EARTH FAULT RELAY FOR SOLIDLY-EARTHED OR RESISTANCE-EARTHED SYSTEMS

Contents

1.   Applications and features

The **XI1-S** of the *PROFESSIONAL LINE* is an all-purpose protection against earth faults, used for electrical machines, lines and networks with solidly earthed or resistance-earthed neutral; it is mainly used in radial networks. Very often the **XI1-S** can be found as backup protection at the central earthing point of the system. It detects all earth-faults occuring in the system. In this case the trip delay selected must exceed the longest time delay setting of any other earthing protection used in the system.

Type **XI1-S-R** with directional current sensing is a selective earth-fault protection and is normally used in ring systems, networks with parallel feeders and in complex meshed systems.

It is possible to select from the following tripping characteristics:

- Definite time overcurrent protection (DMT)
- Inverse time overcurrent protection (IDMT) with selectable tripping characteristics
          Normal Inverse
          Very Inverse
          Extremely Inverse

When compared to the conventional protection equipment all relays of the *PROFESSIONAL LINE* reflect the superiority of digital protection techniques with the following features:

- High measuring accuracy by digital data processing
- Fault indication via LEDs
- Extremely wide operating ranges of the supply voltage by universal wide-range power supply
- Very fine graded wide setting ranges
- Data exchange with process management system by serial interface adapter **XRS1** which can be retrofitted
- RMS measurement
- Extremely short response time
- Compact design by SMD-technology

Note:
The relay type **XI1-E** can be used if a very sensitive earth current relay is needed for earth current measuring without directional feature.

2. Design

Analog inputs

The analog input signals are connected to the protection device via terminals IE1 and IE2.
Addtional for relay type *XI1-S-R* the residual voltage U_E required for determining earth fault direction can be connected from the e-n winding to the terminals Ue and Un.

Auxiliary voltage supply

Unit *XI1-S/-S-R* needs a separate auxiliary voltage supply. Therefore a DC or AC voltage must be used. Unit *XI1-S/-S-R* has an integrated wide range power supply. Voltages in the range from 19 - 390 V DC or 36 - 275 V AC can be applied at connection terminals A1 and A2.
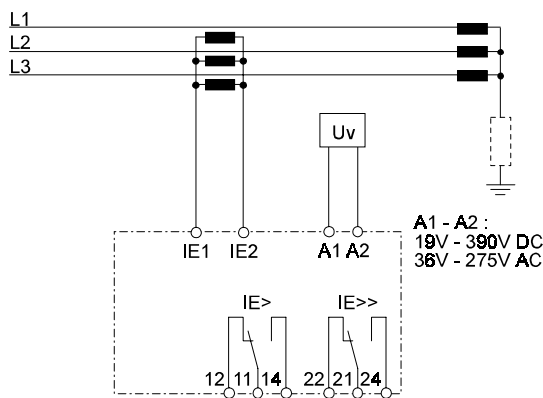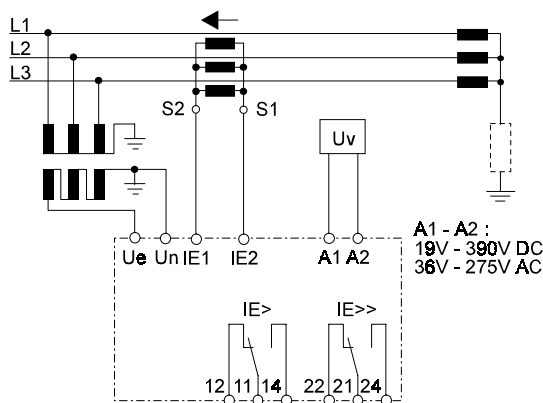

Fig. 2.1: Connections XI1-S

Fig. 2.2: Connections XI1-S-R

Contact positions
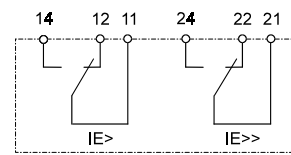
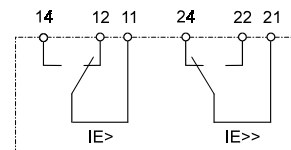Operation without fault or dead conditions
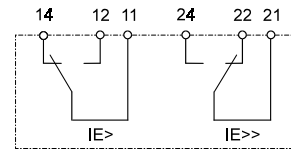
Earth fault low set tripping

Earth fault high set tripping

Fig. 2.3: Contact positions of the output relays

Note:

In case of both the tripping contacts of IE> and IE>> should cause the tripping coil of the C.B. to trip, they have to be interconnected.

A core balance C.T. can be connected to terminals IE1 and IE2 instead of holmgreen circuit.

3. Working principle

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.
A pickup of a supervision circuit is indicated by flashing of the corresponding LED. At tripping the flashing light changes to steady light.

3.1 Determining earth fault direction

The measuring principle for determining the direction is based on phase angle measurement and therefore also on the coincidence-time measurement between earth current and zero sequence voltage.
The residual voltage U_E required for determining earth fault direction can be measured at the e-n winding (Connection at terminals Ue and Un).
Most faults in a characteristic angle are predominantly inductive in character. The characteristic angle between current and voltage at which the greatest measuring sensitivity is achieved has therefore been selected to precede zero sequence voltage U_0 by 110°.
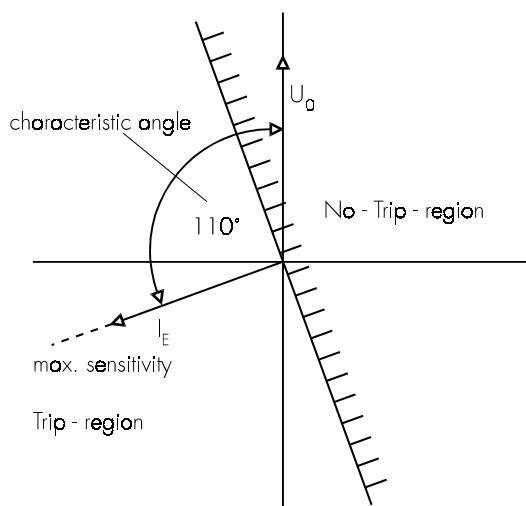

Fig. 3.1: Earth fault in solidly earthed systems

Most faults in a resistance-earthed system are predominantly ohmic in character, with a small inductive component. The characteristic angle for these types of system has therefore been set at +170° in relation to the zero sequence voltage U_0 (see Fig. 3.2).
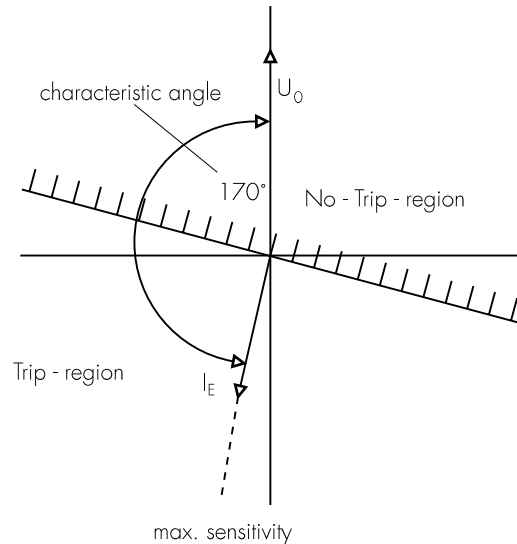

Fig. 3.2: Earth fault in resistance earthed systems

3.2 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 *XI1-S/-S-R*, namely <0.1 VA, has a positive effect on the selection of current transformers. It implies that, if an electromechanical relay is replaced by *XI1-S/-S-R*, a high accuracy limit factor is automatically obtained by using the same current transformer.

4. Operation and settings

All operating elements needed for setting parameters are located on the front plate of the *XI1-S/-S-R* as well as all display elements.
Because of this all adjustments of the unit can be made or changed without disconnecting the unit off the DIN-rail.
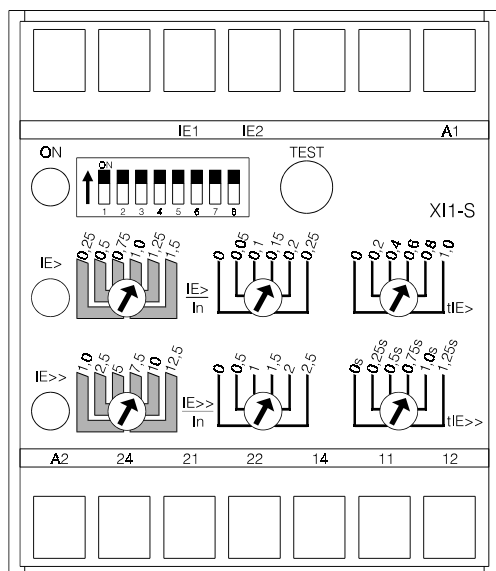

Fig. 4.1: Front plate *XI1-S*
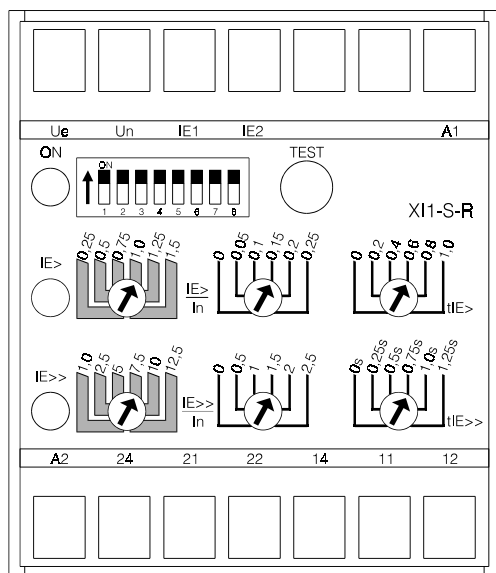
Fig. 4.2: Front plate *XI1-S-R*

For adjustment of the unit the transparent cover has to be opened as illustrated. Do not use force! The transparent cover has two inserts for labels.
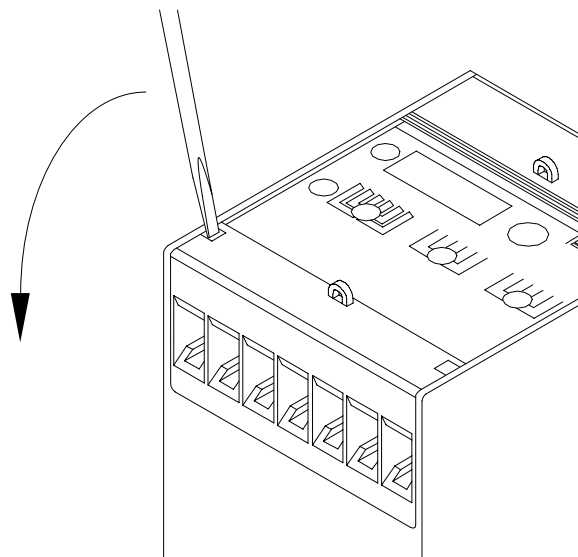
Fig. 4.3: How to open the transparent cover

LEDs

LED „ON" is used for display of the readiness for service (at applied auxiliary voltage Uv). LED IE> and IE>> indicate pickup (flashing) or tripping (steady light) of the corresponding function.

Test push button

This push button is used for test tripping of the unit and when pressed for 5 s a check-up of the hardware takes place. Both output relays are tripped and all tripping LEDs light up.

4.1   Setting of DIP-switches

The DIP-switch block on the front plate of the
XI1-S/-S-R is used for adjustment of the nominal values
and setting of function parameters:

DIP-switch	OFF	ON	Function
1*	DEFT	NINV	
2*	DEFT	VINV	Adjustment of the tripping characteristic
3*	DEFT	EINV	
4	solidly earthed 110°	resistance earthed 170°	Relay characteristic angle (*XI1-S-R* only)
5	not blocked	blocked	Blocking of the IE>> element
6	50 Hz	60 Hz	Adjustment of the rated frequency
7*	x1 s (x1)	x10 s (x2)	Time multiplier DEFT for tIE> (the multipliers for inverse time characteristic are indicated in brackets)
8*	x1 s	x100 s	Time multiplier DEFT for tIE>

Table 4.1: Functions of DIP-switches

*Only one of the DIP-switches 1 - 3 or 7 - 8 shall be in „ON"-position at the same time.

Tripping characteristic

The required tripping characteristic for the time
overcurrent protection can be adjusted with the aid
of DIP–switches 1 - 3. It must be ensured that only
one of the three DIP-switches is switched on.
Wrong adjustment (e.g. 2 DIP-switches „ON") leads
to instant tripping.
For the adjustment of the tripping characteristics, the
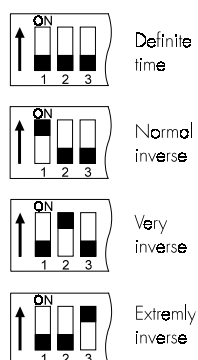following DIP-switch configurations are allowed:

Fig. 4.4: Setting the tripping characteristics

Switching over from solidly earthed neutral to resistance-earthed neutral.

Dependent on the earthing method used, there is a
certain characteristic angle between current and voltage when an earth-fault occurs. By using DIP-switch
4 it can be chosen between solidly earthed neutral
(characteristic angle = 110°) and resistance-earthed
neutral (characteristic angle = 170°).

Blocking of the earth fault high set element (IE>>)

When the DIP-switch 5 is in position „ON", the
earth fault high set element of the relay is blocked.

Rated frequency

With the aid of DIP-switch 6 the rated frequency
can be set to 50 or 60 Hz, depending upon the
given mains characteristics.

Change over of the time multiplier

By using DIP-switch 7, the trip delay tIE> of the
definite time element (DEFT) is multiplied by factor
10 and the inverse time element (NINV, VINV or
EINV) by factor 2.
By using DIP switch 8, the trip delay of the definite
time element can be multiplied by factor 100.

4.2 Setting of the tripping values

The *PROFESSIONAL LINE* units have the unique possibility of high accuracy fine adjustments. For this, two potentiometers are used. The coarse setting potentiometer can be set in discrete steps of 0.25 x In. A second fine adjustment potentiometer is then used for continuously variable setting of the final 0.25. Adding of the two values results in the precise tripping value.

Earth fault low set element IE>

The tripping value can be set in the range from 0.25 - 1.75 x In with the aid of the potentiometer illustrated on the following diagram.

Example:
A tripping value of 1.15 x In is to be set. The set value of the right potentiometer is just added to the value of the coarse setting potentiometer. (The arrow of the coarse setting potentiometer must be inside of the marked bar, otherwise no defined setting value).
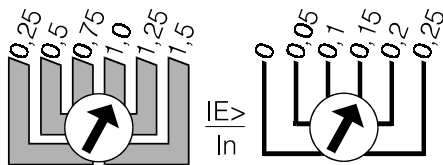

Fig. 4.5: Adjustment example

Trip delay for the earth fault low set element

The time delay for the low set element (DEFT) can be adjusted in the range from 0 - 100 s. For inverse time characteristics (NINV, VINV oder EINV) the time multiplier is adjustable in the range from 0,1 - 2.

Earth fault high set element

The high set element IE>> can be adjusted in the range from 1 - 15 x In. This adjustment is done similar to the low set element adjustment.
Note:
The earth fault high set element of the *XI1-S-R* has **no direction decision**. In case of a fault the relay must trip in **shortest time**.

Trip delay for earth fault high set element

The time delay for the high set element is adjustable in the range from 0 - 1.25 s.

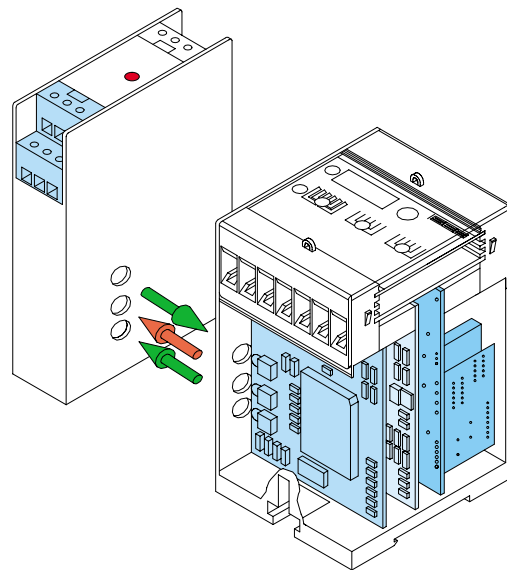## 4.3 Communication via serial interface adapter XRS1

Fig.: 4.6: Communication principle

For communication of the units among each other and with a superior management system, the interface adapter **XRS1** is available for data transmission, including operating software for our relays. This adapter can easily be retrofitted at the side of relay. Screw terminals simplify its installation. Optical transmission of this adapter makes galvanic isolation of the relay possible. Aided by the software, actual measured values can be processed, relay parameters set and protection functions programmed at the output relays. Information about unit **XRS1** in detail can be taken from the description of this unit.

5.   Relay case and technical data

5.1   Relay case

Relay *XI1-S/-S-R* is designed to be fastened onto a DIN-rail acc. to DIN EN 50022, the same as all units of the *PROFESSIONAL LINE*.

The front plate of the relay is protected with a sealable transparent cover (IP40).
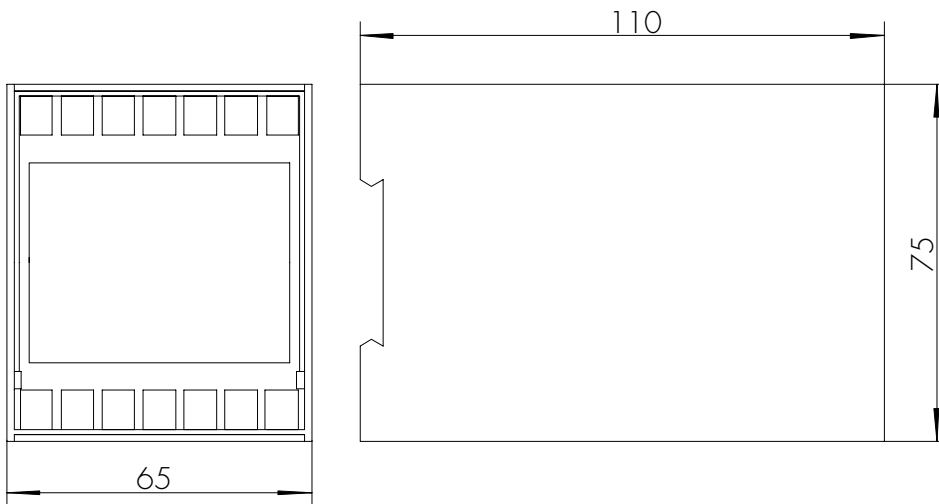

Fig. 5.1: Dimensional drawing

Connection terminals

The connection of up to a maximum 2×2.5 mm^2 cross-section conductors is possible. For this the transparent cover of the unit has to be removed (see para. 4).

5.2 Technical data

Measuring input circuits

Rated frequency fn:	50/60 Hz

Thermal capacity
of the voltage circuit: continuously 120 V AC

Thermal withstand capability
in current circuits:

dynamic current withstand (half wave)	$250 \times In$
for 1 s	$100 \times In$
for 10 s	$30 \times In$
continuously	$4 \times In$

Power consumption   at In = 1 A   0.1 VA
in current circuit   at In = 5 A   0.1 VA

Power consumption
in voltage circuit: at Un = 100 V   0.1 VA

Auxiliary voltage

Rated auxiliary voltage Uv/
Power consumption: 19 - 390 V DC or 36 - 275 V AC (f = 40 - 70 Hz) /
                            4 W (terminals A1 and A2)

Common data

Dropout to pickup ratio:	> 97 %
Resetting time from pickup:	<50 ms
Returning time from trip:	200 ms

Minimum initialization time after
supply voltage has applied: 100 ms

Minimum response time
when supply voltage is available: 50 ms

Output relay

Number of relays:	2
Contacts:	1 changeover contact for each trip relay
Maximum breaking capacity:	ohmic 1250 VA / AC resp. 120 W / DC
	inductive 500VA / AC resp. 75 W / DC
Max. rated voltage:	250 V AC

220 V DC   ohmic load Imax. = 0,2 A
             inductive load Imax. = 0,1 A at L/R ≤ 50 ms
24 V DC   inductive load Imax. = 5 A

Minimum load:	1 W / 1 VA at Umin ≥ 10 V
Maximum rated current:	5 A
Making current (16ms):	20 A
Contact life span:	10^5 operations at max. breaking capacity
Contact material:	AgCdO

System data

Design standard:	VDE 0435 T303; IEC 0801 part 1-4; VDE 0160; IEC 255-4; BS142; VDE 0871
Temperature range at storage and operation:	- 25°C to + 70°C
Constant climate class F acc. DIN 40040 and DIN IEC 68, part 2-3:	more than 56 days at 40°C and 95 % relative humidity
High voltage test acc. to VDE 0435, part 303	
Voltage test:	2.5 kV (eff.) / 50 Hz; 1 min
Surge voltage test:	5 kV; 1.2/50 µs, 0.5 J
High frequency test:	2.5 kV / 1 MHz
Electrostatic discharge (ESD) acc. to IEC 0801, part 2:	8 kV
Radiated electromagnetic field test acc. to IEC 0801, part 3:	10 V/m
Electrical fast transient (burst) acc. to IEC 0801, part 4:	4 kV / 2.5kHz, 15 ms
Radio interference suppression test as per DIN 57871 and VDE 0871:	limit value class A
Repeat accuracy:	1 %
Basic time delay accuracy:	0.5 % or ±25 ms
Basic accuracy of current:	±3 % of the setting value or ±2 % of IE.

Accuracy of time delay in
the range of 2 - 20 x I_s: 2 % DEFT/5 % NINV and VINV/7,5 % EINV/ or 25 ms

Accuracy of the earth
detection (XI1-S-R):

Accuracy of	+1°/-13° at IE ≥ 0,5 x I_N and Ue ≥ 0,5 V
angle measuring:	+1°/-3° at IE ≥ 1 x I_N and Ue ≥ 5 V

Transient overreach at instaneous operation:	≤ 5 %
Temperature effect:	0.08 % per K
Frequency effect:	1 % per K deviation from rated value in the range from ± 10 % of fn (50 or 60 Hz)
Mechanical test:	
Shock:	class 1 acc. to DIN IEC 255-21-2
Vibration:	class 1 acc. to DIN IEC 255-21-1
Degree of protection	
Front plate:	IP40 at closed front cover
Weight:	approx. 0.7 kg
Mounting position:	any
Relay case material:	self-extinguishing

5.3   Definite time earth current protection

Parameter	Setting range	Graduation
IE>	0.25 - 1.75 x In	Continuously variable
IE>>	1 - 15 x In	Continuously variable
tIE>	0 - 1s/0 - 10s/0 - 100s	Continuously variable
tIE>>	0 - 1.25 s	Continuously variable

Table 5.1: Setting ranges and graduation

5.4   Inverse time earth current protection

Tripping characteristics according to IEC 255-4 or BS 142

Normal Inverse
$$t = \frac{0.14}{\left(\dfrac{IE}{IE>}\right)^{0.02} - 1} tIE > [s]$$

Very Inverse
$$t = \frac{13.5}{\left(\dfrac{IE}{IE>}\right) - 1} tIE > [s]$$

Extremely Inverse
$$t = \frac{80}{\left(\dfrac{IE}{IE>}\right)^{2} - 1} tIE > [s]$$

Where:

t	=	trip delay
tIE>	=	time multiplier
IE	=	fault current
IE>	=	setting value of the current

Parameter	Setting range	Graduation
IE>	0.25 - 1.75 x In	Continuously variable
IE>>	1 - 15 x In	Continuously variable
tIE>	0.1 - 2	Continuously variable
tIE>>	0 - 1.25 s	Continuously variable

Table 5.2: Setting ranges and graduation

5.5   Tripping characteristics

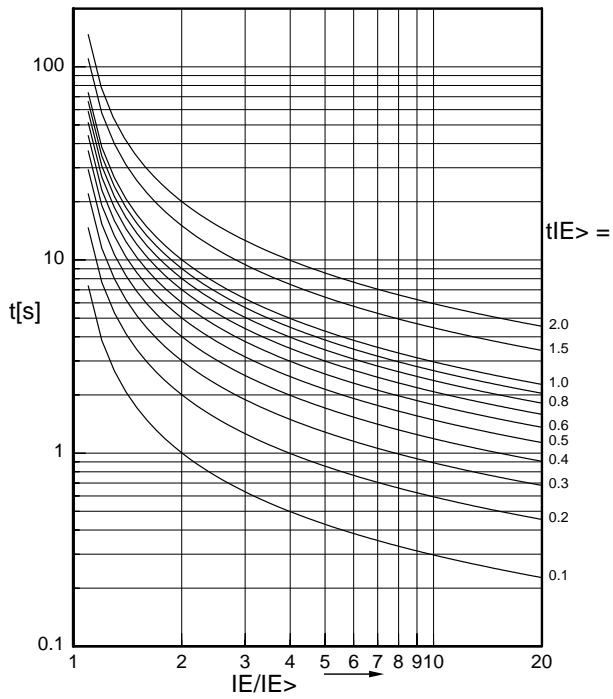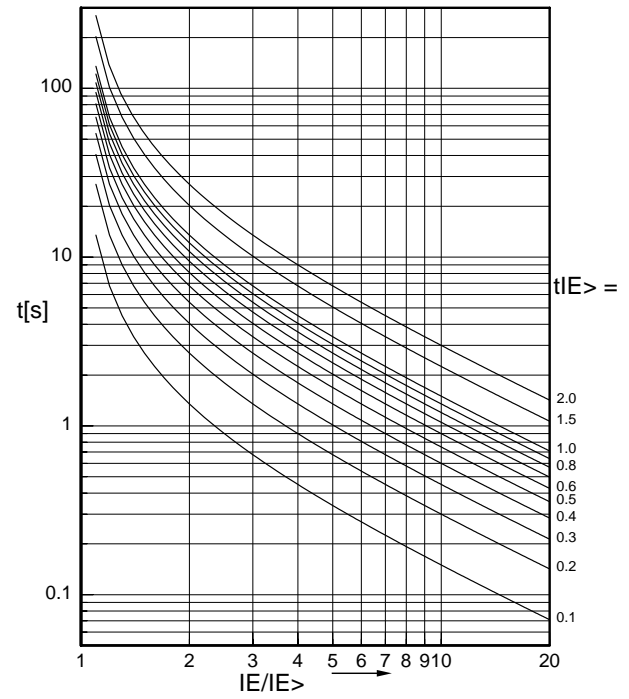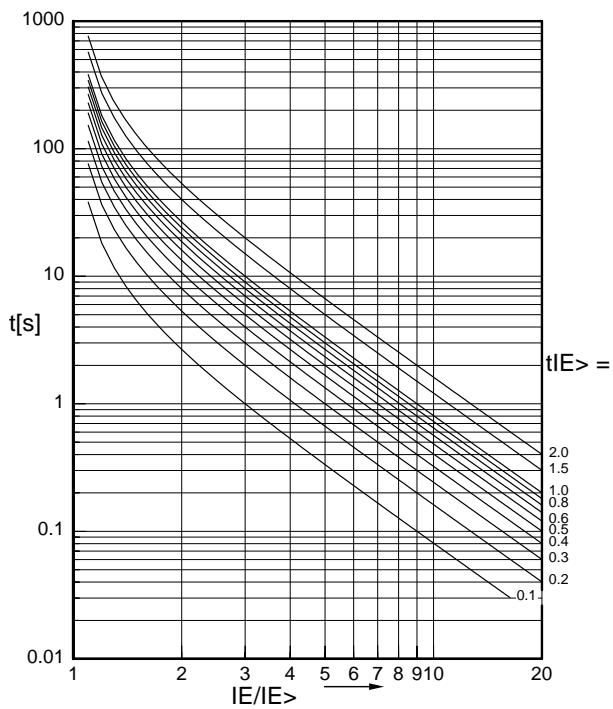

Fig. 5.2: Normal inverse

Fig. 5.4: Very inverse
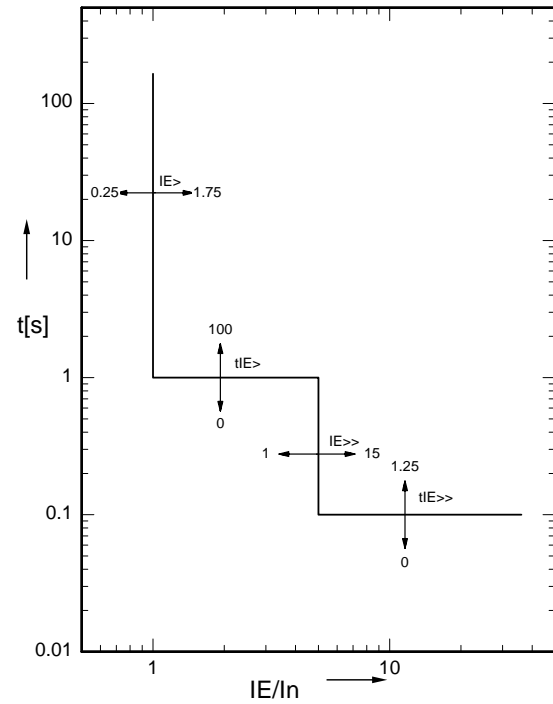

Fig. 5.3: Extremely inverse

Fig.: 5.5:Definite time

6. Order form

Time overcurrent relay	**XI1-**	**S**		
for solidly earthed or resistance earthed systems				
with earth fault directional feature			**R**	
Nominal current:	1 A			**1**
	5 A			**5**

Technical data subject to change without notice!

8.   Setting-list *XI1-S/-S-R*

Project: _____ Woodward job.-no.: _____

Function group: = _____   Location: + _____   Relay code: - _____

Relay functions: _____   Date: _____

Setting of parameters

Function		Unit	Default settings	Actual settings
IE>	Earth fault low set element	x In	0.25	
IE>>	Earth fault high set element	x In	1	
tIE>	Trip delay for earth fault low set element (DEFT)	s	0	
tIE>	Time multiplier for inverse time tripping characteristic			
tIE>>	Trip delay for earth fault high set element	s	0	

DIP-switch	Function	Default settings	Actual settings
1*		DEFT	
2*	Adjustment of the tripping characteristic	DEFT	
3*		DEFT	
4	Relay characteristic angle (*XI1-S-R* only)	solidly earthed 110°	
5	Blocking of the IE>> element	not blocked	
6	Adjustment of the rated frequency	50 Hz	
7*	Time multiplier DEFT for tIE> (the multipliers for inverse time characteristic are indicated in brackets)	x 1s (x1)	
8*	Time multiplier DEFT for tIE>	x 1s	

*Only one of the DIP-switches 1 - 3 or 7 - 8 shall be in „ON"-position at the same time.

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