time delays.

The only external equipment required is a single-phase injection current source (e.g. test set XS92b). The test does **not** require changing the protection settings.
The relay is normally inserted in a separate casing for testing, but testing can be carried out with the relay in situ.

- Separate casing: In this case the relay is withdrawn from its casing and inserted into a separate casing wired to the test set.
  Note: If when preparing for the test the auxiliary supply is interrupted for longer than 10 minutes, the thermal replica will be initialised at $\Delta\vartheta_{0\ automatic}$.
- In situ: The relay can be tested in its own casing providing it is equipped with a test connector.

6.10.2. Current injection

The protection mode has been designed to facilitate testing with a single injection current. This current is applied to each phase in turn (see Table 6.3 and Table 6.4 and Fig. 9.5).

6.10.3. Testing procedure

Selecting the test mode: [M] 990 [E] [V] 0 0 0 1 (or 0 0 0 2) [E]

Switching the test mode: [R] [V] 0 0 0 2 (or 0 0 0 1) [E]

The relay is blocked (no longer standing by) once the entry has been made and "TEST" flashes three times on the display. Then the relay is switched back to stand-by and the display shows continuously:

TEST
0001 (or 0002).

The relay now operates with the settings of the test mode selected. The relay only responds to the [R] key when it is in the test mode. Pressing [R] restarts the relay and it operates once again with the normal settings. The thermal replica $\Delta\vartheta$ is **not** changed by the test mode.

Test mode V 0 0 0 1 for checking the accuracy of settings:

The following functions are active:

M 01 : $I{>>}_1$, M 03 : $I{>}_1$, M 05 : I_2, M 07 : I_0

Corresponding tripping logic settings:

M 101: 0 0 0 1 → AR II (see Fig. 9.5, A8, A9) signals pick up of $I{>>}_1$
M 103: 0 0 1 0 → AR I (see Fig. 9.5, A4, A5) signals pick up of $I{>}_1$
M 105: 0 1 0 0 → MR II (see Fig. 9.5, E7, E8) signals pick up of I_2
M 107: 1 0 0 0 → MR I (see Fig. 9.5, E11, E12) signals pick up of I_0

Table 6.3 and Table 6.4 show the settings with single-phase injection and the corresponding auxiliary relays which respond in relation to the positions of the plug-in links.

Relay type	Plug-in links S1	S2		single phase injection of		Setting of I_0 MR I	I_2 MR II	$I{>}_1$ AR I	$I{>>}_1$ AR II
MCX 913	1-2	I_0 intern.	1-2	current injection	R, S, T	0.175	0.315	0.35	1.4
	2-3		"			0.25	0.45	0.50	2.0
	4-5		"			0.35	0.63	0.70	2.8
	5-6		"			0.50	0.90	1.00	4.0
MCX 913	1-2	I_0 extern.	2-3		R, T	-	0.182	0.35	1.4
MCX 912	2-3		"			see	0.26	0.50	2.0
	4-5		"			Table 6.4	0.364	0.70	2.8
	5-6		"			-	0.52	1.00	4.0

Table 6.3 Settings of I_0 internal, I_2, $I{>}_1$ and $I{>>}_1$ (referred to I_N) in test mode V 0 0 0 1 with single-phase injection. The tolerances are given in the Data Sheet (measuring units are current functions and timer).

Plug-in links			Settings of I_0 external (MRI)		
S1	S2	S3	MCX 913	MCX912-1	MCX912-5
1-2	2-3	1-2	0.7	0.14	0.028
2-3	"	"	1.0	0.20	0.040
4-5	"	"	1.4	0.28	0.056
5-6	"	"	2.0	0.40	0.080
1-2	"	2-3	0.175	0.035	0.007
2-3	"	"	0.25	0.050	0.010
4-5	"	"	0.35	0.070	0.014
5-6	"	"	0.50	0.100	0.020

Table 6.4 Settings of I_0 external (referred to I_N) in test mode V 0 0 0 1.
Single-phase current injection of I_0 (see Fig. 9.5, A6, A7).

Test mode V 0 0 0 2 for checking the time delays

All the timers in the MCX relays have a common digital counter and quartz time base. It thus suffices to check just one time delay.

Only function $I>_1$ is active:

M 03 = 1.0 x I_E
M 04 = 1.0 s
M 103 = 1 1 2 2 → MR I and MR II signal pick-up of $I>_1$ (see Fig. 9.5, E7, E8, E11, E12)
AR I and AR II signal tripping of $I>_1$ (see Fig. 9.5, A4, A5, A8, A9)

Procedure: Inject current at R phase (step change from 0 to 1.5 x setting).

Plug-in link S1	Injection current	Pick-up value
1 - 2	0.5	0.35
2 - 3	0.75	0.5
4 - 5	1.05	0.7
5 - 6	1.5	1.0

Table 6.5 Injection current I_R (referred to I_N) and settings in test mode V 0 0 0 2

Note that the operating times of the auxiliary relays must be taken into account when checking delay times.

6.10.4. Checking the actual settings

Although it is not considered necessary, it is possible to check the actual settings of the individual protection functions used in operation. The procedure in this case is as follows:

1. Isolate the protection function to be tested from the others by connecting its output using the tripping matrix (see Table 9.3) to an auxiliary relay not being used (e.g. MRII or ARII) and connect it ready for testing.
2. Change and save only the setting of the tripping logic for testing: 1 for the pick-up setting, 2 for the time delay.
3. Now test the protection function selected.
4. After testing, reset the tripping logic to its original setting and save it.
5. Repeat steps 2. to 4. for each protection function tested.
6. Go through the procedure for saving settings.

Example: Tripping logic settings

Protection function $I>_1$	Setting in operation				Setting for testing			
	MRI	MRII	ARI	ARII	MRI	MRII	ARI	ARII
Pick-up value	1	0	2	0	1	1	2	0
Time delay	1	0	2	0	1	2	2	0

7. TROUBLE-SHOOTING

Should the green LED (stand-by) on the frontplate go out and contact E15-E16 on the auxiliary stand-by signalling relay be open, the following should be checked:

- that the auxiliary supply is in the permissible range,
- there is no external blocking signal ($\overline{\text{INT0}}$),
- the relay wiring is in order,
- the fuse on PCB 1 (0.8 A slow, or 1.0 A slow) is intact (see Section 6.8.),
- that an $\overline{\text{INT0}}$ has not been caused by two defects in quick succession (see Section 6.4.1.).
  In this case interrupt the auxiliary supply for about 5 s which restarts the relay.

If the relay appears to be standing by (green LED lit), but does not trip when there is overcurrent, the following should be checked:

- there is no external blocking signal (selective blocking),
- the settings are correct (pick-up values and tripping logic),
- and d.c. wiring are correct,
- that current is indeed flowing through the input transformer (Caution! Do not interrupt c.t. circuit conducting current).

Where defects are being signalled, the procedure is given in Section 6.5.

If an apparent defect cannot be remedied by the above measures, the relay together with a description of the symptoms should be returned either to the nearest ABB office or directly to ABB Power Automation Ltd, Reparaturzentrum, Eingnang West, Warenannahme Terminal CA, CH-5401 Baden.

Important:

Before withdrawing the relay from its casing, make sure that the auxiliary supply is switched off to exclude any risk of false tripping.

8. ACCESSORIES AND SPARES

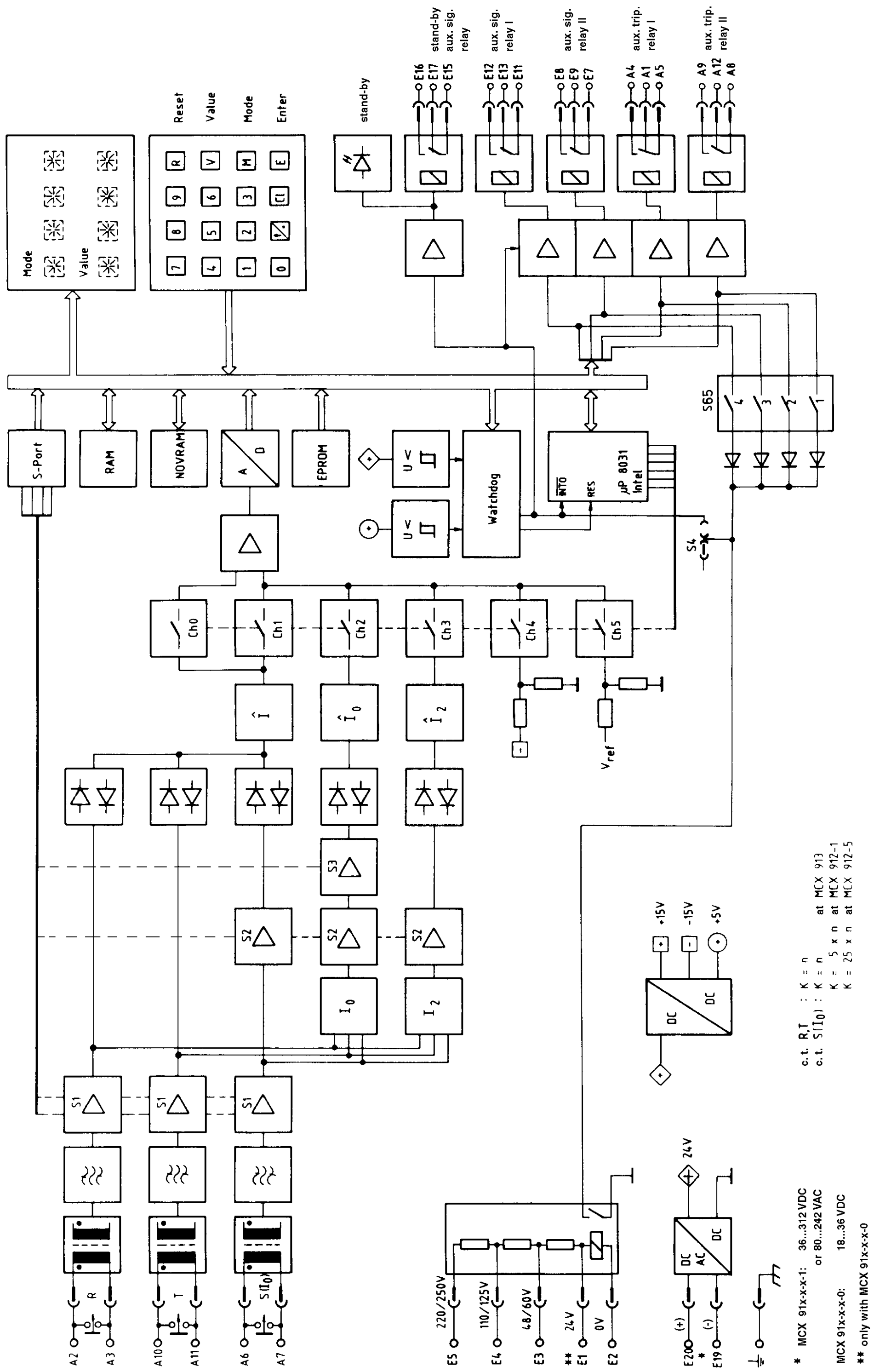
Whenever ordering accessories or spares, please state the type and serial number of the protection relay for which they are intended. If there are a number of relays of the same type in the same installation, stocking a spare relay is recommended.

All spares should be stored in a clean dry room at moderate temperatures. Testing the spare relays at the same time as periodically testing those in operation, i.e. every one to two years, is also recommended.

9. APPENDICES

Fig. 9.1 Motor protection/overcurrent/thermal overload relay MCX913 (BBC size 1 relay casing)

- Above - relay withdrawn form its casing, see Fig. 9.5 for terminal designations (Photo 219 011)
- Below - relay in its casing (Photo 235 218)



HEST 005020.TIF

Fig. 9.2 Block diagram of MCX912/913 (corresponds HESG 323 928)

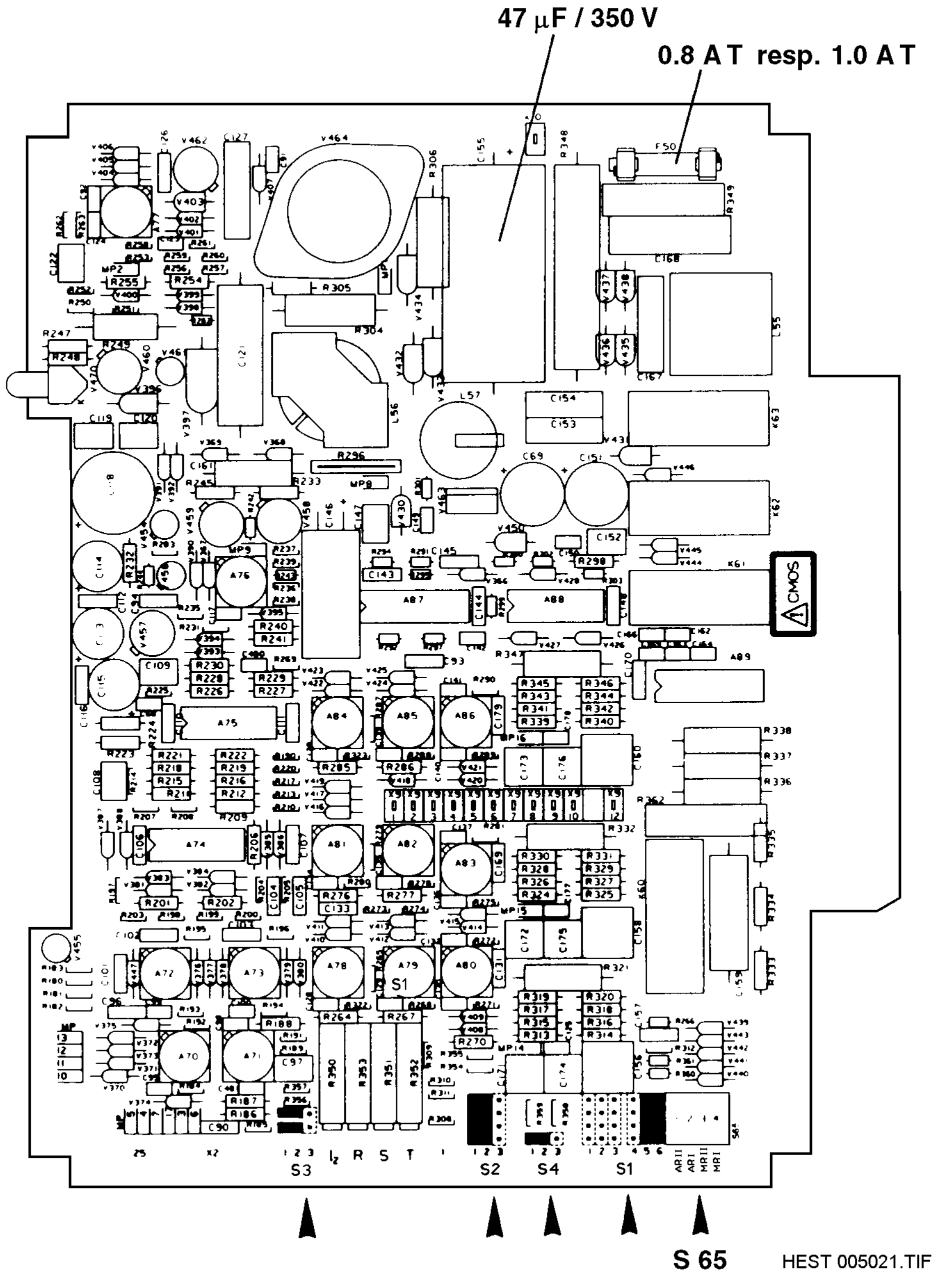
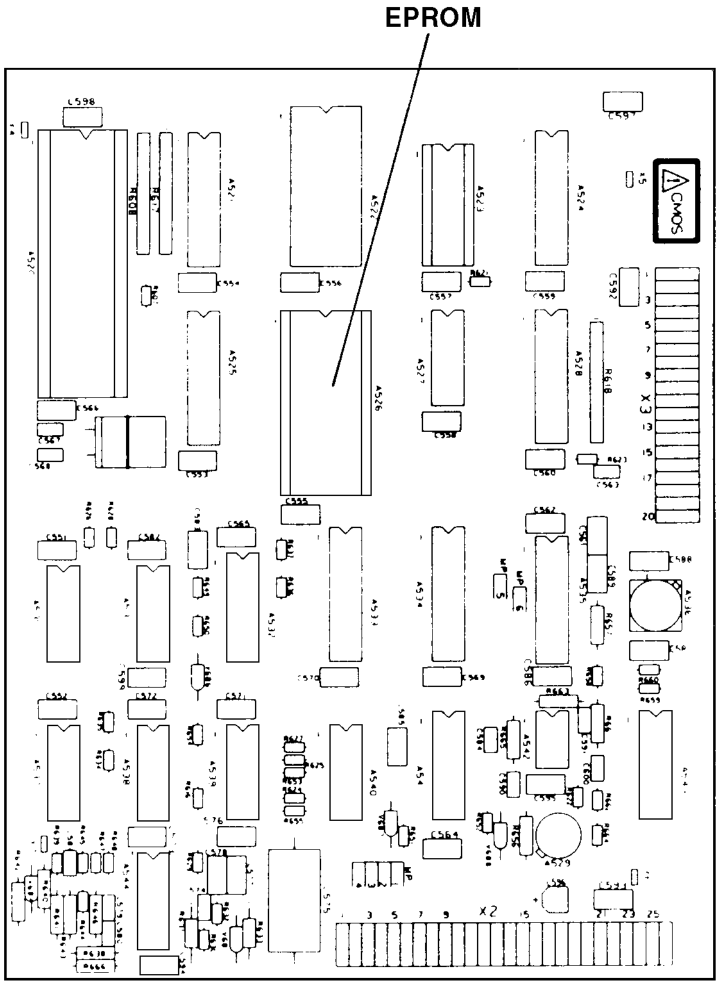


Fig. 9.3 Locations of the plug-in links S1 to S4, DIL switch S65, fuse and electrolytic capacitor (47µF) on PCB1 (corresponds HESG 323 892)



HEST 005022.TIF

Fig. 9.4 PCB 2 showing the EPROM
(corresponds HESG 440 843)

Mode	Setting	Symbol	Range	Resolution	Unit	Defaultvalue
00	base current	I_E	0.30...1.20	0.01	I_{NR}	1.00 *
01	phase faults 1	$I>>_1$	0; 2...20	0.1	I_E	7.0
02	timer	$tI>>_1$	0.00...9.99	0.01	s	0.05
03	overcurrent 1	$I>_1$	0; 0.8...8	0.1	I_E	1.5
04	timer	$tI>_1$	0.1...200	0.1/1	s	20.0
05	NSP	I_2	0; 0.1...0.5	0.01	I_E	0.30
06	timer	tI_2	0.1...200	0.1/1	s	4.0
07	E/F: internal	I_0	0; 0.2...1	0.01	I_E	0.5
	external	I_0	(0; 0.2...4)/k	0.01/(0.001)	I_E	2.0/k *
08	timer int./ext.	tI_0	0.01...100	0.01/0.1	s	0.2
09	I_0-INT. / EXT.	---	1=INT, 0=EXT	1	1	1 *
10	I_0 c.t. ratio	k	1 **	1	1	1 **
11	blocked rotor	$I_{bl.r.}$	0; 0.8...8.0	0.1	I_E	3.0
12	timer	$t_{bl.r.}$	0.1...200	0.1/1	s	15.0
13	run-up	I_{start}	0; 0.8...8.0	0.1	I_E	2.0
14	perm. I^2T for start	I^2T_{start}	1...9999	0.1/1	I_E^2s	1000
15	no-load	I<	0; 0.3...3.0	0.1	I_E	0.5
16	timer	tI<	0.1...200	0.1/1	s	30.0
17	No. of starts from cold	N_{cold}	0; 1...10	1	1	3
18	No. of starts when warm	N_{hot}	0; 1...10	1	1	2
19	time for N N-1	t_{N-1}	1...9999	1	s	600
20	temp. rise $\Delta\vartheta_3$	$\Delta\vartheta_3$	0; 50...200	1	%	70
21	start with excessive temp.	N_S	0, 1, 2	1	1	0
30	temp. rise $\Delta\vartheta_1$	$\Delta\vartheta_1$	0; 50...200	1	%	105
31	temp. rise $\Delta\vartheta_2$	$\Delta\vartheta_2$	0; 50...200	1	%	120
32	hysteresis for $\Delta\vartheta_2$	$H\Delta\vartheta$	1...100	1	%	15
33	heating time const.	$\tau\uparrow$	1...200	1	min	30
34	cooling time const.	$\tau\downarrow$	1...999	1	min	90
38	automatic $\Delta\vartheta_0$	$\Delta\vartheta_0$	0...200	1	%	0
39	manual $\Delta\vartheta_0$	$\Delta\vartheta_0$	0...200	1	%	201
40	setting time for mean value	k_{TE}	0...2 ***	1	1	1
41	phase faults 2	$I>>_2$	0; 2...20	0.1	I_E	0
42	timer	$tI>>_2$	0.00...9.99	0.01	s	0.1
43	overcurrent 2	$I>_2$	0; 0.8...8	0.1	I_E	0
44	timer	$tI>_2$	0.1...200	0.1/1	s	1.0
45	overcurrent	$I>_3$	0; 0.8...8	0.1	I_E	0
46	timer	$tI>_3$	0.1...200	0.1/1	s	1.0
47	selection of function	CTRL 1	1...19	1	1	1

I_{NR} relay rated current (1 A or 5 A)

* depends on plug-in link position

** k = 1 for MCX913
k = 5 for MCX912-1
k = 25 for MCX912-5

*** k_{TE} = 0 Setting time: 8 min
k_{TE} = 1 Setting time: 15 min
k_{TE} = 2 Setting time: 30 min

Note: the modes 09 and 10 are signals and not setting values

Table 9.1 Protection setting ranges

Mode (display)	Load quantity displayed	Resolution	Unit
51	phase-to-neutral current *	0.01/0.1	I_E
52	timer $tI{>}{>}_1$	0.01	s
53	phase-to-neutral current *	0.01/0.1	I_E
54	timer $tI{>}_1$	0.01/1	s
55	NPS current I_2	0.01	I_E
56	timer tI_2	0.1	s
57	neutral current I_0	0.01	I_E
58	timer tI_0	0.01	s
61	phase-to-neutral current *	0.01/1	I_E
62	timer $t_{bl.r.}$	0.1/1	s
63	phase-to-neutral current *	0.01/0.1	I_E
64	starting timer I^2T	0.1/1	$I_E{}^2s$
65	phase-to-neutral current *	0.01/0.1	I_E
66	timer tI<	0.1/1	s
67	counter N_{cold}	1	1
68	counter N_{hot}	1	1
69	timer t_{N-1}	1	s
70	temperature rise $\Delta\vartheta$	1	%
80	temperature rise $\Delta\vartheta$	1	%
81	temperature rise $\Delta\vartheta$	1	%
89	max. mean value of the phase current *	0.01/0.1	I_E
90	mean value of the phase current *	0.01/0.1	I_E
91	phase-to-neutral current *	0.01/0.1	I_E
92	timer $tI{>}{>}_2$	0.01	s
93	phase-to-neutral current *	0.01/0.1	I_E
94	timer $tI{>}_2$	0.1/1	s
95	phase-to-neutral current *	0.01/0.1	I_E
96	timer $tI{>}_3$	0.1/1	s
98	operating hours counter	0.1/1	10 h
99	defect signals	---	---

Table 9.2 Load value displays

* highest of the three phase-to-neutral currents (r.m.s.) respectively the higher of the phase-to-neutral currents when S phase input is used for E/F's.

Tripping logic

Pick-up signalling, tripping or latched tripping can be selected for each of the protection functions given below by appropriately setting the tripping logic to selectively energise the two auxiliary signalling relays (MRI and MRII) or the two auxiliary tripping relays (ARI and ARII).
The default values are given in brackets.

(Logic) Mode	Protection function	'Value' display			
		digit 3 ≙ MR I	digit 2 ≙ MR II	digit 1 ≙ AR I	digit 0 ≙ AR II
101	$I>>_1$	x (2)	x (0)	x (2)	x (0)
103	$I>_1$	x (2)	x (0)	x (2)	x (0)
105	I_2	x (2)	x (0)	x (2)	x (0)
107	I_0	x (2)	x (0)	x (2)	x (0)
111	$I_{bl.r.}$	y (2)	y (0)	y (2)	y (0)
113	I_{start}	x (2)	x (0)	x (2)	x (0)
115	$I<$	x (2)	x (0)	x (2)	x (0)
117	N_{cold}, N_{hot}	x (0)	x (0)	x (1)	x (0)
120	$\Delta\vartheta_3$	z (0)	z (0)	z (0)	z (0)
130	$\Delta\vartheta_1$, $\Delta\vartheta_2$	x (1)	x (0)	x (2)	x (0)
141	$I>>_2$	x (2)	x (0)	x (2)	x (0)
143	$I>_2$	x (2)	x (0)	x (2)	x (0)
145	$I>_3$	x (2)	x (0)	x (2)	x (0)

Table 9.3 Tripping logic

x can only be 0, 1, 2 or 3; y can only be 0, 1 or 2 and z can only be 0 or 1, whereby:

z, y or x = 0 means no auxiliary relay response

z, y or x = 1 means auxiliary relay energised for pick-up or $\Delta\vartheta>\Delta\vartheta_1$; $\Delta\vartheta>\Delta\vartheta_3$;
Special case: N_{cold}, N_{hot} ; see Section 2.2.9.

y or x = 2 means auxiliary relay energised for trip, $\Delta\vartheta>\Delta\vartheta_1$, or No. of start attempts greater than N_{cold} or N_{hot}

x = 3 means auxiliary relay energised and latched.

Example:

The value programmed for mode 105 is 1020. This means that when I_2 picks up, the auxiliary relay MRI is energised and when I_2 trips auxiliary relay ARI is energised.

Mode	Value	Resolution	Unit
151	current when $I>>_1$ tripped	0.01/0.1	I_E
152	$tI>>_1$ elapsed time	0.01	s
153	current when $I>_1$ tripped	0.01/0.1	I_E
154	$tI>_1$ elapsed time	0.01/1	s
155	current when I_2 tripped	0.01	I_E
156	tI_2 elapsed time	0.1/1	s
157	current when I_0 tripped	0.01/(0.001)	I_E
158	tI_0 elapsed time	0.01	s
161	current when $I_{bl.r.}$ tripped	0.01/0.1	I_E
162	$tI_{bl.r.}$ elapsed time	0.1/1	s
163	current when I_{start} tripped	0.01/0.1	I_E
164	remaining I^2T	0.1/1	I^2_E
165	current when I< tripped	0.01/0.1	I_E
166	tI< elapsed time	0.1/1	s
191	current when $I>>_2$ tripped	0.01/0.1	I_E
192	$tI>>_2$ elapsed time	0.1/1	s
193	current when $I>_2$ tripped	0.01/0.1	I_E
194	$tI>_2$ elapsed time	0.1/1	s
195	current when $I>_3$ tripped	0.01/0.1	I_E
196	$tI>_3$ elapsed time	0.1/1	s
199	run-up time t_{start}	0.1/1	s

Table 9.4 Tripping value and elapsed time memory

Special case: Mode 199 displays the run-up time, i.e. the time taken for the starting current to fall below I_{start} , see Section 2.2.4., or the time until I_{start} trips (overflow is displayed, if t_{start} exceeds 9999 s).

Protection function		**Selected functions (mode 47)**																		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
phase faults	$I{>>}_1$	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x
overcurrent	$I{>}_1$	x	x	x	x	x	x		x	x		x	x	x	x		x	x		x
NPS	I_2	x	x	x	x	x	x	x				x				x	x			
E/F	I_0	x	x	x	x	x	x	x				x	x	x	x	x	x			x
blocked rotor	$I_{bl.r.}$	x	x									x								
run-up protection	I_{start}	x	x	x	x		x	x	x		x	x	x	x						
no load check	$I<$	x	x				x													
No. of starts		x	x	x			x													
temp. rise	$\Delta\vartheta_1$, $\Delta\vartheta_2$, $\Delta\vartheta_3$	x	x	x	x	x		x	x	x	x	x	x	x				x		x
phase faults	$I{>>}_2$		x									x	x							x
overcurrent	$I{>}_2$		x									x	x							x
overcurrent	$I{>}_3$		x									x	x							x
Application		Motors						Power transformers and lines					overcurrent							

Table 9.5 Combinations of protection functions which can be selected in mode 47

Note: When a protection function is not active, because it has not been selected in mode 47, then all the corresponding dependent modes in Table 9.1 to Table 9.4 are also inactive and can not be called up.

E.g.: I_{start} inactive → modes 13, 14, 63, 64, 113, 163, 164 also inactive

No. of starts inactive → modes 17, 18, 19, 20, 21, 67, 68, 69 and 117 also inactive.

Exception: Mode 199 (run-up time t_{start}) can always be selected irrespective of the selected function.

Value	Cause of defect	Effect of pressing [R]-key
RST	Hardware reset following a defect (restart)	Defect is flashes with a C on 'mode' display 3 times, then it shows next defect or first value of the FIFO, or erase display.
10	S1 missing or shorted	see defects 50, 60 and 61
11 12 13 14	Settings are for S1 in position 1 - 2, i.e. S1 is not in this position. Settings are for S1 in 2 - 3 Settings are for S1 in 4 - 5 Settings are for S1 in 5 - 6	All the default values of the settings are copied into the operating memory (I_E according to the position of S1), then first value of FIFO or mode 00 (I_E) is shown.
20 21 30	S2 missing or shorted S2 in position 1 - 2 (i.e. internal I_0 , only MCX912) S3 missing or shorted	see defects 50, 60 and 61
31 32	Settings are for S3 in position 1 - 2 and S2 in 2 - 3, i.e. neither is in its position. Settings are for S3 in position 2 - 3 and S2 in 2 - 3	The default values for I_0 and tI_0 are copied into the operating memory (I_0 according to the positions of S2 and S3), then the first value of the FIFO or mode 07 (I_0) is shown.
40	NOVRAM check sum incorrect	see defects 11, 12, 13 and 14
50 60 61	EPROM check sum incorrect A/D converter defect -15 V supply defect	The processor checks whether the defect is still present. If yes, defect display maintained, otherwise defect flashes with C 3 times, then next defect, first value of the FIFO or last mode selected is shown.
70	I_0 inactive, I_2 inactive in an external I_0 scheme	see defects 31 and 32
80	Operating hours counter on 9999 x 10 h	Defects flashes with C 3 times, then operating hours counter set in operating and main memories to zero and mode 98 is shown.

Table 9.6 Defect signals (shown flashing in mode 99)

Once a defect has been signalled, the relay will only respond to the reset key.
All defects excepting RST and 80 actuate the stand-by circuit and block the relay.

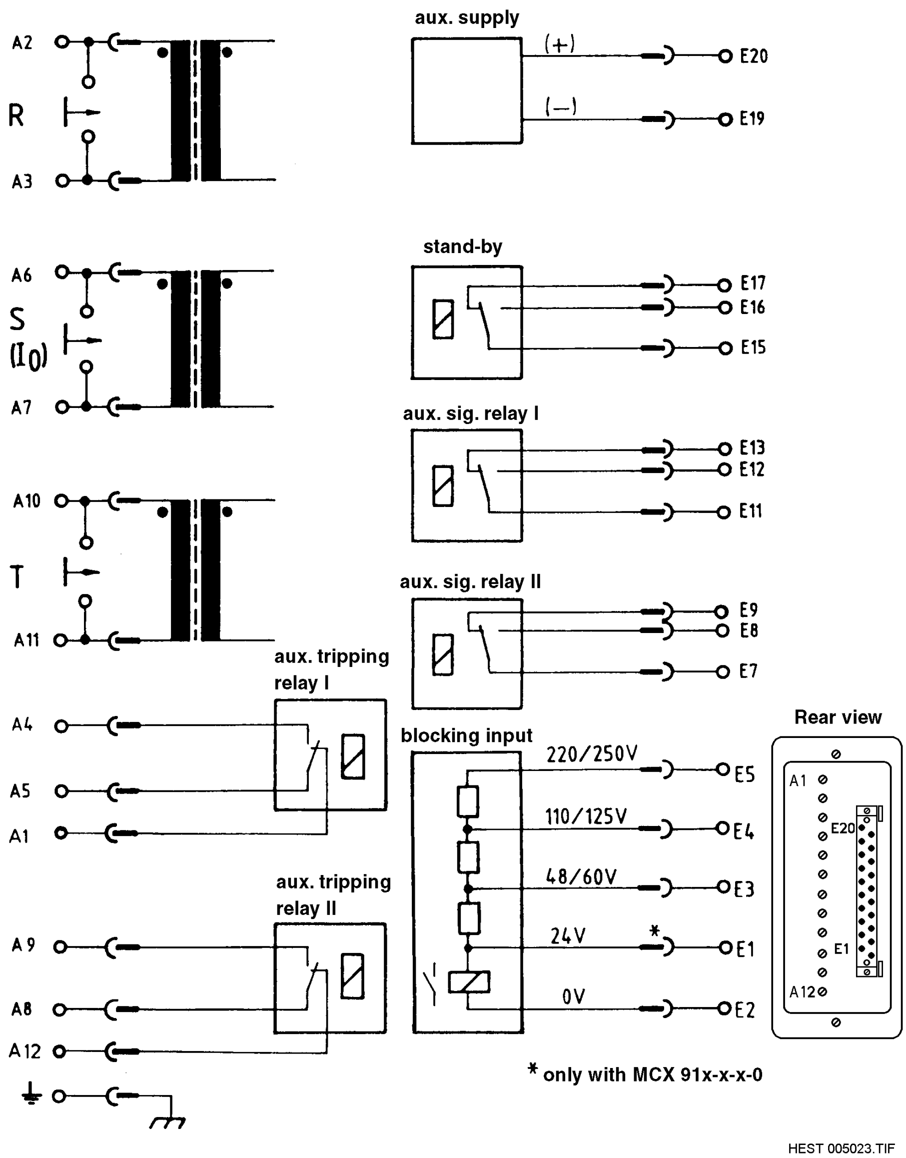


Fig. 9.5 Terminal designations
(corresponds to HESG 440 838)

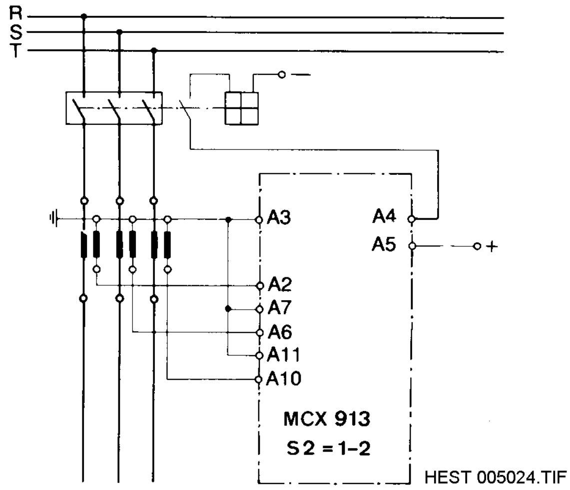


Fig. 9.6 Wiring diagram with internal neutral current derivation

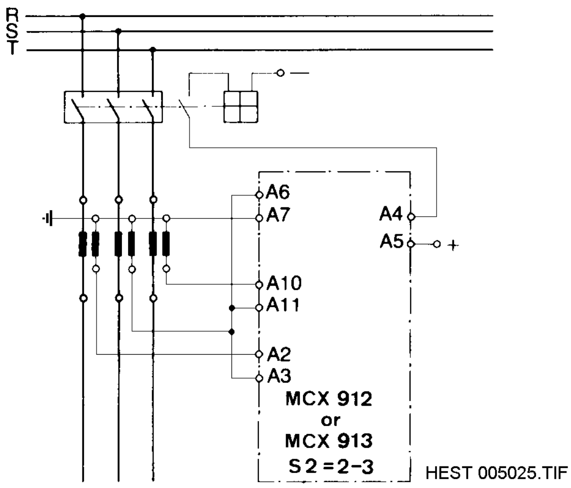


Fig. 9.7 Wiring diagram with external neutral current derivation

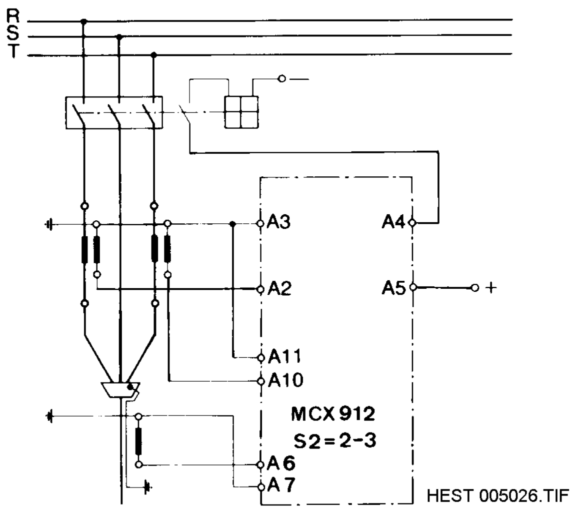


Fig. 9.8 Wiring diagram with external neutral current derivation by a core-balance c.t.

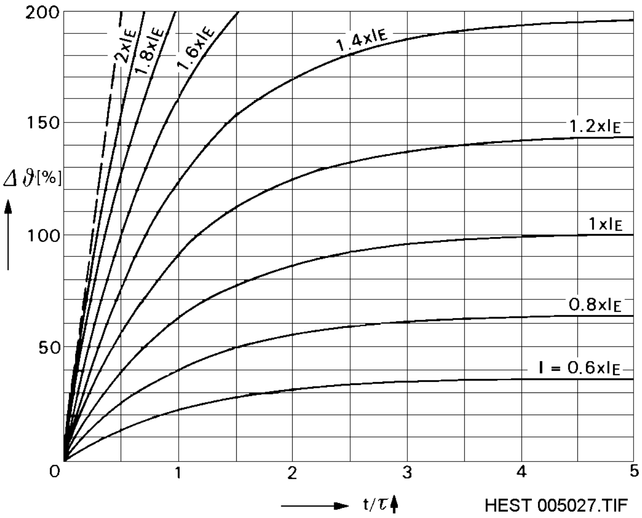


Fig. 9.9

Temperature rise curves for

$0.1 \times I_E \leq I_E < 2 \times I_E$

from cold ($\Delta\vartheta$(t=0) = 0%)

$$\Delta\vartheta = \left|\frac{I}{I_E}\right|^2 \times \left(1 - e^{-\frac{t}{\tau\uparrow}}\right) \times 100 \quad (\%)$$

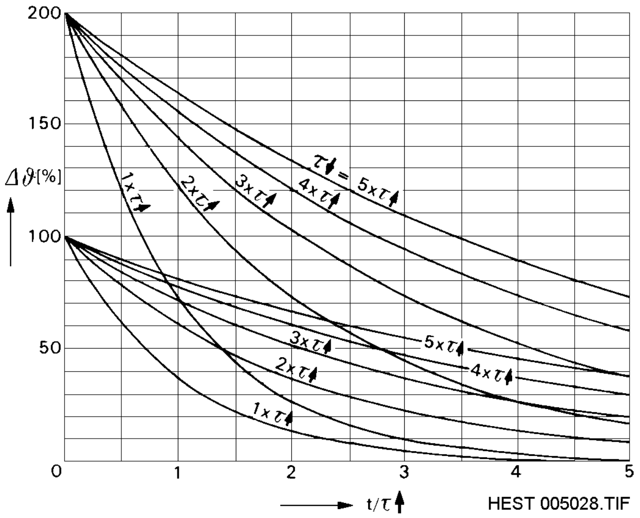


Fig. 9.10

Cooling curves at I = 0 starting from $\Delta\vartheta$ = 100% and 200% in relation to the cooling time constant $\tau\downarrow$

$\tau\downarrow$ = 1 x, 2 x ... 5 x $\tau\uparrow$

$$\Delta\vartheta = \Delta\vartheta(t=0) \times e^{-\frac{t}{\tau\downarrow}} \quad (\%)$$

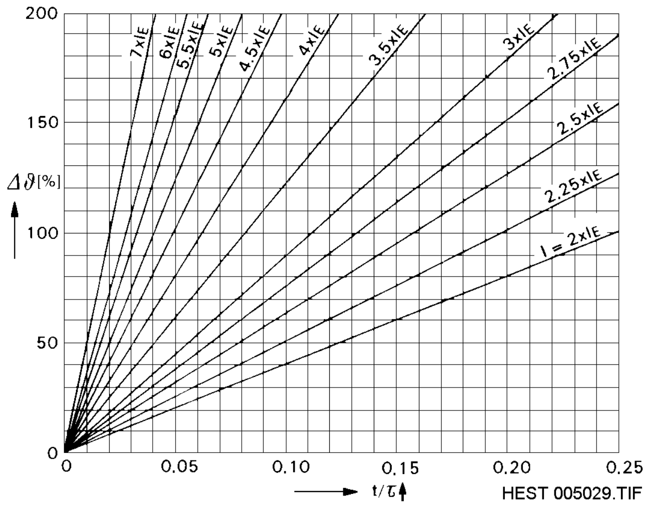


Fig. 9.11

Temperature rise curves for $I \geq 2 \times I_E$ from cold ($\Delta\vartheta$(t=0) = 0%)

$$\Delta\vartheta = \left|\frac{I}{I_E}\right|^2 \times \frac{t}{\tau\uparrow} \times 100 \quad (\%)$$

I =

(phase-to-neutral current)

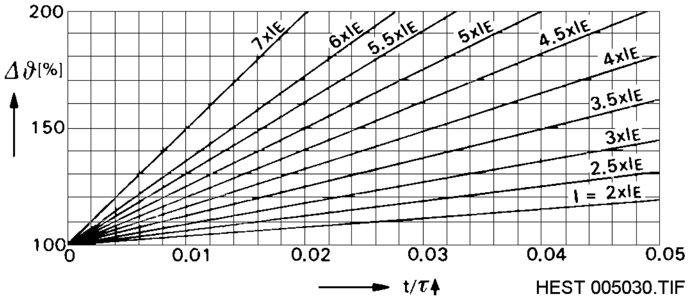
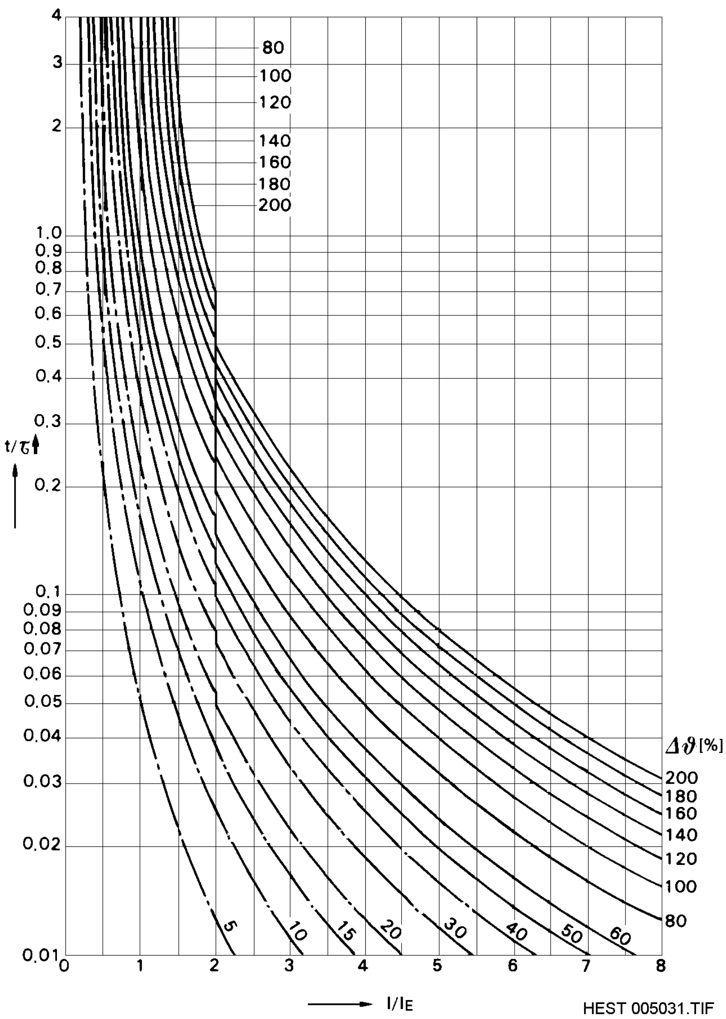


Fig. 9.12

Temperature rise curves for $I \geq 2 \times I_E$ when hot ($\Delta\vartheta(t=0) = 100\%$)

$$\Delta\vartheta = \left(1 + \left|\frac{I}{I_E}\right|^2 x \frac{t}{\tau\uparrow}\right) x100 \quad (\%)$$

I = input current to relay (phase-to-neutral current)



$$\frac{t}{\tau\uparrow} = f\left|\frac{I}{I_E}, \Delta\vartheta_2\right|$$

for $0.1 \times I_E \leq I < 2 \times I_E$:

$$\frac{t}{\tau\uparrow} = \ln \frac{(I/I_E)^2}{(I/I_E)^2 - \Delta\vartheta_2 \, x0.01}$$

for I 2 x I_E:

$$\frac{t}{\tau\uparrow} = \frac{\Delta\vartheta_2 \, x0.01}{(I/I_E)^2}$$

Fig. 9.13 Operating characteristics form cold ($\Delta\vartheta_0 = 0\%$)

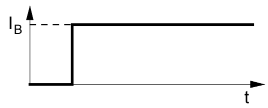
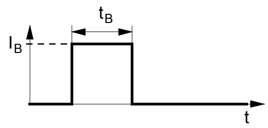
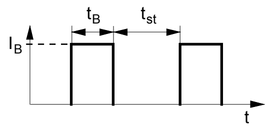
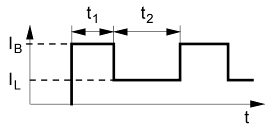
Kind of operation	Current flow	$\tau\downarrow$	$\Delta\vartheta_{max.}$ [%]
continuous		$\tau\downarrow > \tau\uparrow$	$(I_B/I_E)^2 \times 100$
short		$\tau\downarrow > \tau\uparrow$	$(I_B / I_E)^2 \cdot \left\| 1-e^{-\frac{t_B}{\tau\uparrow}} \right\| \cdot 100$
intermittent		$\tau\downarrow > \tau\uparrow$	$(I_B / I_E)^2 \cdot \frac{1-e^{-\frac{t_B}{\tau\uparrow}}}{1-e^{-\left\| \frac{t_B}{\tau\uparrow}+\frac{t_{st}}{\tau\downarrow} \right\|}} \cdot 100$
continuous with varying loads		$\tau\downarrow = \tau\uparrow = \tau$	$\frac{(I_B / I_E)^2 \cdot \left\| 1-e^{-\frac{t_1}{\tau}} \right\| + (I_L / I_E)^2 \left(1-e^{-\frac{t2}{\tau}} \right) \cdot e^{-\frac{t_1}{\tau}}}{1-e^{-\frac{t_1 \cdot t_2}{\tau}}} \cdot 100$

Table 9.7 Maximum temperature rise $\Delta\vartheta_{max.}$ [%] for different kinds of motor operation:
$I_B < 2 \times I_E$

where:

I_B, I_L	load currents
I_E	base current
$\Delta\vartheta_{max.}$ [%]	max. temperature rise
$\tau\downarrow$	cooling time constant
$\tau\uparrow$	heating time constant
t_B	time on load
t_{st}	time at standstill
t_1	time on load at I_B
t_2	time on load at I_L

Frame size [mm] (shaft height)		355	400	450	500	560	630	710	800	900	1000	1120	1250
Motor design	O	20	25	28	30	35	40	50	60	65	70		
	R				45	50	55	60	70	80	90	100	110
	U	30	35	40	45	50							

Table 9.8 Typical mean thermal time constants $\tau\uparrow$ in minutes on BBC induction motors in relation to frame size and design

where:
- O open type
- R enclosed with forced cooling (DIN IP54)
- U completely enclosed with cooling rips (DIN IP54)

Setting Table

STATION: FEEDER:

96-03

Multifunction relay types MCX 912 and MCX 913

Relay datas: ❑ MCX912-.......... ❑ 1 A ❑ 50 Hz
❑ MCX913-.......... ❑ 5 A ❑ 60 Hz

Protected object:

S_N .... kVA U_N .... kV I_N .... A Main C.T. ratio .... A / ..... A

Mode	Symbol	Value	Remarks
00	I_E		
01	$I>>_1$		
02	$tI>>_1$		
03	$I>_1$		
04	$tI>_1$		
05	I_2		
06	tI_2		
07	I_0		
08	tI_0		
11	$I_{bl.r.}$		
12	$tI_{bl.r.}$		
13	I_{start}		
14	I^2T_{start}		
15	$I<$		
16	$tI<$		
17	N_{cold}		
18	N_{hot}		
19	t_{N-1}		
20	$\Delta\vartheta_3$		
21	N_S		
30	$\Delta\vartheta_1$		
31	$\Delta\vartheta_2$		
32	$H\Delta\vartheta$		
33	$\tau\uparrow$		
34	$\tau\downarrow$		
38	$\Delta\vartheta_0$		
40	k_{TE}		
41	$I>>_2$		
42	$tI>>_2$		
43	$I>_2$		
44	$tI>_2$		
45	$I>_3$		
46	$tI>_3$		
47	CTRL 1		

Matrix Mode	Symbol	Value MRI	MRII	ARI	ARII	Value MRI	MRII	ARI	ARII
101	$I>>_1$								
103	$I>_1$								
105	I_2								
107	I_0								
111	$I_{bl.r.}$								
113	I_{start}								
115	$I<$								
117	N_c,N_h								
120	$\Delta\vartheta_3$								
130	$\Delta\vartheta_{1,2}$								
141	$I>>_2$								
143	$I>_2$								
145	$I>_3$								

Tripping matrix:
value 0 blocked
value 1 Starting
value 2 Tripping unlatched
value 3 Tripping latched

S4: Blocking of relay

S4		
1-2	selective blocking	❑
2-3	all functions blocked	❑

S2,S3: Neutral current I_0

Relay type MCX913

S2	S3	I_0		
2-3	1-2	external	0,8...4,0 x I_E	❑
2-3	2-3		0,2...1,0 x I_E	❑
1-2	-	internal	0,2...1,0 x I_E	❑

Relay type MCX 912

S2	S3	I_0		
2-3	1-2	external	0,16...0,8 x I_E	❑ MCX912-1
2-3	2-3		0,04...0,2 x I_E	❑
2-3	1-2	external	0,032...0,16 x I_E	❑ MCX912-5
2-3	2-3		0,008...0,04 x I_E	❑

S1: Base current I_E

S1	Range	
1-2	0.300...0.424 * I_{NR}	❑
2-3	0.425...0.600 * I_{NR}	❑
4-5	0.601...0.848 * I_{NR}	❑
5-6	0.849...1.200 * I_{NR}	❑

S65: Selective blocking

Relay	switch open	switch closed	
MR I	❑	❑	Signal relay I
MR II	❑	❑	Signal relay II
AR I	❑	❑	Tripping relay I
AR II	❑	❑	Tripping relay II

Switch "open": no influence at blocking

Date: Signature:

Client
Date: Signature:

Fig. 9.14

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Have you discovered any mistakes in this publication? If so, please note here the pages, sections etc.

Do you find the publication readily understandable and logically structured? Can you make any suggestions to improve it?

Is the information sufficient for the purpose of the publication? If not, what is missing and where should it be included?

Name Date

Company

Postal code Town Country

Notification Form for Equipment Faults/Equipment Problems

Dear User

Should you be obliged to call on our repair service, we kindly as you to attach a note to the **unit** describing the fault as precisely as possible. This will assist us to carry out the repair swiftly and reliably.
Please attach a completed form to each unit and forward them to the address below.
Many thanks.

ABB Power Automation Ltd.
Repair Centre, Dept. NAP
Eingang West, Warenannahme Terminal CA
CH-5401 Baden

Unit information:

Unit type:

Serial No.: HE ....

In operation since:

Identified faults: (tick off where applicable)

❑ Overfunction

❑ No function

❑ Outside tolerance

❑ Abnormal service temperature

❑ Sporadic error

❑ Unit for checking

Remarks/fault description:

Client: Date:

Adress:

Contact Person: Tel: Fax:

PLEASE NOTE!

Our experience has been shown that, if the information and recommendations contained in these "Operating Instructions" are observed, the best possible reliability of our products is assured.

It is scarcely possible for the operating instructions of technical equipment to cover every eventuality which can occur in practice. We would therefore request you to notify us or our agent in the case of all unusual behaviour, which does not appear to be covered by these operating instructions.

It is pointed out that all local regulations must be observed when connecting and commissioning this equipment in addition to these operating instructions.

Any work that has to be carried out inside the equipment, such as changing soldered links or fitting or removing resistors, may only be performed by correspondingly qualified personnel.

We cannot accept any responsibility for damage incurred as a result of mishandling the equipment regardless of whether particular reference is made in these operating instructions or not.

ABB Power Automation

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