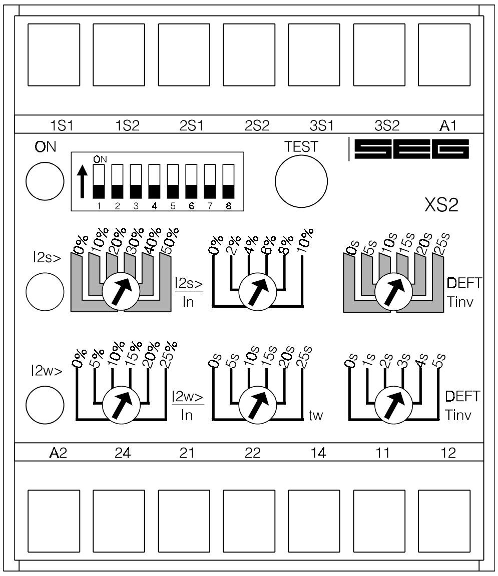
PROFESSIONAL LINE

WOODWARD

SEG

XS2 - Negative sequence relay



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1. Introduction and application

The *XS2* relay is a negative sequence protection relay with universal application. It serves for negative sequence protection of three-phase generators. With a large number of different tripping characteristics and adjustment possibilities, the tripping characteristic can be made suitable for almost every type of generator with regard to its special thermal time-constant.

There is a choice between an independent or an inverse time tripping characteristic. In case of low unbalanced-load, a warning is given after an adjustable time-delay. In case of inadmissible high unbalanced-load, the *XS2* relay trips in accordance with the set characteristic.

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
- Extremely short response time
- Compact design by SMD-technology

In addition to this relay *XS2* has the following special features:
- Adjustable protective functions can be selected i.e.
  - definite time overcurrent protection
  - inverse time overcurrent protection
- Consideration of the thermal generator time constant
- Two steps each for warning and tripping, independently adjustable

2. Design

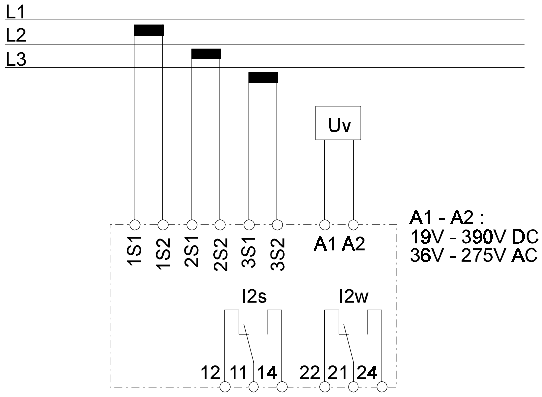


Fig. 2.1: Connections

Analog inputs

The phase currents are connected to the protection device via separate c.t.s to the terminals 1S1 - 3S2.

Auxiliary voltage supply

Unit ***XS2*** needs a separate auxiliary voltage supply. Therefore a DC or AC voltage must be used. Unit ***XS2*** 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.

Contact positions

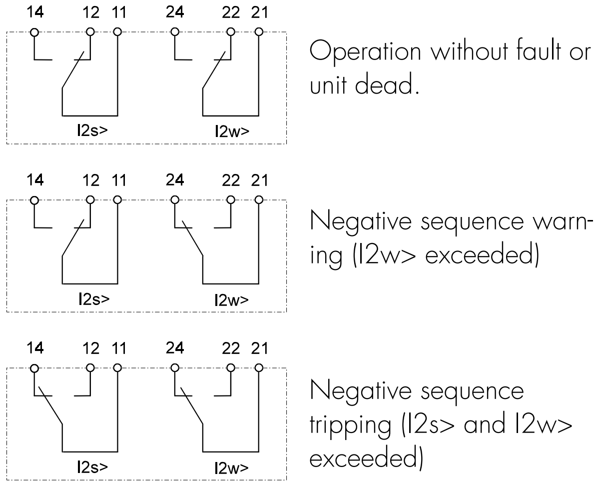


Fig. 2.2: Contact positions of the output relays

3. Working principle

The secondary currents of the main current transformers of the protected object are converted to voltage signals in proportion to the currents via the burdened input transformers. 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 fn = 50 Hz (60 Hz) with a sampling frequency of 600 Hz (720 Hz), namely, a sampling rate of 1.66 ms (1.38 ms) for every measuring quantity.

The essential part of the ***XS2*** relay is a powerful microcontroller. All of the operations, from the analog digital convertion to the relay trip decision, are carried out by the microcontroller digitally.

The calculated actual negative sequence current values are compared with the relay settings. If a negative sequence current exceeds the pickup value, an alarm is given and after the set trip delay has elapsed, the corresponding trip relay is activated.

3.1 Principle of negative sequence protection

An unbalanced-load can be caused due to unequal distribution of current in the grid on account of unequal loading, unsymmetrical line-to-line short-circuits (one phase and two phase), line interruption and also switching operations.

Through the unbalanced-load, negative sequence currents occur in the stator, which cause higher harmonics with odd numbers in the stator winding and higher harmonics with even numbers in the rotor winding. The rotor is particularly endangered in this because the higher harmonics put extra load on the rotor winding and induce eddy currents in massive iron content of the rotor which can even lead to melting of the metal or to the destruction of the metal structure.

An unbalanced-load is, however, permissible in certain limits and with regard to the thermal loading limit of the generator. In order to avoid a premature outage of the generator in case of unbalanced-load, the tripping characteristic of the negative sequence protection should be adapted to the thermal characteristic of the generator.

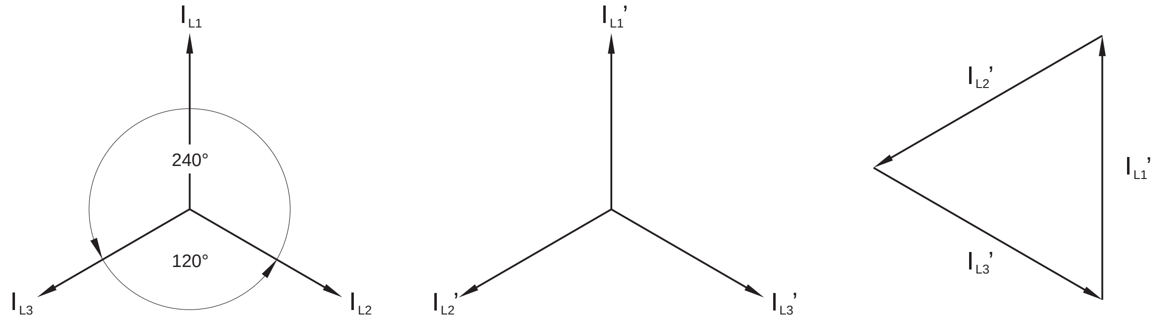
Basically it is established that the better the cooling of the rotor, the lower are generally the permissible negative sequence values. This is due to the fact that with better rotor-cooling the maximum permissible symmetrical load can be chosen higher, however in relation to that, an unbalanced-load is permissible to a lesser extent. For turbo-generators the value of the permissible unbalanced-load is relatively low. Usual values are approx. 10 - 15 % of the load which is permissible with symmetrical load.

The negative sequence relay ***XS2*** has a large number of adjustable tripping characteristics. Protection of almost every type of generator is thereby possible.

In case of unsymmetrical short-circuits in the grid the negative sequence protection relay normally also picks up. In order to ensure selectivity, to the extent the overload carrying capacity of the generator permits it, a tripping time longer than that of the mains protection (e.g. overload protection) is to be selected.

3.2 Measurement principle

A rotating three-phase system can be split according to the method of "Symmetrical Components" into a positive-sequence system, a negative-sequence system and a zero-sequence system. The current in the negative-sequence system is a measure for the magnitude of the unbalanced-load. The *XS2* relay produces a negative-sequence system by rotating the current-vector I_{L2} by 240° and the current-vector I_{L3} by 120°.



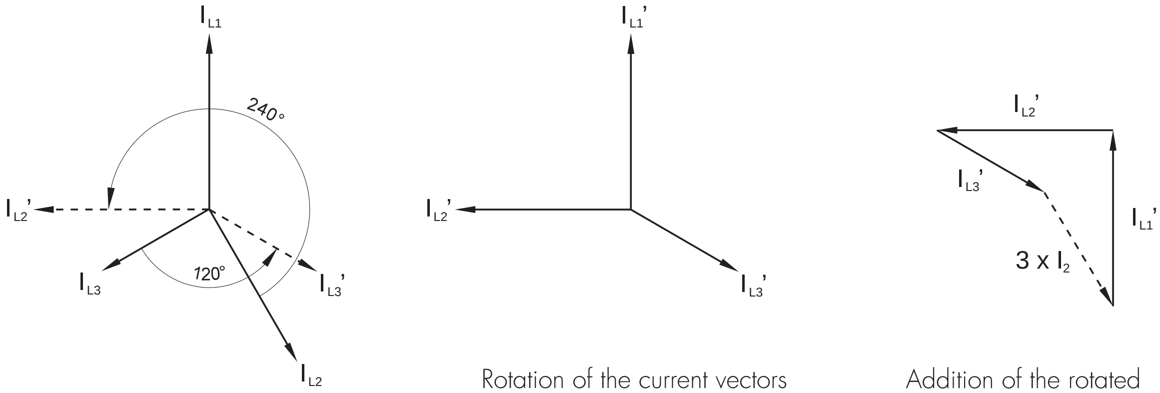
Three-phase system with symmetrical load

Rotation of the current vectors for calculation of the negative sequence system

Addition of the rotated current vectors (I2=0)

Fig. 3.1

A rotating field is produced with opposite direction. If the currents of this negative-sequence system are added, the sum is zero in case of a symmetrically load.



Three-phase system with unbalanced load

Rotation of the current vectors for calculation of the negative sequence system

Addition of the rotated current vectors (I2 > 0)

Fig. 3.2:

Fig. 3.2 shows the current vectors of an unsymmetrically loaded generator. The *XS2* relay forms the negative-sequence system by rotation and adding of the current vectors. Tripping takes place according to the adjusted tripping-characteristic. For exact rotation of the current vectors by 120° or 240°, the accurate setting of the system frequency is necessary.

Definition of the inverse current (I_2)

The inverse current (negative sequence current) is the resultant current in the negative-sequence system after splitting an unsymmetrical system in three symmetrical components. Example: In case of a three-phase generator which is loaded with rated current in only one phase, there is an inverse current of $I_2 = 1/3 \times I_N$.

Adaptation to the generator

For matching the ***XS2*** relay to the respective generator-type, two important generator parameters are required from the generator manufacturer:

a) The continuously permissible negative sequence related to the rated current (I_N) of the generator.

$$K_2 = I_{2S}/I_N$$

This is usually given in % where I_{2S} is the continuously permissible negative sequence current.

b) The generator-constant which is dependent on design

$$K_1 = K_2^2 \times T_{INV}$$

For generator with air-cooling, following values are common:

Generator capacity	<100 MVA	<20 MVA
Continuously permissible unbalanced-load K_2	approx. 8...10 % x I_N	approx. 20 % x I_N
Generator constant K_1	5...30	...60

Further values can be taken from DIN 57 530 part 1 / IEC VDE 0530 part 1.
The maximum permissible time t_{perm} of the negative sequence current I_2 is given by:

$$t_{perm} = \frac{T}{(I_2 / I_{2S})^2 - 1} \text{ with } T = K_1 / K_2^2$$

The following table shows current unbalances at different asymmetry occurences and gives information on test results at different cases of asymmetry, based on a 3-phase power source with adjustable phase angle of the currents.

Example of setting

The following parameters may be given:
Nominal current of generator: 800 A
Current-transformer ratio: 1000/5
Continuously permissible
Unbalanced-load K_2: 12.5 %
Thermal generator constant K_1: $K_2^2 \times t = 8$ s

At first the calculation is done for the generator nominal current related to the secondary side of current transformer:

$$I_{Nsec} = 800 \text{ A} \times 5 / 1000 = 4 \text{ A}$$

The continuously permissible negative sequence current related to the secondary side of the current transformer amounts to:

$$I_{2Ssec} = K_2 \times I_{Nsec} \qquad K_2 = 12.5\ \%$$
$$I_{2Ssec} = 0.125 \times 4 \text{ A} = 0.5 \text{ A}$$

The pickup value I_{2S} of the negative sequence currents (related to I_N = 5A) can be calculated to:

$$I_{2S} = 0.5 \text{ A} / 5 \text{ A} = 0.1\ (10\%)$$

The time-constant T for the selection of the tripping characteristic can be calculated as follows:

$$K_1 = 8 \text{ s} \qquad K_2 = 12.5\ \%$$
$$T = K_1 / K_2^2 = 8 \text{ s} / ,125^2 = 512 \text{ s} \approx 500 \text{ s}$$

For the warning stage I_{2W}, a somewhat lower value than I_{2S} (e.g. 10 %) is used. The setting value I_{2W} then works out as follows:

$$I_{2W} = 10\ \% \times I_N / \text{Current-transformer ratio} / I_{Nsec}$$

$$I_{2W} = \frac{0.10 \cdot 800 \text{ A}}{\frac{1000}{5} \cdot 4 \text{ A}} = 0.064\ (6.4\ \%)$$

It is recommended that the time-delay t_W for the negative sequence warning has to be adjusted to about 5 s.

Current						Negative sequence current
I_{L1} (x In)	Angle (°)	I_{L2} (x In)	Angle (°)	I_{L3} (x In)	Angle (°)	I_2 (x In)
1.00	-	0	-	0	-	0.33
0	-	1.00	-	0	-	0.33
0	-	0	-	1.00	-	0.33
1.00	0	1.00	240	1.00	120	1.00
1.00	0	1.00	120	1.00	240	0
1.00	0	1.00	180	0.00	-	0.578
0	-	1.00	0	1.00	120	0.33

Table 3.1: Negative sequence currents at different asymmetry examples

4. Operation and settings

All operating elements needed for setting parameters are located on the front plate of the *XS2* 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.

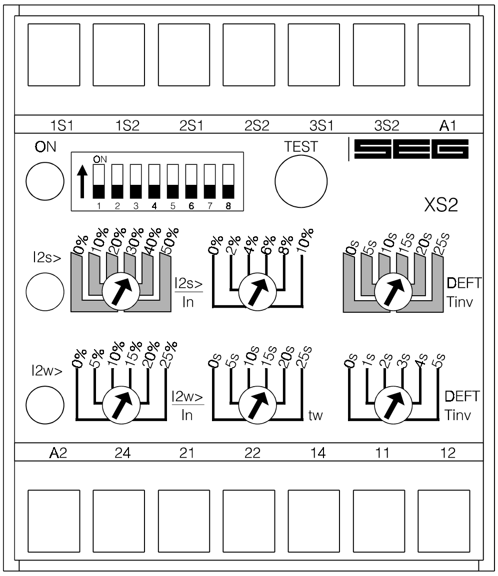


Fig. 4.1: Front plate

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.

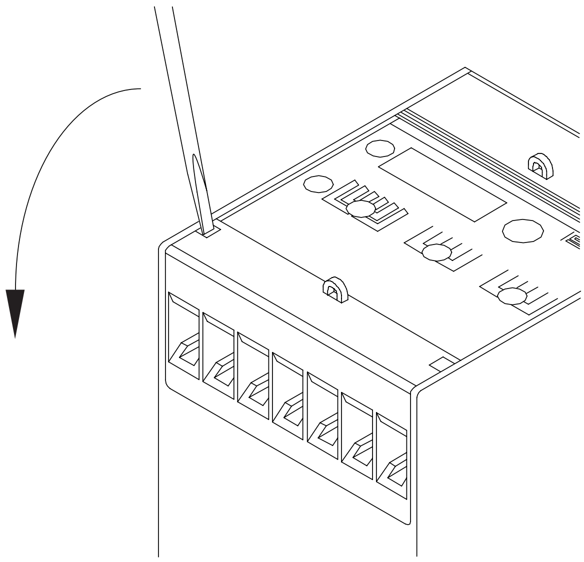


Fig. 4.2: How to open the transparent cover

LEDs

LED „ON" is used for display of the readiness for service (at applied auxiliary voltage Uv). LEDs I2s> and I2w> signal 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 *XS2* is used for adjustment of the nominal values and setting of function parameters:

DIP-switch	OFF	ON	Function
1	DEFT	TINV	Switch over for inverse time / definite time tripping (I2s>)
2			
3	x1	x10	Time multipier for DEFT-characteristic (I2s>)
4	x10	x100	Time multipier for INV-characteristic (I2s>)
5	x1	x10	Time multipier for tw (I2w>)
6	50 Hz	60 Hz	Rated frequency
7			
8			

Table 4.1: Functions of DIP-switches

Tripping characteristic

The tripping characteristic requested for the current unbalance protection can be adjusted by using DIP-switch 1:

DIP switch 1 OFF = definite time characteristic (DEFT) selected for I2s>

DIP switch 1 ON= inverse time characteristic (INV) selected for I2s>

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.

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 course setting potentiometer can be set in descrete steps of 10 % steps. A second fine adjustment potentiometer is then used for continuously variable setting of the final 0 - 10 %. Adding of the two values results in the precise tripping value.

Negative sequence current element I2s>

The tripping value I2s> can be set in the range from 3 - 60 % In with the aid of the potentiometer illustrated on the following diagram.

Example:
A tripping value of 36 % 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).

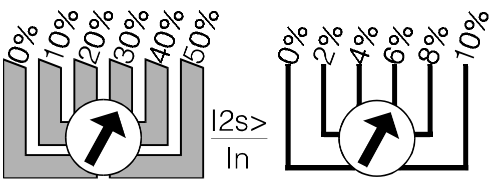


Fig. 4.3: Adjustment example

Negative sequence current warning

The negative sequence current element I2w> can be adjusted continuously variable in the range from 3 - 25 % In.

Time delay (DEFT) or (INV)

The time delay for current unbalance tripping I2s> (DIP switch 1 OFF = DEFT) can be adjusted continuously variable in the range from 0 - 30 s or 0 - 300 s. For the inverse time characteristic (DIP-switch 1 ON=INV), the value of the generator time constant is adjustable in the range from 100 - 300s or 100 - 3000s.

Time delay tw

The time delay tw for warning of current unbalance I2w> can be adjusted in the range 0 - 25s or 0 - 250s.
The tripping characteristic is always definite time.

4.3 Communication via serial interface adapter XRS1

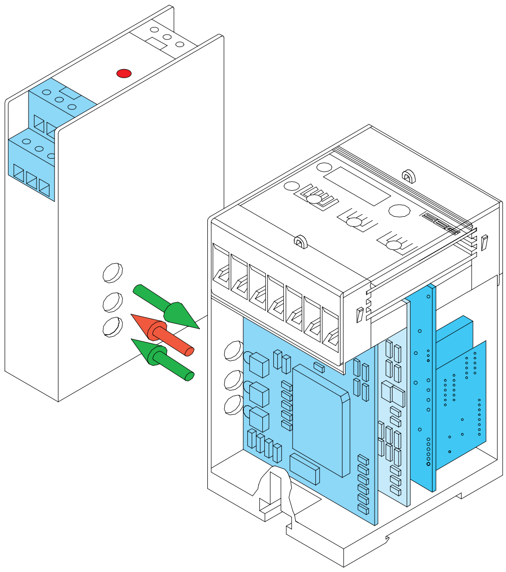


Fig.: 4.4: Communication principle

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 *XS2* 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).

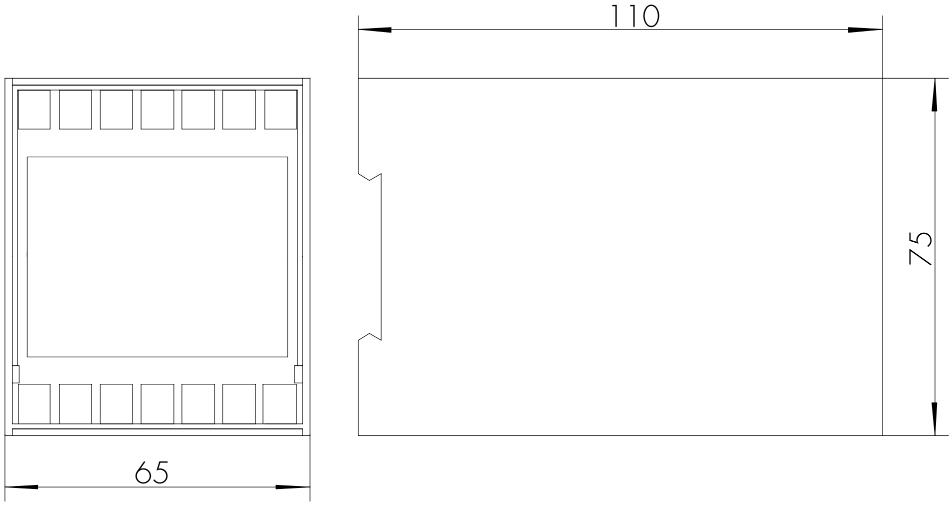


Fig. 5.1: Dimensional drawing

Connection terminals

The connection of up to a maximum 2 x 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 withstand capability in current circuits:	dynamic current withstand (half wave)	250 x In
	for 1 s	100 x In
	for 10 s	30 x In
	continuously	4 x In
Power consumption	at In = 1 A 0.1 VA	
in current circuit	at In = 5 A 0.1 VA	

Auxiliary voltage

Rated auxiliary voltage Uv/ Power consumption:	19 - 390 V DC or 36 - 275 V AC / 4 W (terminals A1 and A2)
Maximum permissible auxiliary voltage discontinuance t_u	U_V = 24 V_{DC}: t_u = 8 ms, U_V = 48 V_{DC}: t_u = 35 ms
	U_V > 60 V_{DC}: t_u = 50 ms

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:	120 ms
Minimum response time when supply voltage is available:	70 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:	2 % of In
Accuracy of time delay:	3 % DEFT / 7,5 % INV / or ± 30 ms
Transient overreach at instaneous operation:	≤ 5 %
Temperature effect:	0.02 % per K
Frequency effect:	3 % per K deviation from rated value
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. 0.5 kg
Mounting position:	any
Relay case material:	self-extinguishing

Parameter	Setting range	Graduation
I2s>	3 - 60 % In	Continuously variable
I2w>	3 - 25 % In	Continuously variable
DEFT / INV	0 -30 s / 0 - 300 s 100 - 300 s/ 100 - 3000 s	Continuously variable
tw	0 -25 s / 0 - 250 s	Continuously variable

Table 5.2: Setting ranges and graduation

Technical data subject to change without notice !

5.3 Tripping characteristic

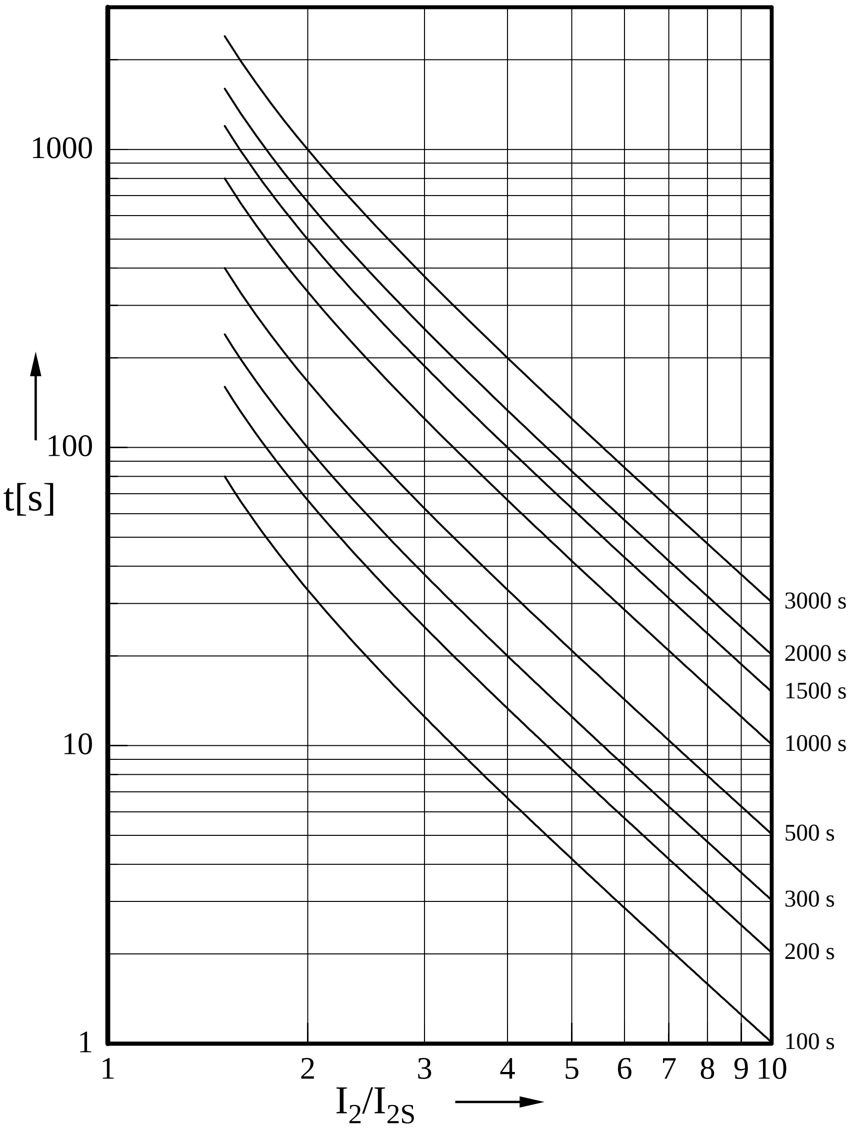


Fig. 5.2: Tripping characteristic

Setting-list *XS2*

Project: ______________________________ SEG job.-no.: ________________

Function group: = ____________ Location: + ________ Relay code: - ________________

Relay functions: ____________________________ Date: ________________

Setting of parameters

Function		Unit	Default settings	Actual settings
I2s>	Negative sequence tripping	% In	0	
I2W>	Negative sequence warning	% In	3	
t DEFT/INV	Tripping delay	s	0	

DIP-switch	Function	Default settings	Actual settings
1	Switch over for inverse time / definite time tripping (I2s>)	DEFT	
2			
3	Time multipier for DEFT-characteristic (I2s>)	x1	
4	Time multipier for INV-characteristic (I2s>)	x10	
5	Time multipier for tw (I2w>)	x1	
6	Rated frequency	50 Hz	
7			
8			

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