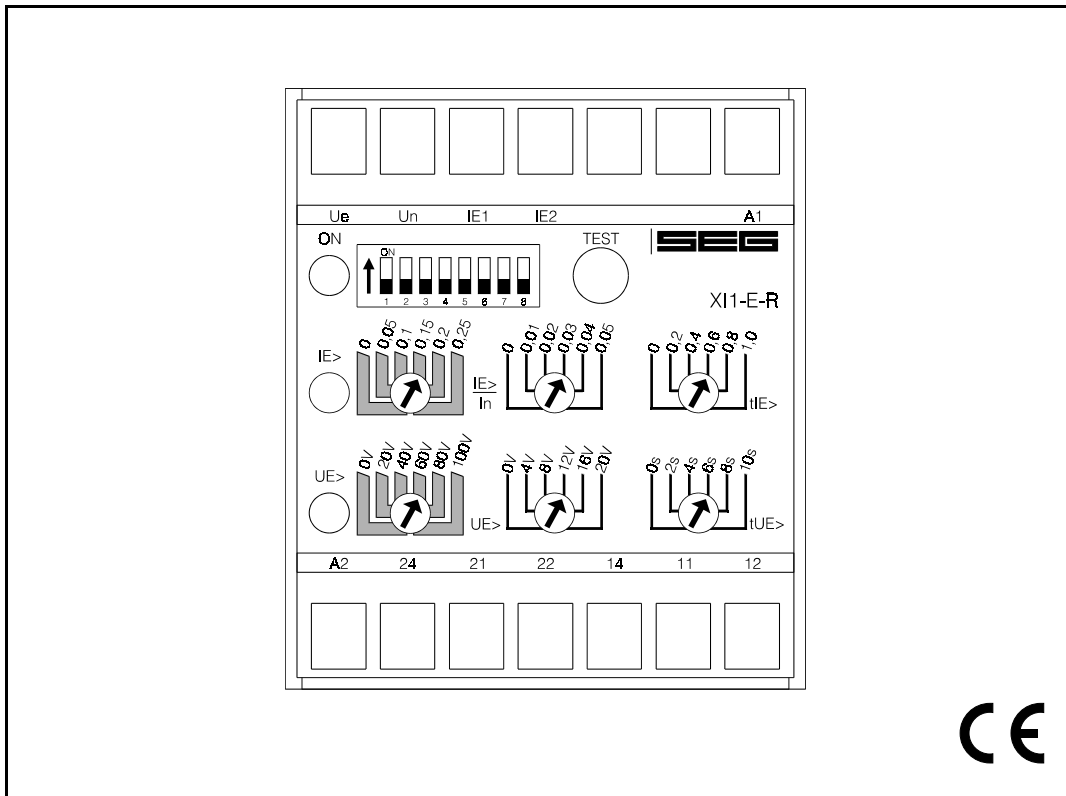


**XI1-E/-E-R** - Earth fault relay for isolated or compensated systems



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## 1. Applications and features

The *XI1-E* of the *PROFFESIONAL LINE* is an all-purpose protection against earth faults, used for electrical machines, lines and isolated or compensated systems; it is mainly used in radial networks. Very often the *XI1-E* can be found as backup protection at the central earthing point of the system. It detects all earth faults occurring 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.

Relay variant *XI1-E-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.

When compared to the conventional protection equipment all relays of the *PROFFESIONAL 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-S* can be used if a not 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. The residual voltage  $U_E$  required for determining earth fault direction can be connected from the e-n winding to the terminals  $U_e$  and  $U_n$  (X11-E-R).

### Auxiliary voltage supply

Unit X11-E/-E-R needs a separate auxiliary voltage supply. Therefore a DC or AC voltage must be used. Unit X11-E/-E-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.

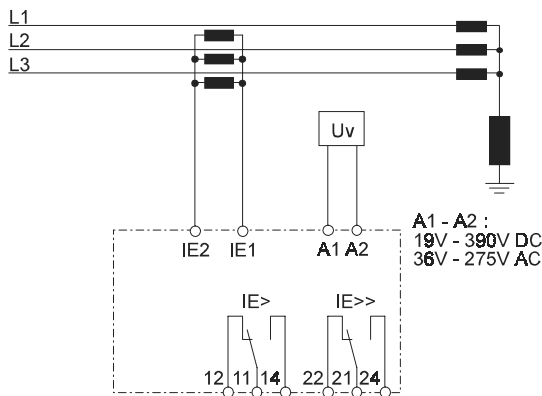


Fig. 2.1: Connections X11-E in holmgreen circuit

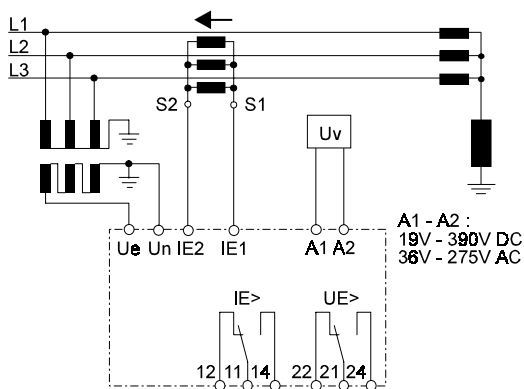


Fig. 2.2: Connections X11-E-R in holmgreen circuit

### Contact positions X11-E

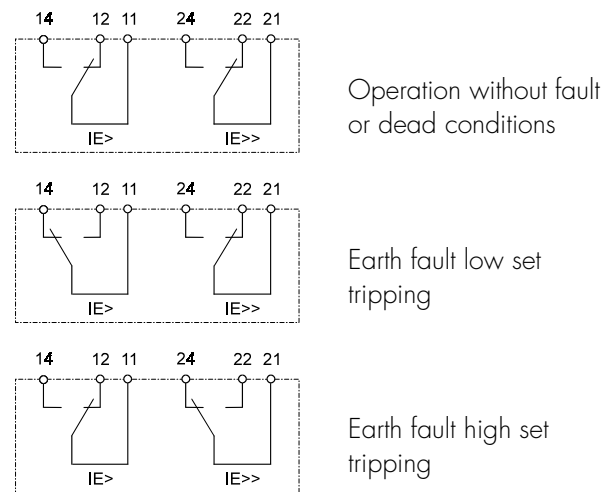


Fig. 2.3: Contact positions X11-E

#### 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.

### Contact positions X11-E-R

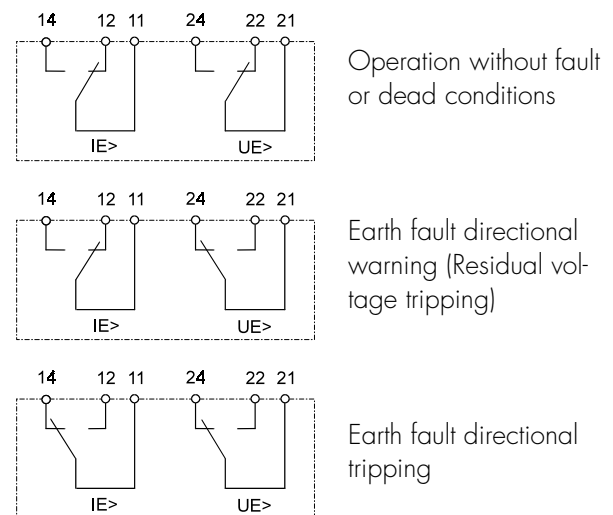


Fig. 2.4: Contact positions X11-E-R

#### Note:

No earth fault directional tripping takes place without exceeding the residual voltage setting. 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 suppressed 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 Earth-fault directional feature (E-R-relay type)

For earth-fault direction detection it is mainly the question to evaluate the power flow direction in zero sequence system. Both the residual voltage and neutral (residual) current on the protected line are evaluated to ensure a correct direction decision.

The residual voltage  $U_E$  required for determining earth fault direction can be measured at the e-n winding (Connection at terminals  $U_e$  and  $U_n$  see fig. 2.2) Total current can be measured by connecting the unit either to a ring core C.T. or to current transformers in a Holmgreen circuit. However, maximum sensitivity is achieved if the **XI1-E-R** is connected to a ring core C. T.

In isolated or compensated systems, measurement of reactive or active power is decisive for earth-fault detection. It is therefore necessary to set the E-R-relay type to measure according to  $\sin \varphi$  or  $\cos \varphi$  methods, depending on the neutral-point connection method (see table. 4.1).

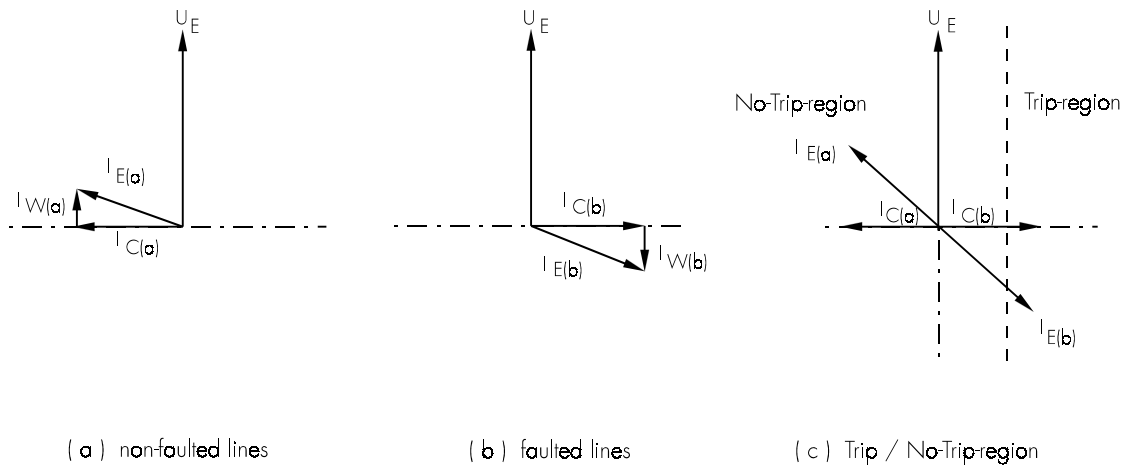


Fig. 3.1: Phase position between the residual voltage and zero sequence current for faulted and non-faulted lines in case of isolated systems ( $\sin \varphi$ )

- $U_E$  - residual voltage
- $I_E$  - zero sequence current
- $I_C$  - capacitive component of zero sequence current
- $I_W$  - resistive component of zero sequence current

By calculating the reactive current component ( $\sin \varphi$  adjustment) and then comparing the phase angle in relation to the residual voltage  $U_E$ , the E-R-relay type determines whether the line to be protected is earth-faulted.

On non-earth-faulted lines, the capacitive component  $I_{C(a)}$  of the total current precedes the residual voltage by an angle of  $90^\circ$ . In case of a faulty line the capacitive current  $I_{C(b)}$  lags behind the residual voltage at  $90^\circ$ .

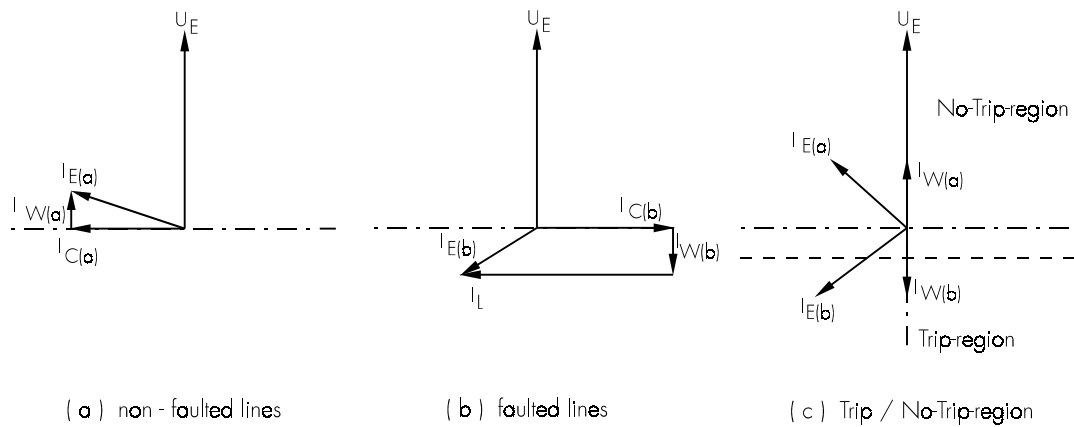


Fig. 3.2: Phase position between the residual voltage and zero sequence current for faulted and non-faulted lines in case of compensated systems ( $\cos \varphi$ )

$U_E$  - residual voltage

$I_E$  - zero sequence current

$I_L$  - inductive component of zero sequence current (caused by Petersen coil)

$I_C$  - capacitive component of zero sequence current

$I_W$  - resistive component of zero sequence current

In compensated mains the earth fault direction cannot be determined from the reactive current components because the reactive part of the earth current depends upon the compensation level of the mains. The ohmic component of the total current (calculated by  $\cos \varphi$  adjustment) is used in order to determine the direction.

The resistive component in the non-faulted line is in phase with the residual voltage, while the resistive component in the faulted line is opposite in phase with the residual voltage.

By means of an efficient digital filter harmonics and fault transients in the fault current are suppressed. Thus, the uneven harmonics which, for instance, are caused by an electric arc fault, do not impair the protective function.

If the measured residual voltage is higher than the setting value  $U_E$ , relay  $U_E$  trips after the adjusted trip delay  $t_{UE}$  has expired. At this moment the instant relay  $U_E$  picks up and the earth fault direction is calculated by using the  $\sin \varphi$  or  $\cos \varphi$  algorithm.

If the ohmic component ( $\cos \varphi$ -measuring) or capacitive component ( $\sin \varphi$ -measuring) of the total current is above setting value  $I_E$ , relay  $I_E$  trips after the adjusted trip delay  $t_{IE}$  has expired.

### 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:  $K1 = 2$

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-E/-E-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-E/-E-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-E/-E-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.

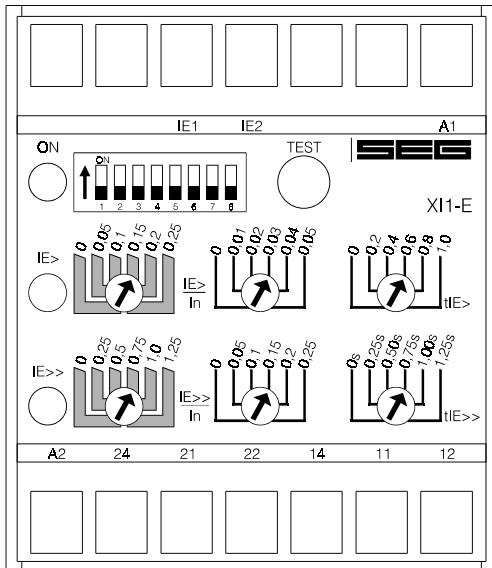


Fig. 4.1: Front plate XI1-E

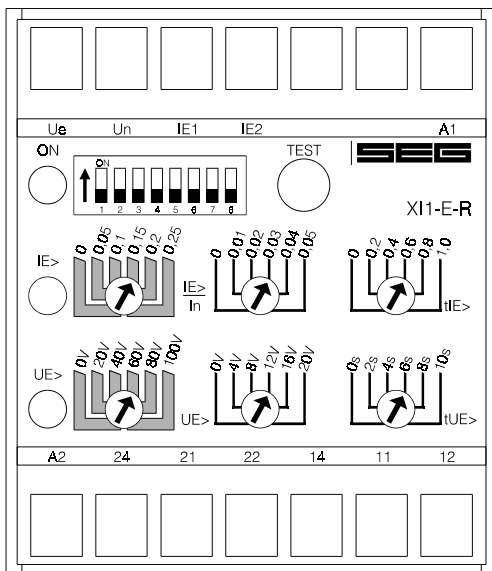


Fig. 4.2: Front plate XI1-E-R

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.

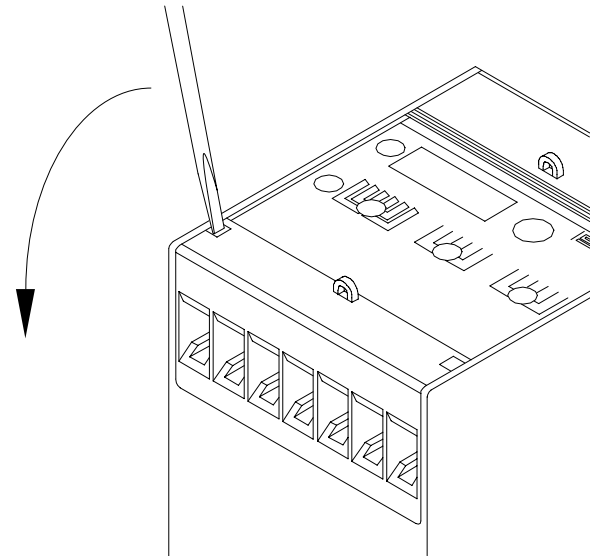


Fig. 4.3: How to open the transparent cover

### LEDs

LED „ON“ is used for display of the readiness for service (at applied auxiliary voltage  $U_v$ ). LED IE> and IE>> (IE> and UE> at **XI1-E-R**) 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-E/-E-R* is used for adjustment of the nominal values and setting of function parameters:

Type XI1-E:

DIP-switch	OFF	ON	Function
1			No function
2			No function
3			No function
4			No function
5	not blocked	blocked	Blocking of the IE>> element
6	50 Hz	60 Hz	Rated frequency
7*	x1 s	x10 s	Time multiplier for tIE>
8*	x1 s	x100 s	Time multiplier for tIE>

Table 4.1: Functions of XI1-E DIP-switches

\*Only one of the DIP-switches 7 - 8 shall be in „ON“-position at the same time.

Type XI1-E-R:

DIP-switch	OFF	ON	Function
1			No function
2			No function
3			No function
4			No function
5	sin	cos	Calculation procedure for isolated / compensated systems
6	50 Hz	60 Hz	Rated frequency
7*	x1 s	x10 s	Time multiplier for tIE>
8*	x1 s	x100 s	Time multiplier for tIE>

Table 4.2: Functions of XI1-E-R DIP-switches

\*Only one of the DIP-switches 7 - 8 shall be in „ON“-position at the same time.

### Blocking of the earth fault high set element of XI1-E-R (IE>>)

When the DIP-switch 5 is in position „ON“, the earth fault high set element of the *XI1-E* is blocked.

### Calculation procedure for isolated / compensated systems.

Dependent on the earthing method used, the directional element of the *XI1-E-R* can be chosen by using DIP-switch 5 for isolated (sin $\phi$ -measuring) or compensated (cos $\phi$ -measuring) systems.

### 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> is multiplied by factor 10.

By using DIP switch 8, the trip delay tIE> 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  $0.05 \times I_n$ . A second fine adjustment potentiometer is then used for continuously variable setting of the final  $0.05 \times I_n$ . Adding of the two values results in the precise tripping value.

### Earth fault low set element

The tripping value  $I_{E>}$  can be set in the range from  $0 - 0.3 \times I_n$  (min. limit value  $0.001 \times I_n$ ) with the aid of the potentiometer illustrated on the following diagram.

Example:

A tripping value  $I_{E>}$  of  $0.18 \times I_n$  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).

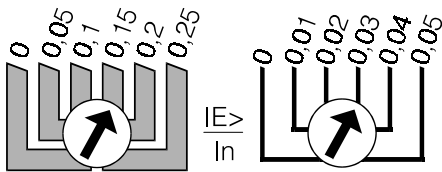


Fig. 4.4: Adjustment example

### Trip delay for the earth fault low set element

The time delay for the low set element can be adjusted in the range from  $0 - 100$  s.

### Earth fault high set element (X11-E)

The high set element  $I_{E>>}$  can be adjusted in the range from  $0 - 1.5 \times I_n$  (min. limit value  $0.001 \times I_n$ ). This adjustment is done similar to the low set element adjustment.

### Trip delay for earth fault high set element (X11-E)

The time delay for the high set element  $t_{I_{E>>}}$  is adjustable in the range from  $0 - 1.25$  s.

### Residual voltage element (X11-E-R)

The residual voltage element  $U_{E>}$  can be adjusted in the range from  $10 - 120$  V. This adjustment is done similar to the adjustment of the earth fault low set element.

### Trip delay for the residual voltage element (X11-E-R)

The time delay for the residual voltage element  $t_{U_{E>}}$  can be adjusted in the range from  $0 - 10$  s.

## 4.3 Communication via serial interface adapter XRS1

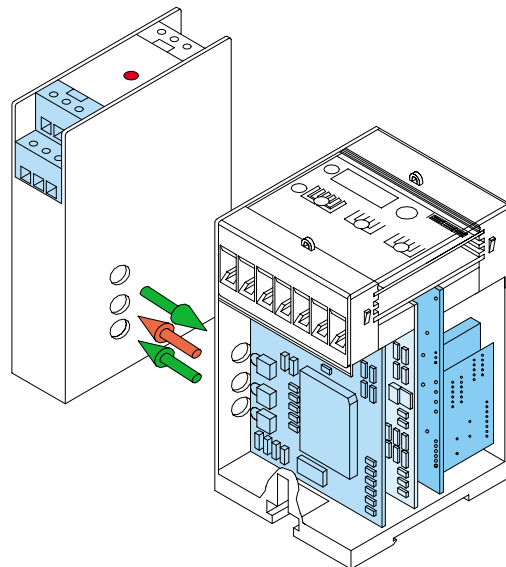


Fig. 4.5: communication principle

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-E/-E-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).

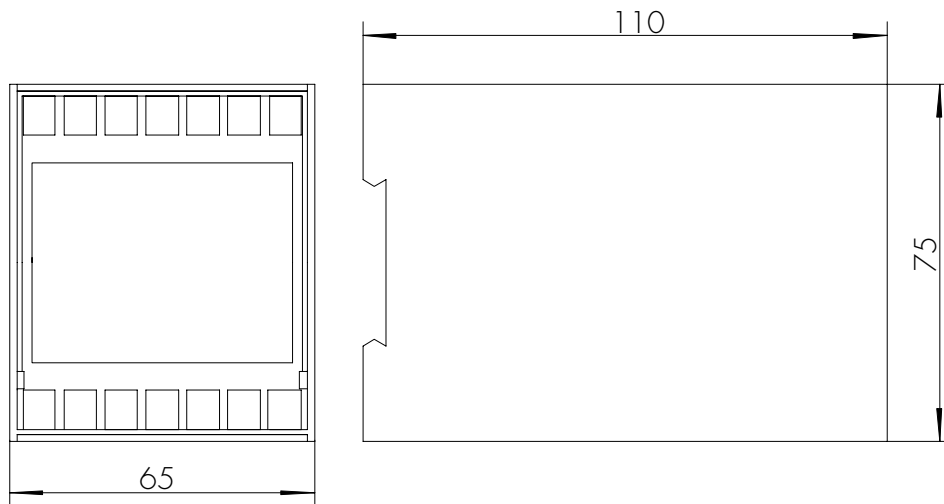


Fig. 5.1: Dimensional drawing

### Connection terminals

The connection of up to a maximum  $2 \times 2.5 \text{ mm}^2$  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 $f_n$ :	50/60 Hz	
Thermal withstand capability in current circuits:	dynamic current withstand (half wave) for 1 s for 10 s continuously	250 x $I_n$ 100 x $I_n$ 30 x $I_n$ 4 x $I_n$
Thermal capacity of the voltage circuit:	continuously	120 V AC
Power consumption in current circuit	at $I_n = 1$ A at $I_n = 5$ A	0.1 VA 0.1 VA
Power consumption in voltage circuit	at $U_n = 100$ V	0.1 VA

### Auxiliary voltage

Rated auxiliary voltage $U_v$ / Power consumption:	19 - 390 V DC or 36 - 275 V AC ( $f = 40 - 70$ Hz)/ 4 W (terminals A1 and A2)
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### 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 $I_{max.} = 0,2$ A inductive load $I_{max.} = 0,1$ A at $L/R \leq 50$ ms 24 V DC inductive load $I_{max.} = 5$ A
Minimum load:	1 W / 1 VA at $U_{min} \geq 10$ 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
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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 characteristic quantities:	±2 % of $I_E$ the setting value or $\pm 0.002 \times I_N$ ±1 % of $U_e$ or $\pm 0,5$ V
Transient overreach at instantaneous operation:	≤ 5 %
Temperature effect:	0.08 % per K
Frequency effect:	1 % per Hz deviation from rated value in the range from ±10 % of $f_n$ (50 Hz or 60 Hz)
Earth fault direction accuracy ( <b>XI1-E-R</b> )	
Real current component measuring in compensated systems:	$I_E \times \cos \varphi$
Reactive current component measuring in isolated systems:	$I_E \times \sin \varphi$
Accuracy of measured angle at $U_e > 20$ V:	± 6° at $I_E = 0.002 \times I_N$ ± 3° at $I_E = 0.005 \times I_N$ ± 2° at $I_E = 0.010 \times I_N$ ± 1° at $I_E \geq 0.015 \times I_N$
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 Setting ranges XII-E

Parameter	Setting range	Graduation
IE>	0 - 0.3 x In (min. limit value 0.001 x In)	Continuously variable
IE>>	0 - 1.5 x In (min. limit value 0.001 x In)	Continuously variable
tIE>	0 - 1 s / 0 - 10 s / 0 - 100 s	Continuously variable
tIE>>	0 - 1.25 s	Continuously variable

Tabelle 5.1: Setting ranges and graduation

### 5.4 Setting ranges XII-E-R

Parameter	Setting range	Graduation
IE>	0 - 0.3 x In (min. limit value 0.001 x In)	Continuously variable
tIE>	0 - 1 s / 0 - 10 s / 0 - 100 s	Continuously variable
UE>	10 - 120 V	Continuously variable
tUE>	0 - 10 s	Continuously variable

Tab 5.2: Setting ranges and graduation

## 6. Order form

Earth fault current relay	<b>XII-</b>	<b>E</b>		
for isolated / compensated systems				
with earth fault directional feature		<b>R</b>		
Nominal current:	1 A			<b>1</b>
	5 A			<b>5</b>

Technical data subject to change without notice!

## 8. Setting-list XI1-E/-E-R

Project: \_\_\_\_\_ SEG 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	0.001	
IE>>	Earth fault high set element	x In	0.001	
tIE>	Trip delay for earth fault low set element (XI1-E)	s	0	
tIE>>	Trip delay for earth fault high set element (XI1-E)	s	0	
UE>	Residual voltage element (XI1-E-R)	V	1	
tUE>	Trip delay for residual voltage element (XI1-E-R)	s	0	

### DIP-switch settings

DIP-switch	Function	Default settings	Actual settings
1	No function		
2	No function		
3	No function		
4	No function		
5	Blocking of IE>> element (XI1-E) or calculation procedure isolated/compensated systems (XI1-E-R)	not blocked/sin	
6	Rated frequency	50 Hz	
7*	Time multiplier for tIE>	x1 s	
8*	Time multiplier for tIE>	x1 s	

\*Only one of the DIP-switches 7 - 8 shall be in „ON“-position at the same time.



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