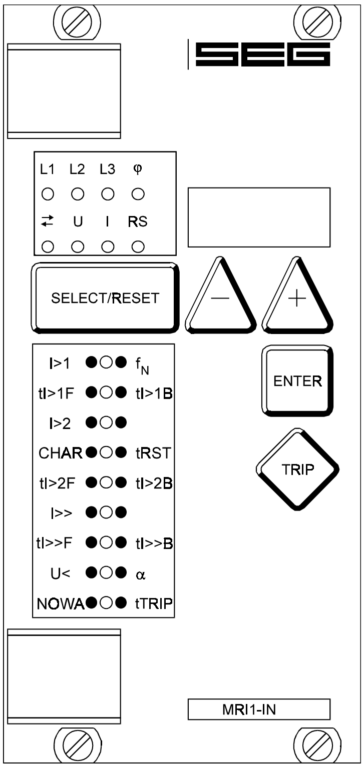
MRI1-IN - Sensitive directional time overcurrent relay



Contents

Important:
For additional common data of all *MR*-relays please refer to manual „*MR* - Digital Multifunctional relays“.

This manual is valid for relay software version from D19_1.00 onwards

1 Introduction and application

The sensitive time overcurrent relay *MRI1-IN* with directional features is mainly used for system decoupling where generators operating in parallel with high impedance grids.

With very high impedance grids (where load changes cause big voltage changes) vector surge relays or df/dt relays cannot be used for mains decoupling because even insignificant load changes (load connection or disconnetion) can cause vector surges or frequency changes (df/dt) in the local grid and so result in unintended mains decoupling.

For many industrial grids with local power generators, feedback into the grid of the Electrical Utility Company during parallel operation is not wanted because such feedback into the public grid can jeopardize a secure local power supply during mains failures.
The *MRI1-IN* with its very accurate setting range detects even minimal current imports from the system during feedback into the public grid.

The *MRI1-IN* is additionally provided with two overcurrent elements, a high set element as well as a characteristic angle element which can be adjusted continuously. So the *MRI1-IN* can be used in all meshed systems and doubly infeeded lines as normal directional time overcurrent protection. Its functions are as follows:

- Definite time overcurrent protection (UMZ)
- Inverse time overcurrent protection (AMZ) with selectable tripping characteristic

Furthermore, the relay can be employed as a back-up protection for distance and differential protective relays.

2 Features and characteristics

- Digital filtering of the measured values by using discrete Fourier analysis to suppress the high frequence harmonics and DC components induced by faults or system operations
- Selectable protective functions between:
  - definite time overcurrent relay and
  - inverse time overcurrent relay
- Selectable inverse time characteristics according to BS 142 and IEC 255-4:
  - Normal Inverse
  - Very Inverse
  - Extremely Inverse
- Reset setting for inverse time characteristics selectable
- High set overcurrent unit with instantaneous or definite time function.
- Two element time ovcercurrent relay for phase faults
- Directional feature for application to the doubly infeeded lines or meshed systems.
- Measuring the phase current during short-curcuit free operation, storage of the trip values in case of failure
- Extremely accurate current setting range
  I>1: 0.5% to 25% I_N (used as mains decoupling against feeding back into the grid).
  I>2: 50% to 200% I_N (used as normal time overcurrent protection with directional features)
- Three directional elements with different tripping times for both directions
- Withdrawable modules with automatic short circuit of C.T. inputs when the modules are withdrawn.
- External blocking function
- Characteristic angle with directional features, adjustable from 0° to 355°
- Adjustable dwell time
- Overcurrent element I>2, selectable either with or without undervoltage supervision

3 Design

3.1 Connections

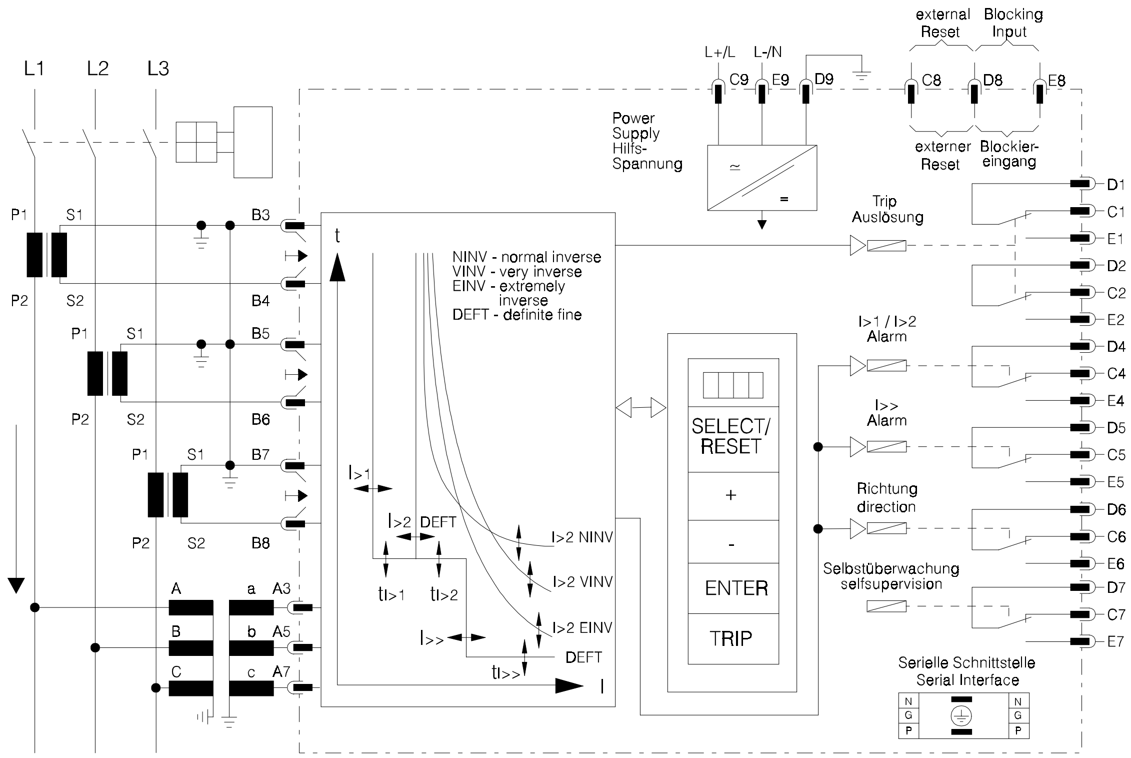


Figure 3.1: Anschlußbild

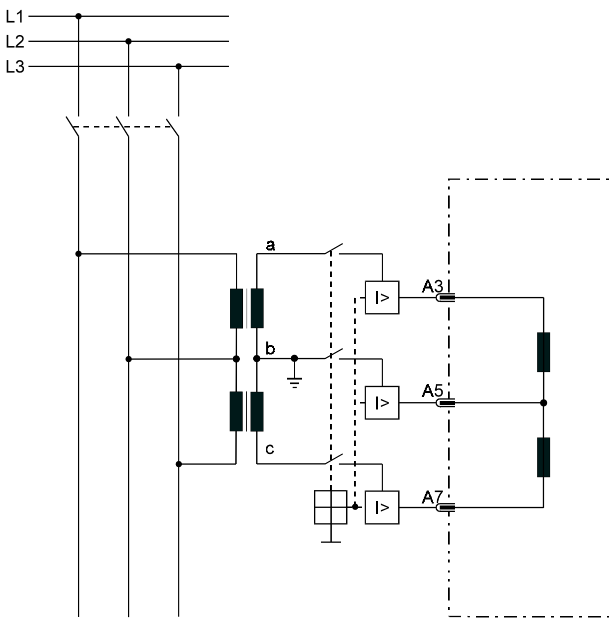


Figure 3.2: Voltage transformer in V-connection for the directional detection at overcurrent and short-circuit protection.

3.1.1 Analog input circuits

The protection unit receives the analog input signals of the phase currents I_{L1} (B3-B4), I_{L2} (B5-B6), I_{L3} B7-B8 and phase voltages U_1 (A3), U_2 (A5), U_3 (A7) each via separate input transformers.
The phase voltages can be applied in V-connection alternatively according to Figure 3.2.
The constantly detected current and voltage measuring values are galvanically decoupled, filtered and finally fed to the analog/digital converter.

3.1.2 Output relays

The *MRI1-IN* has five output relays. One output relay with two change-over contacts is employed for tripping, the other relays each with one change-over contact for alarm.

- Tripping output relay C1, D1, E1, C2, D2, E2
- Low set overcurrent alarm relay (I>) C4, D4, E4
- High set overcurrent alarm relay (I>>) C5, D5, E5
- Directional detection C6, D6, E6
- Self-supervision alarm relay C7, D7, E7

All trip and alarm relays are working current relays, the relay for self supervision is an idle current relay.

3.1.3 Blocking input

By applying the aux. voltage to D8/E8 all trip functions are blocked. Pickup and directional features are still indicated by LEDs. The alarm relays will not be blocked.

3.1.4 External reset input

See chapter 5.4

3.2 Front plate

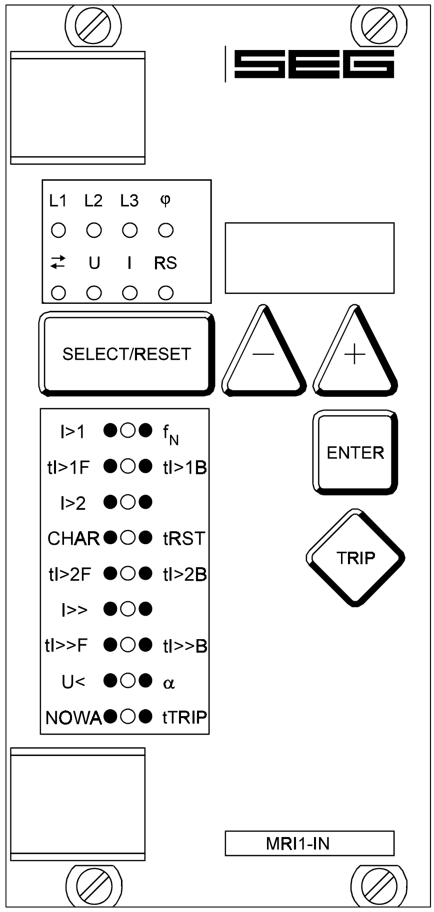


Figure 3.3: Frontplatte MRI1-IN

All LEDs are two-coloured. LEDs left to the alphanumerical display light-up green during measuring and red at an alarm. LEDs U and I are used for measuring and light up green.

LEDs underneath the push button <SELECT/RESET> light-up green during setting and inquiry of the setting values printed left to the LEDs. They light-up red when the setting values printed at the right to the LEDs are activated.

The LED marked with letters RS lights up yellow during setting of the slave address for serial data communication.

4 Working principle

4.1 Analog circuits

The incoming currents from the main current transformers on the protected object are converted to voltage signals in proportion to the currents via the input transformers and burden. The noise signals caused by inductive and capacitive coupling are supressed by an analog R-C filter circuit.

The analog voltage signals are fed to the A/D-converter of the microprocessor and transformed to digital signals through Sample- and Hold-circuits. The analog signals are sampled at 50 Hz (60 Hz) with a sampling frequency of 800 Hz (960 Hz), namely, a sampling rate of 1.25 ms (1.04 ms) for every measuring quantity.

4.2 Digital circuits

The essential part of the *MRI1* relay is a powerful microcontroller. All of the operations, from the analog digital conversion to the relay trip decision, are carried out by the microcontroller digitally. The relay program is located in an EPROM (Electrically-Programmable-Read-Only-Memory). With this program the CPU of the microcontroller calculates the three phase currents and ground current in order to detect a possible fault situation in the protected object.

For the calculation of the current value an efficient digital filter based on the Fourier Transformation (DFFT - Discrete Fast Fourier Transformation) is applied to suppress high frequency harmonics and DC components caused by fault-induced transients or other system disturbances. The calculated actual current values are compared with the relay settings. If a phase current exceeds the pickup value, an alarm is given and after the set trip delay has elapsed, the corresponding trip relay is activated.

The relay setting values for all parameters are stored in a parameter memory (EEPROM - Electrically Erasable Programmable Read-only Memory), so that the actual relay settings cannot be lost, even if the power supply is interrupted.

The microprocessor is supervised by a built-in "watchdog" timer. In case of a failure the watchdog timer resets the microprocessor and gives an alarm si-gnal, via the output relay "self supervision".

4.3 Directional feature

A built-in directional element in *MRI1* is available for application to doubly infeeded lines or to ring networks.

The measuring principle for determining the direction is based on phase angle measurement and therefore also on coincidence time measurement between current and voltage. Since the necessary phase voltage for determining the direction is frequently not available in the event of a fault, whichever line-to-line voltage follows the faulty phase by 90° is used as the reference voltage for the phase current.
The characteristic angle at which the greatest measuring sensitivity is achieved can be set to precede the reference voltage in the range from 0° to 355°.

The TRIP region of the directional element is determined by rotating the phasor on the maximum sensitivity angle for ± 90°, so that a reliable direction decision can be achieved in all faulty cases.

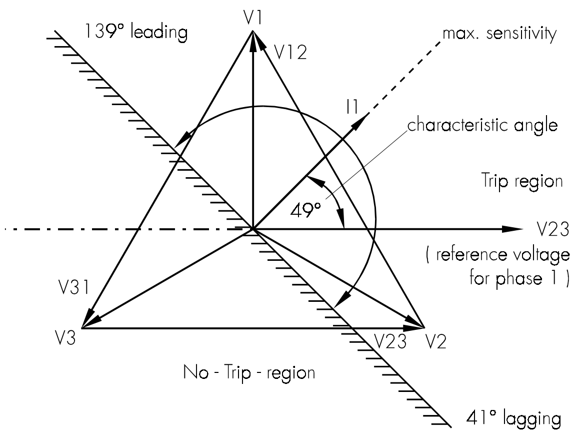


*Figure 4.1: TRIP/NO-TRIP region for directional element in **MRI1-IN** (directional measuring in phase 1)*

By means of accurate hardware design and by using an efficient directional algorithm a high sensitivity for the voltage sensing circuit and a high accuracy for phase angle measurement are achieved so that a correct directional decision can be made even by close three-phase faults.

As an addition, to avoid maloperations due to disturbances, at least two periods (40 ms at 50 Hz) are evaluated.

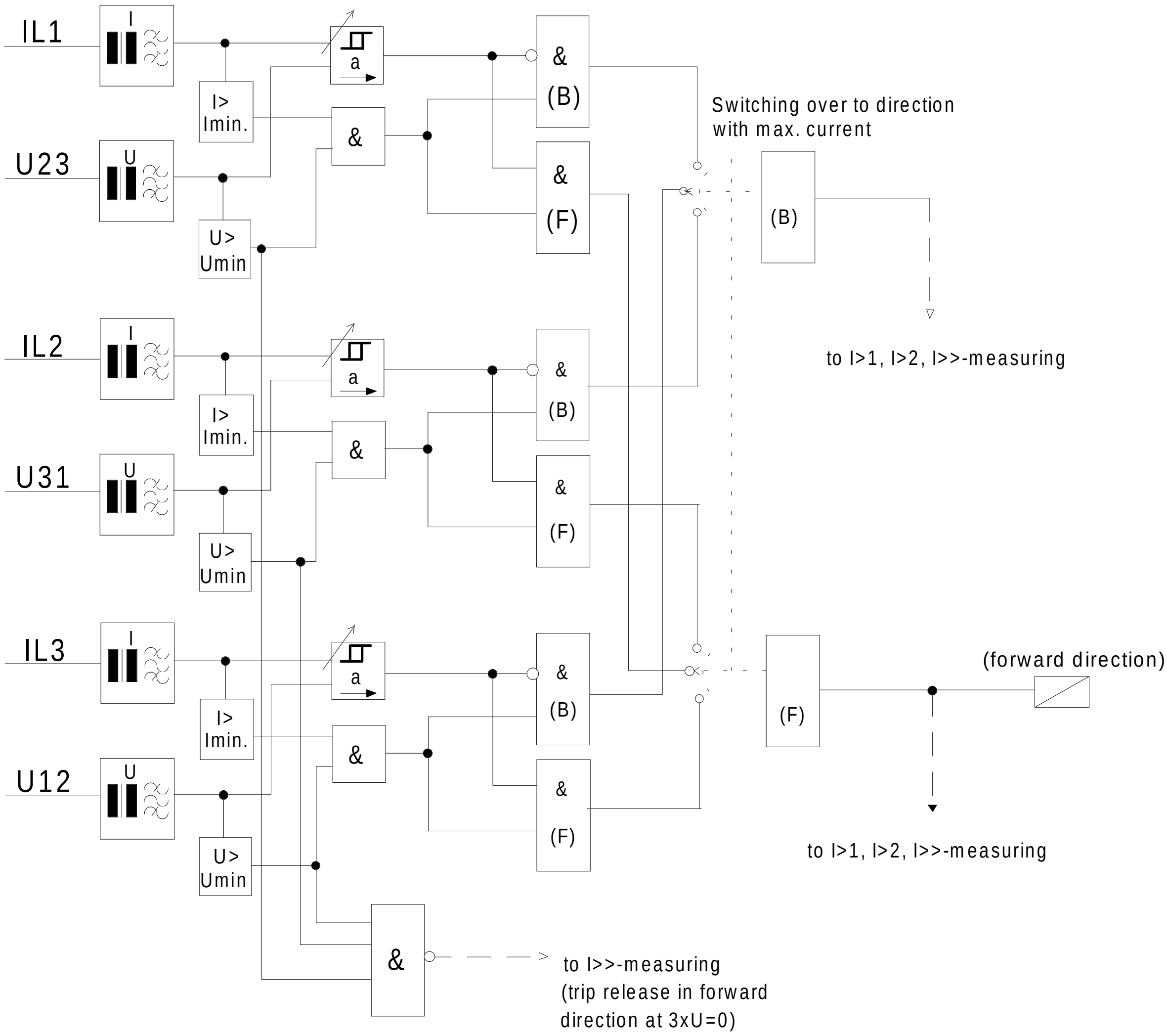


Figure 4.2: Block diagram direction detection

Die Meßgrößen I und U müssen mindestens im Bereich der unteren Einstellgrenzen des Gerätes liegen, damit eine zuverlässige Messung erfolgen kann. Sind diese Kriterien erfüllt, so erfolgt die Richtungsentscheidung über die Auswertung des Winkels zwischen Strom und Spannung, wobei die Phase mit dem höchsten Strom ausschlaggebend ist. Ist die Phasenspannung bei einem nahen Kurzschluß zu gering, wird die Kurzschlußstufe auf Vorwärtsfehler umgeschaltet.

4.4 Demand imposed on the main current transformers

The current transformers have to be rated in such a way, that a saturation should not occur within the following operating current ranges:

Independent time overcurrent function: K1 = 2
Inverse time overcurrent function: K1 = 20
High-set function: K1 = 1.2 - 1.5
K1 = Current factor related to set value
Moreover, the current transformers have to be rated according to the maximum expected short circuit current in the network or in the protected objects.
The low power consumption in the current circuit of *MRI1-IN*, namely <0,2 VA, has a positive effect on the selection of current transformers. It implies that, if an electromechanical relay is replaced by *MRI1-IN*, a high accuracy limit factor is automatically obtained by using the same current transformer
.

5 Operation and setting

5.1 Display and LEDs

5.1.1 Display

Function	Display shows	Pressed pushbutton	Corresponding LED
Normal operation:	|SEG		
Measured operating values: Voltage U_{12}, U_{23}, U_{31} Currents I_{L1}, I_{L2}, I_{L3} Phase angel φ_1, φ_2, φ_3	actual current measured values related to I_N; Voltages in volt and angle in °	<SELECT/RESET> one time for each value	I ,U ,φ, L1, L2, L3
Measuring range overflow	max.	<SELECT/RESET>	L1, L2, L3
Setting values:	Current and time settings	<SELECT/RESET> one time for each parameter	I>1; I>2; I>>; tI>1F; tI>1B; I>2F; tI>2B; tI>>F; tI>>B
Time current characteristics for phase overcurrent element (CHAR)	DEFT/NINV/VINV/ EINV	<SELECT/RESET> <+> <->	
Reset setting (only available at in-verse time characteristic	0s / 60s	<SELECT/RESET> <+> <->	t_{RST}
Relay characteristic angle for phase current directional feature	RCA in degree (°)	<SELECT/RESET> <+> <->	α
Undervoltage pickup value	Voltage in volt	<+> <-><SELECT/RESET>	U<
Warning reverse direction no warning warning	 NOWA WBAK	<SELECT/RESET>	LED →←(red) + I>
Nominal frequency	f = 50 / f = 60	<+> <-><SELECT/RESET>	f_N
Dwell time	auto / 200	<SELECT/RESET> <+> <->	t_{TRIP}
Blocking of function	EXIT	<+> until max. setting value	LED of blocked parameter
Slave address for serial interface	1-32	<+> <-><SELECT/RESET>	RS
Recorded fault data	Tripping currents and other fault data	<SELECT/RESET> one time for each phase	L1, L2, L3, I, U, φ I>1, I>2, I>>
Save parameter?	SAV?	<ENTER>	
Save parameter!	SAV!	<ENTER> for about 3 s	
Software version	First part (e.g D01-) Sec. part (e.g. 8.00)	<TRIP> one time for each part	
Manual trip	TRI?	<TRIP> three times	
Inquire password	PSW?	<TRIP><ENTER>	
Relay tripped	TRIP	<TRIP> or after fault tripping	
Secret password input	„XXXX"	<+><-> <ENTER> <SELECT/RESET>	
System reset	|SEG	<SELECT/RESET> for about 3 s	

Table 5.1: Possible indication messages on the display

See chapter 5.2.14

5.1.2 LED indications

LED	light up at	LED-color	LED-display	Function
L1, L2, L3, I	Indication of current measuring	green (L1-L3), yellow (I)	continuous	Current measuring in all phases
L1, L2, L3, U	Indication of voltage measuring	green (L1-L3), yellow (U)	continuous	Voltage measuring in all phases e.g. LED U+L1+L2 shows U12
L1, L2, L3, φ	Indication of phase angle	green (L1-L3), green (φ)	continuous	Phase angle between current and voltage, e.g. LED φ+L1 shows angle between U1 and IL1. (Impedance angle; do not mix-up with α!)
L1, L2, L3	Pickup	red	flashing	Pickup of a supervision circuit
L1, L2, L3	Tripping	red	continuous	Tripping
→←	Direction indication	green	continuous	Current flow in vorward direction
→←	Direction indication	red	continuous	Current flow in reverse direction
RS	Setting	yellow	continuous	Adjustment of slave address
I>1	Setting	green	continuous	Overcurrent setting I>1
I>1	Pickup	red	flashing	Overcurrent pickup I>1
I>1	Tripping	red	continuous	Overcurrent tripping I>1
tI>1F	Setting	green	continuous	Trip delay tI>1F
tI>1B	Setting	red	continuous	Trip delay tI>1B
I>2	Setting	green	continuous	Overcurrent setting I>2
I>2	Pickup	red	flashing	Overcurrent pickup I>2
I>2	Tripping	red	continuous	Overcurrent tripping I>2
CHAR	Setting	green	continuous	Setting of tripping characteristic
tRST	Setting	red	continuous	Reset mode for inverse time charac-teristics
tI>2F	Setting	green	continuous	Trip delay tI>2F
tI>2B	Setting	red	continuous	Trip delay tI>2B
I>>	Setting	green	continuous	High set overcurrent setting I>>
I>>	Pickup	red	flashing	High set overcurrent pickup I>>
I>>	Tripping	red	continuous	High set overcurrent tripping I>>
tI>>F	Setting	green	continuous	Trip delay tI>>F
tI>>B	Setting	red	continuous	Trip delay tI>>B
U<	Setting	green	continuous	Undervoltage setting U<
U<	Pickup	red	flashing	Undervoltage pickup U<
U<	Tripping	red	continuous	Undervoltage tripping U<
α	Setting	red	continuous	Characteristic angle
NOWA	Setting	green	continuous	Blocking /no blocking at faults in reverse direction
f_N	Setting	red	continuous	Rated frequency setting
tTRIP	Setting	red	continuous	Dwell time

Table 5.2: LED indication

F = Forward
B = Backward

5.2 Setting procedure

After push button <SELECT/RESET> has been pressed, always the next measuring value is indicated. Firstly the operating measuring values are indicated and then the setting parameters. By pressing the <ENTER> push button the setting values can directly be called up and changed.
For parameter setting a password has to entered first. (Please refer to 4.4 of description „*MR*-Digital Multifunctional Relays")

5.2.1 Pickup value for the sensitive overcurrent element (I>1)

When setting the pickup value for the sensitive overcurrent element, a value referring to the rated current I_N is shown on the display. The following applies: I>> = value displayed x rated current I_N
The sensitive overcurrent element I> can be adjusted in the range 0.005 - 0.25 x I_N

5.2.2 Trip delay for the sensitive overcurrent element ($t_{I>1F/B}$)

The trip delay for the sensitive overcurrent element I>1 can be adjusted in the time range 0.1 - 260 s separately for forward and backward faults.
tI>1F - trip delay for forward faults
tI>1B - trip delay for backward faults
If tripping for backward faults is not requested, it can be blocked by adjusting the trip delay tI>1B to EXIT.

5.2.3 Pick-up value for the standard overcurrent element (I>2)

The standard overcurrent element (I>2) can be adjusted from 0.5 - 2 x I_N.

5.2.4 Time current characteristics for phase overcurrent element (CHAR)

By setting this parameter, one of the following 4 messages appears on the display:

DEFT - Definite Time
NINV - Normal Inverse
VINV - Very Inverse
EINV - Extremely Inverse

Anyone of these four characteristics can be chosen by using <+> <->-pushbuttons, and can be stored by using <ENTER>-pushbutton.

5.2.5 Reset setting for inverse time tripping characteristics in the phase current path (t_{RST})

To ensure quick tripping, even with recurring fault pulses shorter than the set trip delay, the reset mode for inverse time tripping characteristics can be switched over.
If the adjustment tRST is set at 60s, the tripping time is only reset after 60s faultless condition.
This function is not available if tRST is set to 0. With fault current break the trip delay is reset immediately and started again at recurring fault current.

5.2.6 Trip delay or time factor for the standard overcurrent element ($t_{I>2F/B}$)

The trip delay for the standard overcurrent element can be adjusted in the time range 0.1 - 260 s separately for forward and backward faults (definite time tripping characteristic). For the inverse tripping characteristic the adjustment range for forward and backward faults tI> is 0.07 - 20. The wide setting range of the time factor tI> up to 20 makes setting of long-term tripping characteristics possible.

If the trip delay for backward faults is set longer than the one for forward faults, the protective relay works as a "backup"-relay for the other lines on the same busbar. This means that the relay can clear a fault in the backward direction with a longer time delay in case of refusal of the relay or the circuit breaker on the faulted line.
In order to avoid an unsuitable arrangement of relay modes due to carelessness of the operator, the following precautions are taken:

After change of the trip characteristic, LEDs for trip delay and time multiplier setting (tI>2F/B) light up. This warning signal indicates to the operator that he has to adjust the trip delay or time multiplier to the changed operational mode or trip characteristic. The LEDs keep flashing until the trip delay or time multiplier have been readjusted. If readjustment has not been done within 5 minutes (time allowed for setting of parameters), trip delay and time factor are set automatically to the lowest pickup value (shortest possible trip delay) by the processor. When setting the trip characteristic to "Definite Time", the definite time is shown as seconds on the display (e.g. 0.35 = 0.35s). This indication can be changed step-by-step with keys <+><->. When setting to inverse time, the time factor is displayed. This too can be changed step-by-step with keys <+><->.

If the trip delay or time factor is set to infinity (on the display "EXIT" is shown), tripping of relay element I>2F or I>2B is blocked, but the WARN relay remains activated.

By setting the trip delay, the actual set value for forward faults appears on the display first and the LED under the arrows is alight green. It can be changed with push button <+> <-> and then stored with push button <ENTER>. After that, the actual trip delay (or time multiplier) for backward faults appears on the display by pressing push button <SELECT/RESET> and the LED under the arrows is alight red.

Usually this set value should be set longer than the one for forward faults, so that the relay obtains its selectivity during forward faults. If the time delays are set equally for both forward and backward faults, the relay trips in both cases with the same time delay, namely without directional feature.

If the time delay for backward faults is set out of range ("EXIT" on the display) and additional"NOWA" is adjusted the relay does not trip at backward faults, namely, the relay is blocked for backward faults.

Note:
When selecting dependent tripping characteristics at relays with directional phase current detection, attention must be paid that a clear directional detection will be assured only after expiry of 40 ms.

5.2.7 Current setting for high set element (I>>)

The current setting value of this parameter appearing on the display is related to the nominal current of the relay
This means: I>> = displayed value x I_N.

The high set element I>> can be adjusted form 0.5 - 16 x I_N.
When the current setting for high set element is set out of range (on display appears "EXIT"), the high set element of the overcurrent relay is blocked.
The high set element can be blocked via terminals E8/D8 (refer to connection diagram).

5.2.8 Trip delay for high set element (tI>>F/B)

The trip delay for the high set element I>> is always independent. On the display a time value (seconds) is shown.
The setting procedure for forward and backward fault outlined under 5.2.6 does also apply for the trip delay of the high set element.

5.2.9 Undervoltage release (U<) of the overcurrent supervision (I>2)

When directional overcurrent relays are used for mains decoupling not only an information on overcurrent and load flow direction is requested but also on undervoltage so that uncritical load flow changes and severe system failures can be considered differently. To realize this, the overcurrent element I>2 can be combined with release of the undervoltage U<. The overcurrent element I>2 trips only if at least one of the three voltages are below the set undervoltage release value U<. If undervoltage relase is not needed, it can be blocked by EXIT.

5.2.10 Characteristic angle (α)

The characteristical angle for directional determination can be set in a range from 0° - 355° by parameter α, advancing the respective reference voltage. (See chapter 4.3).

5.2.11 NOWA/WBAK- adjustment

There is possibility to inhibit the alarm relay in case of a fault in reverse direction. With pushbutton <SELECT> the corresponding menu point is reached. The display shows either the character "NOWA" - no alarm when afault occurs in reverse direction or "WBAK" - alarm relay is energized when a fault occurs in reverse direction. The setting is accomplished by pressing pushbuttons <+> or <-> and is stored with <ENTER>.

5.2.12 Dwell time

To prevent that the C.B. trip coil circuit is interrupted by the *MRI1-IN* first, i.e. before interruption by the C.B. auxiliary contact, the dwell time can be set by parameter tTRIP = 200.
This setting ensures that the *MRI1-IN* remains in self holding for 200ms after the fault current is interrupted.
If tTRIP is set to AUTO, the trip element of the *MRI1-IN* is reset immediately after the fault current is switched off
(Provided that coding is accordingly; see chapter 4.2 in technical description *MR* - Digital Multifunctional Relays).

5.2.13 Nominal frequency (f_N)

The adapted FFT-algorithm requires the nominal frequency as a parameter for correct digital sampling and filtering of the input currents.
By pressing <SELECT> the display shows "f=50" or "f=60". The desired nominal frequency can be adjusted by <+> or <-> and then stored with <ENTER>.

5.2.14 Adjustment of the slave address

By pressing <SELECT/RESET> the display shows the slave address. LED "RS" lights up. The slave address can be adjusted from 1 - 32 by push buttons <+> and <–>.

5.3 Measured value indication

The following measuring quantities can be indicated on the display during normal service:

- Apparent current in phase 1 (LED L1 green and I yellow)
- Apparent current in phase 2 (LED L2 green and I yellow)
- Apparent current in phase 3 (LED L3 green and I yellow)
- Voltage U12 (LED U yellow and L1+L2 green)
- Voltage U23(LED U yellow and L2+L3 green)
- Voltage U31(LED U yellow and L1+L3 green)
- Impedance angle (e.g. LEDs φ + L1 show the impedance angle between U1 and IL1).

The measured current values shown on the display refer to the rated current.
The measured voltage values are shown in "volts".
Parameters of the impedance angle are always shown with a + or - sign (e.g. -60° in L1 means the I_{L1} lags voltage U_1 by 60°.

5.4 Reset

Unit *MRI1* has the following three possibilities to reset thedisplay of the unit as well as the output relay at jumper position J3=ON.

Manual Reset
- Pressing the pushbutton <SELECT/RESET> for some time (about 3 s)

Electrical Reset
- Through applying auxiliary voltage to C8/D8

Software Reset
- The software reset has the same effect as the <SELECT/RESET> pushbutton (see also communication protocol of RS485 interface).

The display can only be reset when the pickup is not present anymore (otherwise "TRIP" remains in display).

During resetting of the display the parameters are not affected.

5.5 Setting value calculation

5.5.1 Sensitive definite time overcurrent protection

Overcurrent element (I>1)
For setting the sensitive overcurrent pick-up value, the maximal permissible current taken from the mains during generator parallel operation is the main criterion.

5.5.2 Definite time overcurrent element

Low set element (I>2)
The pickup current setting is determined by the load capacity of the protected object and by the smallest fault current within the operating range. The pickup current is usually selected about 20% for power lines, about 50% for transformers and motors above the maximum expected load currents.
The delay of the trip signal is selected with consideration to the demand on the selectivity according to system time grading and overload capacity of the protected object.

High set element I>>
The high set element is normally set to act for near-by faults. A very good protective reach can be achieved if the impedance of the protected object results in a well-defined fault current. In case of a line-transformer combination the setting values of the high set element can even be set for the fault inside the transformer.
The time delay for high set element is always independent to the fault current.

5.5.3 Inverse time overcurrent element

Time multiplier setting
The time multiplier setting for inverse time overcurrent is a scale factor for the selected characteristics. The characteristics for two adjacent relays should have a time interval of about 0.3 - 0.4 s.

Low set element (I>2)
Apart from the tripping characteristic, a pickup value for the phase current path is adjusted. The current measuring value shown on the display refers to the rated current.
The pickup current is determined according to the maximum expected load current. For example:

Current transformer ratio: 400/5A
Maximum expected load current: 300A
Overload coefficient: 1.2 (assumed)
Starting current setting:
$Is = (300/400) \times 1.2 = 0.9 \times I_N$

High set element I>>
The high set current setting is set as a multiplier of the nominal current. The time delay tI>> is always independent to the fault current.

6 Relay testing and commissioning

The test instructions following below help to verify the protection relay performance before or during commissioning of the protection system. To avoid a relay damage and to ensure a correct relay operation, be sure that:

- the auxiliary power supply rating corresponds to the auxiliary voltage on site.
- the rated current and rated voltage of the relay correspond to the plant data on site.
- the current transformer circuits and voltage transformer circuits are connected to the relay correctly.
- all signal circuits and output relay circuits are connected correctly.

6.1 Power-On

NOTE!
Prior to switch on the auxiliary power supply, be sure that the auxiliary supply voltage corresponds with the rated data on the type plate.

Switch on the auxiliary power supply to the relay and check that the message "ISEG" appears on the display and the self supervision alarm relay (watchdog) is energized (Contact terminals D7 and E7 closed).

6.2 Testing the output relays and LEDs

NOTE!
Prior to commencing this test, interrupt the trip circuit to the circuit breaker if tripping is not desired.
By pressing the pushbutton <TRIP> once, the display shows the first part of the software version of the relay (e.g. „D08-“). By pressing the pushbutton <TRIP> twice, the display shows the second part of the software version of the relay (e.g. „4.01“). The software version should be quoted in all correspondence. Pressing the <TRIP> button once more, the display shows "PSW?". Please enter the correct password to proceed with the test. The message "TRI?" will follow. Confirm this message by pressing the pushbutton <TRIP> again. All output relays and LEDs should then be activated and the self supervision alarm relay (watchdog) be deactivated one after another with a time interval of 3 second. Thereafter, reset all output relays back to their normal positions by pressing the pushbutton <SELECT/RESET> (about 3 s).

6.3 Checking the set values

By repeatedly pressing the pushbutton <SELECT>, all relay set values may be checked. Set value modification can be done with the pushbutton <+><-> and <ENTER>. For detailed information about that, please refer to chapter 5.
For a correct relay operation, be sure that the frequency set value (f=50/60) has been selected according to your system frequency (50 or 60 Hz).

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter, Ammeter with class 1 or better
- Auxiliary power supply with the voltage corresponding to the rated data on the type plate
- Single-phase current supply unit (adjustable from 0 to ≥ 4 x In)
- Single-phase voltage supply unit (adjustable from 0 to ≥ 1.2 x Un)
- Timer to measure the operating time (Accuracy class ≤ ±10 ms)
- Switching device
- Test leads and tools

6.4.2 Test circuit

Figure 6.1: Test circuit

For testing the *MRI1-IN* it is necessary to have current and voltage sources where the phase position can be adjusted. In Figure 6.1 a single-phase test circuit is shown with adjustable current and voltage source. During the test procedure one of the input parameters (current or voltage) should be kept stable and in terms of value and phase the other one to be adjusted accordingly. The internal phase angle of the *MRI1-IN* between current and voltage used for the directional evaluation is 90°. The following table shows the input currents and associated reference voltages (see chapter 4.3).

Current input	Reference voltage
I1	U23
I2	U31
I3	U12

Table 6.1: Current and corresponding reference voltages

If the single-phase current source is connected to terminals B3/B4 (phase 1) - as shown in Figure 6.1, the voltage source has to be connected to the corresponding voltage inputs A5/A7. The sensitivity for directional phase detection can be adjusted between 0° and 355° and so the highest sensitivity can be achieved at setting 45°, i.e. when the input current advances the input voltage by 45°. So the tripping range at this setting in forward direction is 135° advancing to 45° lagging if the fringe ranges are neglected due to the inaccuracy of measurement.

For testing the directional detection a test voltage identical to the rated voltage is connected to terminals A5/A7 and a current of at least 0.005 x I_N impressed upon the current inputs B3/B4. Now the voltage or current phase angle can be changed in order to test the tripping range of the relay. When changing the phase angle, the directional change is indicated by colour changing of the associated LED (green for forward direction and red for reverse direction).

Tripping of the relay can be prevented during this procedure by setting the trip delay for forward and backward direction to EXIT. For check purposes the trip delay for forward and backward has to be set differently because there is only one trip relay for both directions.

Special attention must be paid to the right polarity of test current and test voltage. As shown in Figure 6.1 the polarity of the test sources and connection terminals is marked with a *. When the current and voltage sources are connected according to this test circuit, the *MRI1-IN* trips if the current advances the voltage by 45° and the characteristical angle is set to highest sensitivity. Irrespectively of the polarity, the current must be higher than the set pickup value.

6.4.3 Checking the input circuits and measured values

Inject a current, which is less than the relay pickupcurrent set values, in phase 1 (terminals B3-B4), and check the measured current on the display by pressing the pushbutton <SELECT>. For a relay with rated current In = 5A, for example, a secondary current injection of 1A should be indicated on the display with about 0.2 (0.2 x In). The current can be also injected into the other current input circuits (Phase 2: terminals B5-B6, Phase 3: terminals B7-B8, Earth current: terminals B1-B2) in the same manner. Compare the displayed current value with the reading of the ammeter. The deviation must not exceed 5%. By using an RMS-metering instrument, a greater deviation may be observed if the test current contains harmonics. Because the *MRI1-IN* relay measures only the fundamental component of the input signals, the harmonics will be rejected by the internal DFFT-digital filter. Whereas the RMS-metering instrument measures the RMS-value of the input signals.

6.4.4 Checking the operating and resetting values of the relay

Inject a current which is less than the relay set values in phase 1 of the relay and gradually increase the current until the relay starts, i.e. at the moment when the LED I> and L1 light up or the alarm output relay I> is activated as well as to apply an equivalent reference voltage. The current in trip direction is only increased until the relay is energized. Read the operating current indicated by the ammeter. The deviation must not exceed 5% of the set operating value.

Furthermore, gradually decrease the current until the relay resets, i.e. the alarm output relay I> is disengaged. Check that the resetting current is smaller than 0.97 times the operating current.
Repeat the test on phase 2, phase 3 and earth current input circuits in the same manner.

6.4.5 Checking the relay operating time

To check the relay operating time, a timer must be connected to the trip output relay contact. The timer should be started simultaneously with the current injection in the current input circuit and stopped by the trip relay contact. Set the current to a value corresponding to twice the operating value and inject the current instantaneously. The operating time measured by the timer should have a deviation of less than 3% of the set value or ±10 ms at definite time tripping characteristic (Accuracy at inverse time tripping characteristics refer to IEC 255 part 3).
Repeat the test on the other phases or with the inverse time characteristics in the similar manner.
In case of inverse time characteristics the injected current should be selected according to the characteristic curve, e.g. two times I_S. The tripping time may be red from the characteristic curve diagram or calculated with the equations given under "technical data".
Please observe that during the secondary injection test the test current must be very stable, not deviating more than 1%. Otherwise the test results may be wrong.

6.4.6 Checking the high set element of the relay

Set a current above the set operating value of I>>. Inject the current instantaneously and check that the alarm output relay I>> (contact terminals D5/E5) operates. Check the tripping time of the high set element according 6.4.5.

Check the accuracy of the operating current setting by gradually increasing the injected current until the I>> element picks up. Read the current value form the ammeter and compare with the desired setting.

Repeat the entire test on other phases and earth current input circuits in the same manner.

Note !
Where test currents >4 x I_N are used, the thermal withstand capability of the current paths has to be considered (see technical data, chapter 7.1).

6.4.7 Checking the external blocking and reset functions

The external blocking input inhibits the function of the high set element of the phase current. To test the blocking function apply auxiliary supply voltage to the external blocking input of the relay (terminals E8/D8). Thereafter a current has to be injected which normally causes the protection functions to trip (e.g. I>1). At the time the associated alarm relay energizes, the trip relay must not trip.
Remove the auxiliary supply voltage from the blocking input. Inject a test current to trip the relay (message „TRIP" on the display). Interrupt the test current and apply auxiliary supply voltage to the external reset input of the relay (terminals C8/D8). The display and LED indications should be reset immediately.

6.5 Primary injection test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test described above. With the difference that the protected power system should be, in this case, connected to the installed relays under test „on line", and the test currents and voltages should be injected to the relay through the current and voltage transformers with the primary side energized. Since the cost and potential hazards are very high for such a test, primary injection tests are usually limited to very important protective relays in the power system.

Because of its powerful combined indicating and measuring functions, the *MRI1-IN* relay may be tested in the manner of a primary injection test without extra expenditure and time consumption.
At the *MRI1-IN* it is also possible to display the voltages and individual impedance angles.

6.6 Maintenance

Maintenance testing is generally done on site at regular intervals. These intervals vary among users depending on many factors: e.g. the type of protective relays employed; the importance of the primary equipment being protected; the user's past experience with the relay, etc.

For electromechanical or static relays, maintenance testing will be performed at least once a year according to the experiences. For digital relays like *MRI1-IN*, this interval can be substantially longer. This is because:

- the *MRI1-IN* relays are equipped with very wide self-supervision functions, so that many faults in the relay can be detected and signalized during service. Important: The self-supervision output relay must be connected to a central alarm panel!
- the combined measuring functions of *MRI1-IN* relays enable supervision the relay functions during service.
- the combined TRIP test function of the *MRI1-IN* relay allows to test the relay output circuits.

A testing interval of two years for maintenance will, therefore, be recommended.
During a maintenance test, the relay functions including the operating values and relay tripping characteristics as well as the operating times should be tested.

7 Technical data

7.1 Measuring input circuits

Rated data:	Nominal current I_N	1A or 5A
	Nominal voltage U_N	100 V, 230 V, 400 V
	Nominal frequency f_N	50/60 Hz adjustable
Power consumption in:	at I_N = 1 A	<0.12 VA
current circuit	at I_N = 5 A	<0.12 VA
Power consumption in voltage circuit:	<1 VA	
Thermal withstand capability in current circuit:	dynamic current withstand	
	(half-wave)	250 x I_N
	for 1 s	100 x I_N
	for 10 s	30 x I_N
	continuously	4 x I_N
Thermal withstand in voltage circuit:	continuously	1.5 x U_N

7.2 Common data

Dropout to pickup ratio:	> 97 %
Returning time:	50 ms
Time lag error class index E:	± 10 ms
Minimum operating time:	60 ms
Transient overreach at instantaneous operation:	≤ 5 %

Influences on the current measurement

Auxiliary voltage:	in the range of $0.8 < U_H / U_{HN} < 1.2$ no additional influences can be measured
Frequency:	in the range of $0.9 < f / f_N < 1.1$; < 0.2 % / Hz
Harmonics:	up to 20 % of the third harmonics; < 0.08 % per percent of the third harmonic up to 20 % of the fifth harmonic; < 0.07 % per percent of the fifth harmonic
Influences on delay time:	no additional influences can be measured

7.3 Setting ranges and steps

7.3.1 Time overcurrent protection

Function	Parameter	Setting range	Step	Tolerance
Overcurrent 1 (sensitive)	I>1	0.5%…25% I_N	0.1%; 0.2%; 0.5%; 1%	±5% from set value or ±0,2% x In
	tI>1F tI>1B	0.1…260s 0.1…260s	0.02s; 0.05s; 0.1s; 0.2s; 0.5s; 1s; 2s; 5s; 10s; 20s	±3% or ±20ms
Overcurrent 2 (normal)	I>2	50%…200% I_N	2%; 5%	±5% from set value or ±0,2% x In
	CHAR	DEFT; NINV VINV; EINV		
	tI>2F; tI>2B	0.1…260s (DEFT) 0.07…20 (Inverse time)	0.02s; 0.05s; 0.1s; 0.2s; 0.5s; 1s; 2s; 5s; 10s; 20s 0.01; 0.02; 0.05; 0.1; 0.2; 0.5	±3% or ±20ms
High set element	I>>	0,5…16xI_N	0.02; 0.05; 0.1; 0.2; 0.5 x In	±5% from set value
	tI>>	0.1…2.0s	0.02; 0.05; 0.1s	±3% or ±20ms
Undervoltage	U<	Un=100V: 2…150V Un=230V: 2…340V Un=400V: 5…600V (EXIT= no undervoltage release)	1V 2V 5V	±5% from set value
Characteristic angle	α	0°…355° (I lags before U_{Ref})	5°	±3°
Blocking at backward faults	NOWA	NOWA WBAK		
Reset-Mode	tRST	0 s / 60 s		
Dwell time	tTRIP	„auto"/"200"		
Rated frequency	f_N	50/60Hz		

Table 7.1:Setting ranges and graduation

7.3.2 Inverse time overcurrent protection relay

According to IEC 255-4 or BS 142

Normal Inverse

$$t = \frac{0.14}{\left(\frac{I}{Is}\right)^{0.02} - 1} t_I > [s]$$

Very Inverse

$$t = \frac{13.5}{\left(\frac{I}{Is}\right) - 1} t_I > [s]$$

Extremely Inverse

$$t = \frac{80}{\left(\frac{I}{Is}\right)^{2} - 1} t_I > [s]$$

Where:

t	=	tripping time
t_I>	=	time multiplier
I	=	fault current
Is	=	Starting current

7.3.3 Direction unit

Circuit:	90°
Characteristic angle α:	0 - 355°
Pickup limit of the directional elements:	
theoretical pickup limit:	±90°
Tolerance of the pick-up limit:	±3° der theoretischen Ansprechgrenze
Returning angle of the pickup limit at rated voltage and current:	<±3°
Sensitivity:	At measuring voltages >0.35 % U_N and currents > setting value, a forward fault can be identified at the characteristical angle.
Stability of the directional decision:	At measuring voltages <0.35 % U_N all directional elements are blocked and the high set element I>> trips when the set value in forward direction is exceeded.

Technical data subject to change without notice!

7.4 Inverse time characteristics

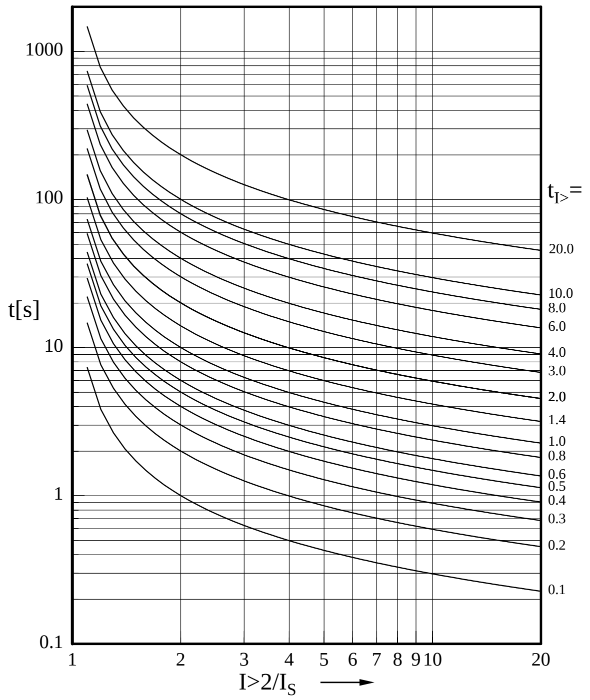


Figure 7.1: Normal Inverse I>2/I_S

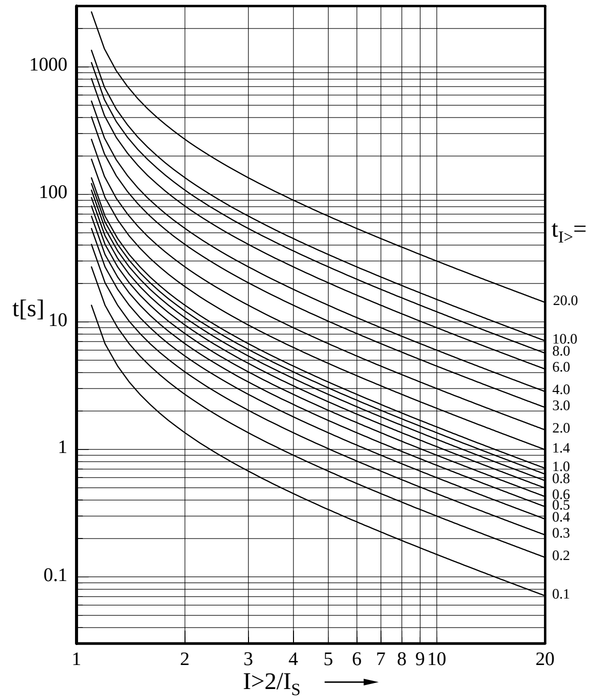


Figure 7.3: Very Inverse I>2/I_S

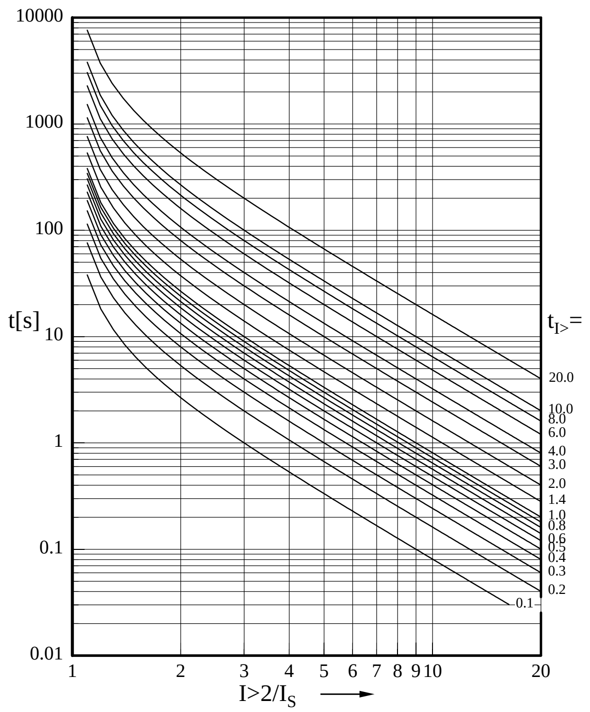


Figure 7.2: Extremely Inverse I>2/I_S

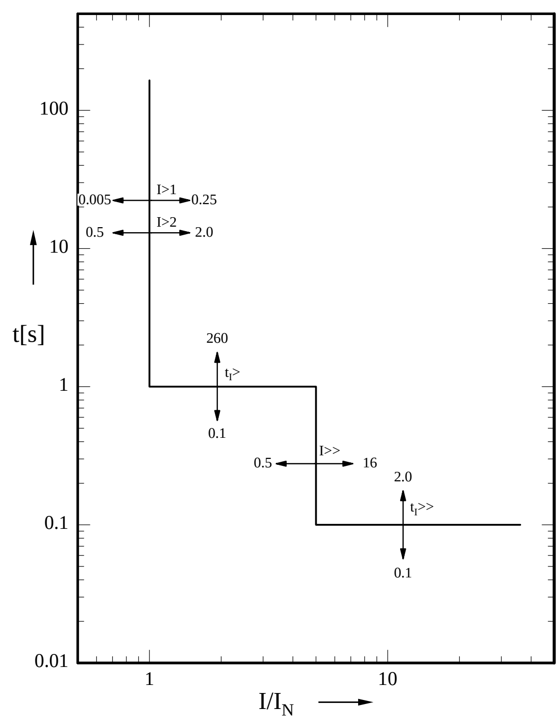


Figure 7.4: Definite time overcurrent relay

NINV, VINV and EINV apply for I>2 settings,
DEFT for all elements (I>1, I>2 and I>>)

8 Order form

Sensitive directional
time overcurrent relay ***MRI1-***

			I		N		
3-phase measuring I>, I>>							
Rated current	1 A 5 A			**1** **5**			
Sensitive directional feature for mains decoupling							
Rated voltage	100 V 230 V 400 V					**1** **2** **4**	
Housing (12TE)	19"-rack Flush mounting						**A** **D**

Setting list *MRI1-IN*

Note !
All settings must be checked at site and should the occasion arise, adjusted to the obect/item to be protected.

Project: ______________________ SEG job.-no.: ______________________

Function group: = ______________ Location: + __________ Relay code: ______________________

Relay function: ______________________ Password: ______________________

Date: ______________________

Setting of parameters

Function		Unit	Default settings	Actual settings
I>1	Pickup value for sensitive overcurrent element	I_N	0.005	
tI>1F	Tripping delay for sensitive overcurrent element (forward direction)	s	0.1	
tI>1B	Tripping delay for sensitive overcurrent element (reverse direction)	s	0.1	
I>2	Pickup value for the normal overcurrent element	I_N	0.5	
CHAR	Tripping characteristic for the normal overcurrent element		DEFT	
t_{RST}	Reset mode for definite time characteristics	s	0	
tI>2F	Time delay for normal overcurrent element (forward direction)	s	0.1	
tI>2B	Time delay for normal overcurrent element (reverse direction)	s	0.1	
I>>	Pickup value for high set element	I_N	0.5	
tI>>F	Tripping delay for the high set element (forward direction)	s	0.1	
tI>>B	Tripping delay for the high set element (reverse direction)	s	0.1	
U<	Pickup voltage for undervoltage release at I>2	V	150V/340V/600V*	
α	Characteristic angle	°	0	
t_{TRIP}	Dwell time	ms	AUTO	
f_N	Rated frequency	Hz	50	
RS	Slave address of serial interface		1	

* Setting dependent from the rated voltage 100 V / 230 V / 400 V

Setting of code jumpers

Code jumper	J1		J2		J3	
	Default setting	Actual setting	Default setting	Actual setting	Default setting	Actual setting
Plugged						
Not plugged	X		X		X	

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