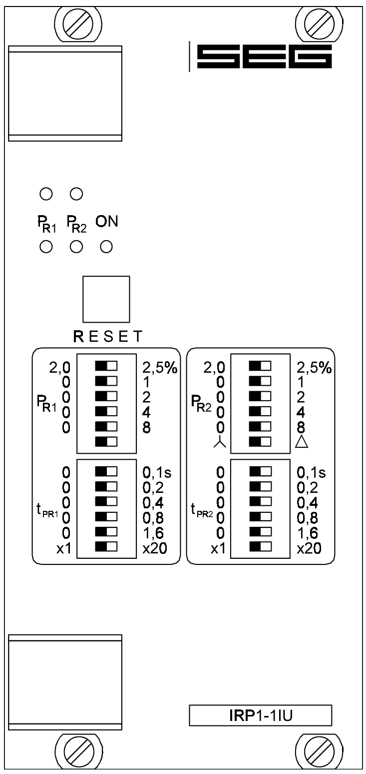
HIGH TECH LINE

IRP1 - Reverse power relay



Contents

1 Summary

When compared with traditional protection systems the protective relaying with ***MR***- and ***IR***-relays of our *HIGH TECH LINE* offers several advantages.

All ***MR*** protection relays are based on microprocessor technology. They present the generation of our most efficient protection relays, because of their capabilties to process the measuring values digitally and to perform arithmetical and logical operation. Additional advantages such as very low power consumption, adaptability, possibilities for self-supervision, flexible construction, selection of relay characteristics are completely utilized.

Some ***IR*** protection relays are based on microprocessor and some on analog technique. They present our low-priced protection relay generation and are used for all basic protection applications.

The following properties of the ***IR*** protection relays, such as:

- Integration of multiple protection functions into one compact housing,
- User-friendly setting procedure by means of DIP-switches,
- Compact design due to SMD-technique,

are their superiority over the traditional protection systems.

For all applications of a more complex nature, e.g. directional earth fault detection and where operating convenience, fault analysis and communication ability are required, ***MR***-relays are used.

All relays of the *HIGH TECH LINE* are available for through panel mounting and in 19" racks.
Connection terminals are of plug-in type.
All IEC/DIN regulations required for the individual application are reliably met by these relays.

2 Application

The ***IRP1*** is used for reverse power supervision in low voltage and medium voltage systems. The load is measured in one phase only on the assumption that the phases are loaded symmetrically.

Among other applications the relay can be used as reverse power relay for protection against reverse power of turbo generators and diesel gen.-sets if this prime mover fails.
For generators operating in parallel with a mains or another generator, it is imperative to supervise the power direction. If for example the prime mover fails the alternator operates as a motor and drives the prime mover (diesel or turbine). The ***IRP1*** "recognizes" the reverse of the power direction and switches off the alternator. This way, power losses and damages of the prime mover are avoided.

3 Features and characteristics

- Static protection relay
- Single-phase reverse power measuring P_{R1} and P_{R2}
- Sensitive reverse power measuring with fine graded adjustment
- Separate adjustable trip delay for P_{R1} and P_{R2}
- Star-delta adjustment
- Wide operating ranges of the supply voltage (AC/DC)
- Plug-in technology with self-shorting C.T. circuits
- Coding plug for presetting of LED indications and the trip relays
- Codable additional phase shifting

4 Design

4.1 Connections

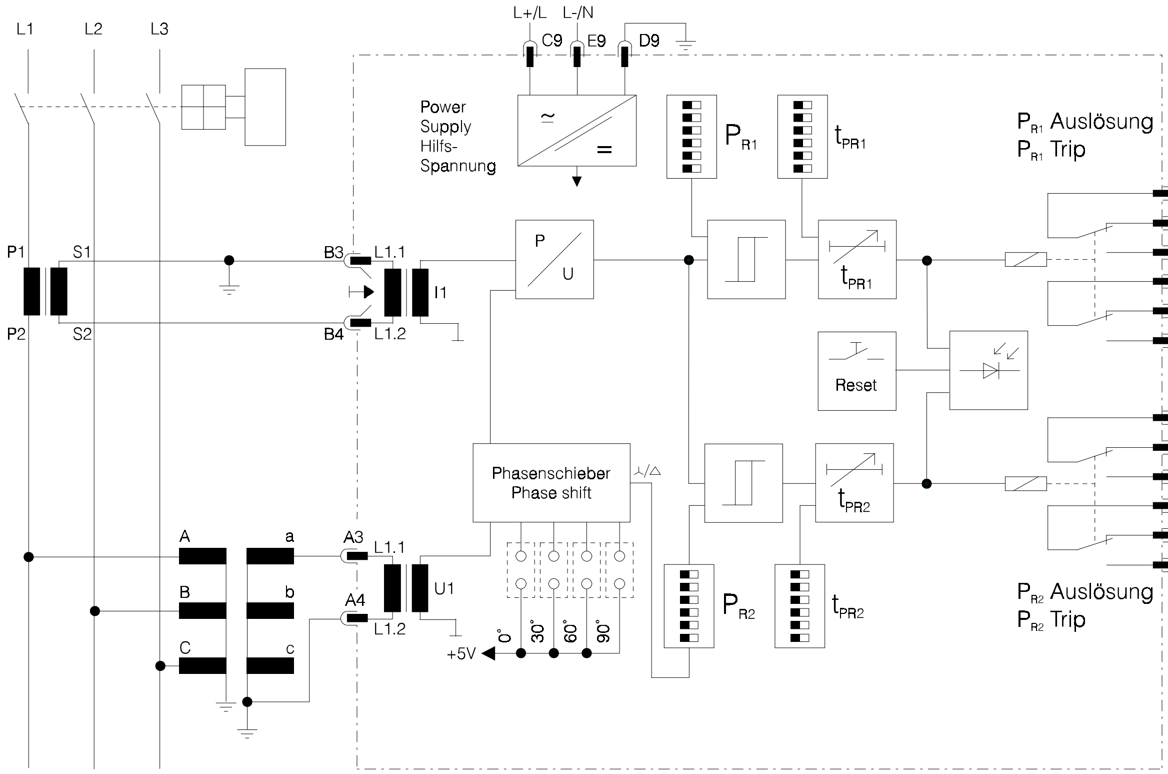


Fig. 4.1: Connection diagram IRP1

4.1.1 Analog input circuits

The analogue input signal of the phase current I_{L1} is led to the protection relay via terminals B3 - B4. The phase-to-phase or and phase-to-neutral voltage are connected via terminals A3 - A4. For medium voltage and high voltage systems a voltage transformer is needed for this. The system voltage of low voltage systems can be connected directly to the measuring inputs.

4.1.2 Output relays

The *IRP1* is equipped with two trip relays each with two change-over contacts:

- Tripping: C1, D1, E1; C2, D2, E2
- Tripping: C3, D3, E3; C4, D4, E4

4.2 Front plate

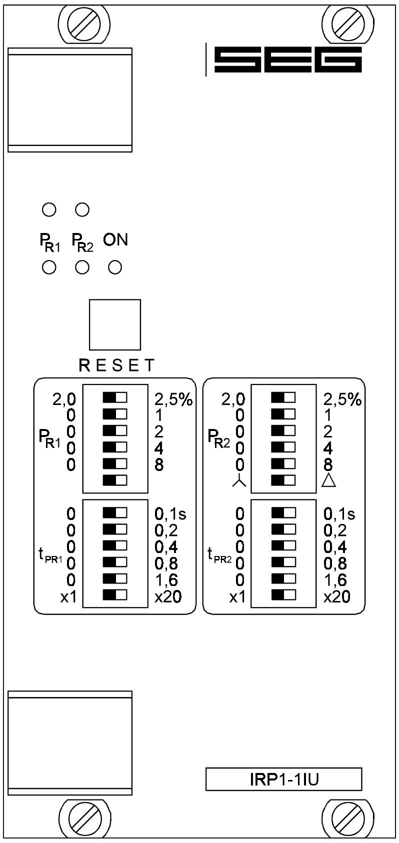


Fig. 4.2: Front plate

The front plate of the protective device *IRP1* comprises the following operation and indication elements:

- 4 DIP-switches for the setting of the tripping values and times
- 5 LEDs for pickup/trip indication and readiness for service
- 1 pushbutton <RESET>

4.2.1 LEDs

There are 5 LEDs at the front plate of the *IRP1* which indicate the following operational modes:

- Readiness for operation, LED ON (green)
- Pickup of P_{R1}, upper LED (yellow)
- Pickup of P_{R2}, upper LED (yellow)
- Trip of P_{R1}, lower LED (red)
- Trip of P_{R2}, lower LED (red)

4.2.2 DIP-switches

The 4 sets of DIP-switches on the front plate serve to adjust the tripping values and tripping times

4.2.3 <RESET>-pushbutton

Pushbutton <RESET> is used for acknowledgement and reset after fault clearance (refer to 4.3).
The LEDs and output relays which are encoded for latching must be reset manually by pressing the pushbutton <RESET>.

4.3 Code jumpers

There are 4 code jumpers behind the front plate of the *IRP1* at the lower part for presetting the LED indications and the trip behaviour of the output relays.
The yellow pickup LEDs cannot be coded, they light up as soon as the setting value is exceeded and extinguish automatically when the setting value is fall short.
Before leaving the factory, all code jumpers are pluged into their sockets.
The coding sockets are allocated to the functions as follows:

- coding socket 1 + 2 = reverse power tripping P_{R1}
- coding socket 3 + 4 = reverse power tripping P_{R2}

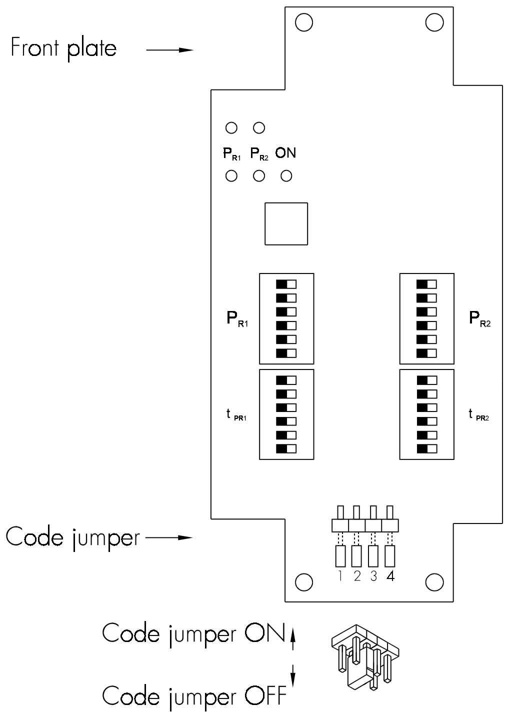


Fig. 4.3: Code jumper

Code jumper	Function	Code jumper position	Mode
1	Rerverse power indication P_{R1}	OFF	latching of red LED P_{R1}
		ON	automatic reset of red LED P_{R1}
2	Rerverse power tripping P_{R1}	OFF	latching of trip relay P_{R1}
		ON	automatic reset of trip relay P_{R1}
3	Rerverse power indication P_{R2}	OFF	latching of red LED P_{R2}
		ON	automatic reset of red LED P_{R2}
4	Rerverse power tripping P_{R2}	OFF	latching of trip relay P_{R2}
		ON	automatic reset of trip relay P_{R2}

Table 4.1: Function of code jumpers

4.3.1 Y/Δ - Adjustment

When connecting voltage inputs to phase-to-neutral voltage, current vector I_{L1} is parallel to voltage vector U_{1N} (at pure active power). DIP switch at the front must be in position Y. Angular displacement is 0°.
For connection to phase-to-phase voltage, current I_{L1} in phase L1 and voltage U_{23} are used for power calculation. In this case current vector I_{L1} is perpendicularly to voltage vector U_{23} (at pure active power). The DIP switch must be in position Δ. Angular displacement is 90°.

4.3.2 Coding of the phase shifter

Phase shifting between current and voltage can be adjusted from 0 - 90° by 30° steps. Consequently the actual phase shifting (dependent on the connection Y or Δ and the related phase shifting) is increased by the set value. In this manner a certain characteristical angle can be preadjusted. So the max. sensitivity of the relay can be set to cosφ = 0.87 and 0.5 inductive or capacitive. Together with Y/Δ adjustment any phase shifting between 0° - 180° is possible in 30° steps between current and voltage. This can be helpful if, for instance, U_{1N} or U_{23} are not available for measuring; it is also possible to use currents and voltages of other phases. In such a case sketching of a vector diagram is very useful.

The four coding facilities are on the PCB left to the front plate.

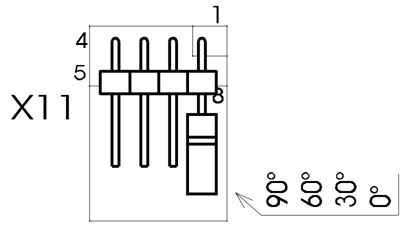


Fig. 4.4: Code jumpers for phase shifting

There is no phase shift adjusted with the initial adjustment (0°), i.e. coding plug applied at the right. If the coding plug is applied one, two or three positions further to the left this means the phase is shifted 30°, 60° or 90°. The trip function is blocked if either a second coding plug is applied or there is no coding plug at all.

Y/ Δ	Adjustment	Angular displacement between I_{L1} and U_{1N}
Y	0°	0°
	30°	30°
	60°	60°
	90°	90°
Δ	0°	90°
	30°	120°
	60°	150°
	90°	180°

5 Working principle

The *IRP1* is provided with two output relays P_{R1} and P_{R2}, having separate adjustable pickup values and trip delays.

Measuring principle:
Voltage and current measured are galvanically decoupled via the input CT. Dependent on relay connection (Y or Δ) and encoding, either phase-to-neutral voltage U_{1N} or phase-to-phase voltage U_{23} is used as reference voltage for load calculation. Current is measured in phase L1.

For the *IRP1* a stable system voltage is required. The load is calculated by evaluating value and phase angle of the current. If the set thresholds P_{R1} or P_{R2} are exceeded, the respective supervision circuit picks up and the corresponding LED lights up yellow. After the set trip delay has elapsed, the relay trips and respective LED lights up red.

5.1 Calculation of the setting value at reverse power

Should the relay, for instance, trip at a generator reverse power of 10 %, this does not mean that the setting value of the *IRP1* is 10 %. Based on the transformer transformation ratio, the switching point has to be calculated.

The *IRP1* measures the power in one phase of the transformer secondary side. The power is assumed to be symmetrical

The generator phase power must be related to the transformers secondary side.

Essential data

S_G[kVA]	rated generator apparent power
cos(φ):	rated generator power factor
In:	rated current of *IRP1*
Un:	rated voltage of *IRP1*
n_I:	transformation ratio of the CT
n_U:	transformation ratio of the VT

Connetion of the *IRP1* to phase-to-phase voltage:

Conversion of the generator phase power P_{GS} based on the CT secondary side:

$$P_{GS} = \frac{S_G \cdot \cos(\varphi)}{\sqrt{3} \cdot n_U \cdot n_I}$$

With the permissible generator reverse power P_{GS} , the setting value P_R is then calculated as follows:

$$P_{R>}(\%) = \frac{\frac{S_G \cdot \cos(\varphi)}{\sqrt{3} \cdot n_U \cdot n_I}}{Un \cdot In} \cdot P_{RG}(\%)$$

Calculation example 1: Medium voltage 10 kV

- generator apparent power: S_G = 1875 kVA
- rated power factor: cos(φ) = 0,8
- rated voltage of *IRP1*: Un = 110 V (phase-to-phase voltage)

When the relay is expected to trip at a generator reverse power of 6 %, calculation of the setting value is as follows:

$$P_R > (\%) = \frac{\frac{1875\ kVA \cdot 0{,}8}{\sqrt{3} \cdot 20 \cdot 100}}{110\ V \cdot 5A} \cdot 6(\%) \approx 5\%$$

According to the above example, the *IRP1* has to be set to 5 % so that it trips at a generator reverse power of 6 % (rated generator active power).

Connection of the *IRP1* to phase-to-neutral voltage

Conversion of the generator phase power P_{GS} based on the transformer secondary side:

$$P_{GS} = \frac{S_G \cdot \cos(\varphi)}{3 \cdot n_U \cdot n_I}$$

With the permissible generator reverse power P_{GS}, the setting value P_R is then calculated as follows:

$$P_{R>}(\%) = \frac{\frac{S_G \cdot \cos(\varphi)}{3 \cdot n_U \cdot n_I}}{Un \cdot In} \cdot P_{RG}(\%)$$

Calculation example 2: Low voltage 400 V, connection-to-phase voltage

- generator apparent power: S_G = 625 kVA
- rated power factor: cos(φ) = 0,8
- rated current of *IRP1*: In = 5 A
- rated voltage of *IRP1*: Un = 230 V (phase-to-neutral voltage)
- transformation ratio of the CT: n_I = 1000 A / 5 A
- no VT required

When the relay is expected to trip at a generator reverse power P_{RG} of 5 %, calculation of the setting value $P_{R>}$ is as follows:

$$P_{R>}(\%) = \frac{\frac{625\ kVA \cdot 0{,}8}{3 \cdot 1 \cdot 200}}{230\ V \cdot 5A} \cdot 5(\%) = 3{,}6\% \approx 4\%$$

According to the above example, the *IRP1* has to be set to 4 % so that it trips at a generator reverse power of 5 % (rated generator active power).

6 Operations and settings

6.1 Setting of the parameters by means of DIP-switches

All DIP-switches required for setting of the parameters are located on the front plate.

6.1.1 Setting of the pickup value for reverse power supervision

The pickup values for reverse power tripping P_{R1} or P_{R2} can be adjusted by the DIP switches in a range from 2 % to 17.5 % P_N in 0.5 % steps. The pickup value is calculated from the total of all DIP switch positions.

Example:
A pickup value P_{R1} of 5.5 % of the rated power is to be adjusted

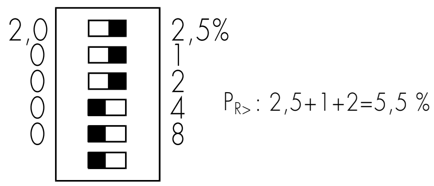


Fig. 6.1:Adjustment example

6.1.2 Setting of the trip delays

The trip delays t_{PR1} and t_{PR2} can be adjusted by the DIP switches in a range from 0.1 s to 62 s with a grading of 0.1 s or 2 s. The pickup value is calculated from the total of all DIP switch positions.

Example:
A delay time of 14 s is to be adjusted:

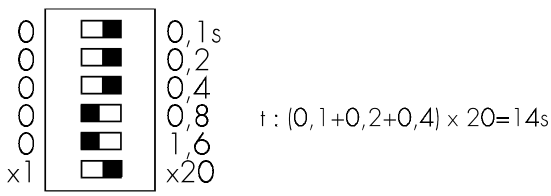


Fig. 6.2: Setting of the delay times

6.2 Fault indication

There are four LEDs at the front plate of the *IRP1* for indicating faults. The pickup LEDs above P_{R1} and P_{R2} light up yellow, and LEDs below P_{R1} and P_{R2} light up red when the respective output relay trips.

6.3 Reset

6.3.1 Manual reset

When the <RESET> push button is pressed, the trip relay is reset and the LED indication extinguishes. This on condition that all code jumpers are unpluged.

6.3.2 Automatic reset

Code jumpers 1 and 3:
The yellow and red fault indications (LED P_{R1} and $P_{R2)}$) are coded for latching if the code jumpers are not applied to sockets 1 and 3. Therefore any fault indication can only be reset manually by pressing the <RESET> push button.

If the code jumpers are applied to sockets 1 and 3, the fault indication is automatically reset as soon as the fault is removed.

Code jumpers 2 and 4:
The trip relays are coded for latching if the code jumpers are not applied to sockets 2 and 4. Therefore any fault indication can only be reset manually by pressing the <RESET> push button.
If the code jumpers are applied to sockets 2 and 4, the fault indication is automatically reset as soon as the fault is removed.

7 Housing

The *IRP1* can be supplied in an individual housing for flush-mounting or as a plug-in module for installation in a 19" mounting rack according to DIN 41494. Both versions have plug-in connections.
Relays of variant D are complete devices for flush mounting, whereas relays of variant A are used for 19" rack mounting. Housing variant A to be installed in switchboards of protection class IP51. For switchboards of lower protection classes housing variant D can be used.

7.1 Individual housing

The individual housing of the *IRP1* is constructed for flush-mounting. The dimensions of the mounting frame correspond to the requirements of DIN 43700 (72 x 144 mm). The cut-out for mounting is 68 x 138 mm.

The front of the *IRP1* is covered with a transparent, sealable flap (IP54).
For case dimensions and cut-out refer to "technical data". The individual housing is fixed with the supplied clasps from the rear of the switchboard panel.

7.2 Rack mounting

The *IRP1* is in general suitable for installation in a modular carrier according to DIN 41494. The installation dimensions are: 12 TE; 3 HE.
According to requirements, the *IRP1*-devices can be delivered mounted in 19" racks.
If 19" racks are used the panel requires protection class IP51. For switchboards with lower degree of protection must be used individual housing.

7.3 Terminal connections

The plug-in module has a very compact base with plug connectors and screwed-type connectors.

- max. 4 poles screw-type terminals for voltage and current circuits (terminal connectors series A and B with a short time current capability of 500 A / 1 s).
- 27 poles tab terminals for relay outputs, supply voltage etc.(terminal connectors series C, D and E, max. 6 A current carrying capacity). Connection with tabs 6.3 x 0.8 mm for cable up to max. 1.5 mm^2 or with tabs 2.8 x 0.8 mm for cable up to max. 1 mm^2.

By using 2.8 x 0.8 mm tabs a bridge connection between different poles is possible.

The current terminals are equipped with self-closing short-circuit contacts. Thus, the *IRP1*-module can be unplugged even with current flowing, without endangering the current transformers connected.

The following figure shows the terminal block of *IRP1*

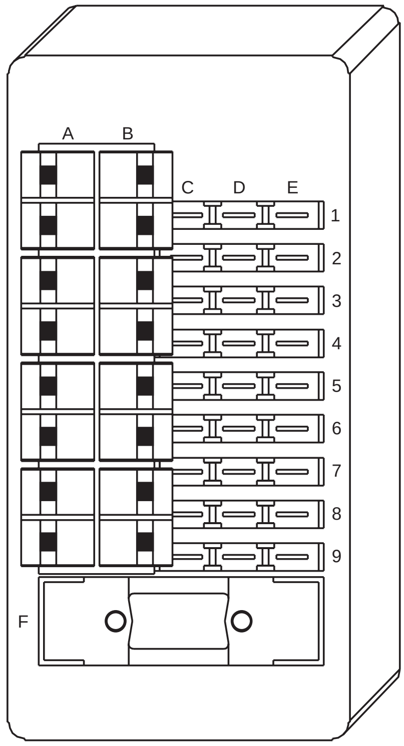


Fig. 7.1: Terminal block of IRP1

8 Relay testing and commissioning

The following test instructions should 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 are connected to the relay correctly.
- all signal circuits and output relay circuits are connected correctly.

8.1 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 (terminals C9/E9) and check that the LED "ON" on the front lights up green.

8.2 Checking the set values

Check all relay set values and see if they are set correctly as you have desired. Set values can be modified by means of the DIP-switches on the front.

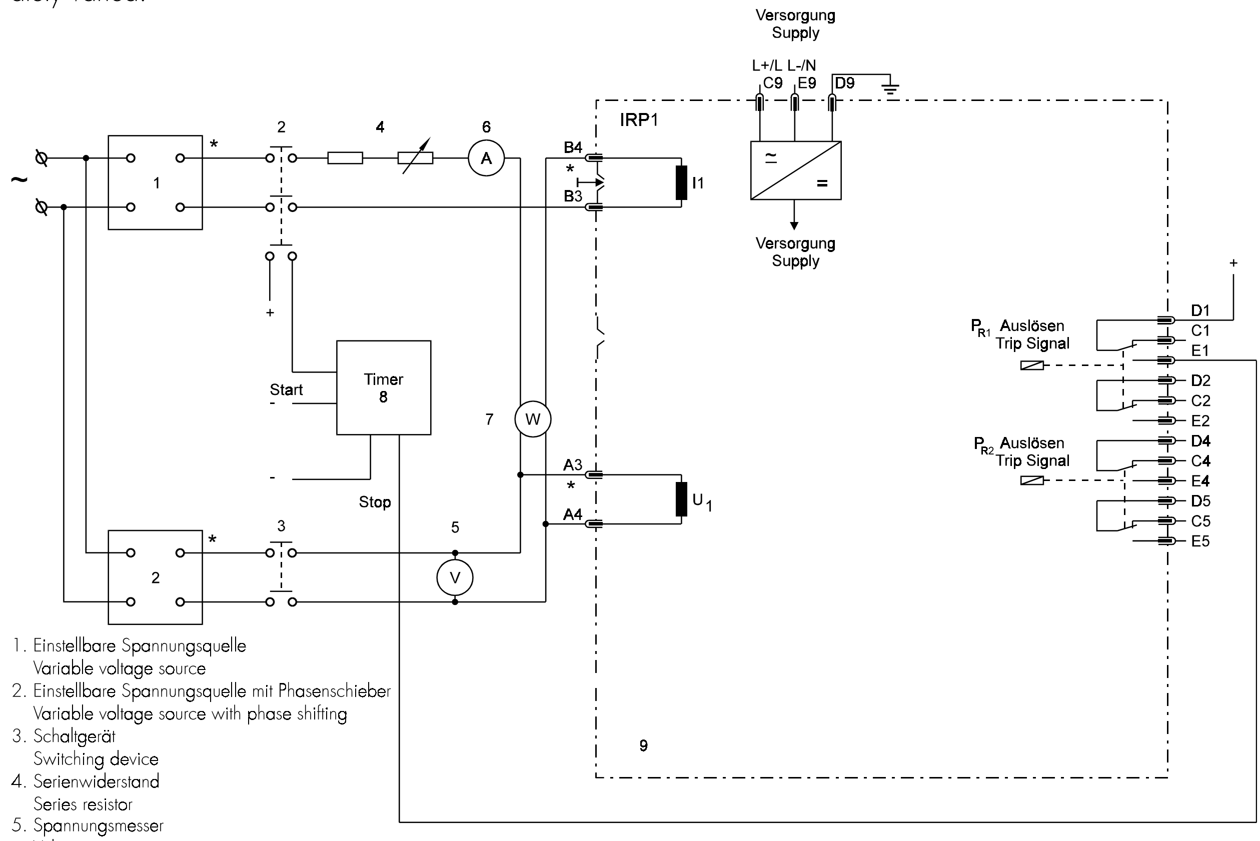
8.3 Secondary injection test

8.3.1 Test equipment

- Voltmeter with class 1 or better
- Ammeter with class 1 or better
- Powermeter 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 ≥ 2.0 x I_N)
- Single-phase voltage source (adjustable from 0 to ≥ 1.2 x U_N)
- Timer to measure the operating time
- Switching device
- Test leads and tools

8.3.2 Test circuit

For testing power relays, you need both current and voltage input signals with adjustable phase shifting. Figure 8.1 shows an example of a single phase test circuit with adjustable voltage and current energizing the *IRP1* relay under test.
For testing the power relay, the input voltage shall be applied to the relay via terminals A3/A4. The input current (B3/B4) and phase angle shall be appropriately varied.



1. Einstellbare Spannungsquelle
   Variable voltage source
2. Einstellbare Spannungsquelle mit Phasenschieber
   Variable voltage source with phase shifting
3. Schaltgerät
   Switching device
4. Serienwiderstand
   Series resistor
5. Spannungsmesser
   Voltmeter
6. Strommesser
   Ammeter
7. Leistungsmesser
   Wattmeter
8. Zeitgeber
   Timer
9. zu testendes Relais
   Relay under Test

Fig. 8.1: Test circuit

With regard to the right polarity great care must be taken when applying the test current and test voltage to the relay. In figure 8.1 the relay and test source polarity are indicated by a * mark near the terminals. If the voltage and current sources are connected acc. to the above test circuit diagram, the reverse power will be measured correctly.

8.3.3 Checking the operating and resetting values of the relay

A test voltage equal to the rated voltage has to be applied to terminals A3/A4. For checking the operating and resetting values the test current must be increased until the relay picks up. LED P_{R1} or P_{R2} lights up.

The deviation of power measurement related to the reading of the power meter must not exceed 5% (refer to 5.1)

The reset value is ascertained by decreasing test current gradually until the relay P_{R1} or P_{R2} releases (with the relevant coding, see chapter 6.3.2). The reset value must not exceed 0.95 times the operating value.

8.3.4 Checking the trip delay

To check the trip delay, a timer to is be connected to the trip relay contact. The timer should be started simultaneously with the current injection in the current input circuit and stopped by the trip relay contact. Apply rated voltage to the relay and set the current to a value corresponding to twice the pickup value and inject the current instantaneously. The trip delay measured by timer should have a deviation <3% of the set value or 20 ms (in case of a short trip delay).

8.4 Primary injection test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test above described. Since the cost and potential hazards are very high for such a test, especially if staged fault tests are intended, primary injection tests are usually limited to very important protective relays in the power system.

8.5 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 static relays like *IRP1*, maintenance testing will be performed at least once a year according to the experiences.

9 Technical Data

9.1 Measuring input

Rated data:

Nominal voltage:	100 V; 230 V; 400 V	
Nominal current I_N:	1 A or 5 A	
Nominal frequency f_N:	50/60 Hz	
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 capability in voltage circuit:	continuously	2 x U_N
	for 400 V	1.2 x U_N

9.2 Auxiliary voltage

Rated auxiliary voltages U_H:	24 V	operating range	16 - 60 V AC / 16 - 80 V DC
	110 V	operating range	50 - 270 V AC / 70 - 360 V DC
Power consumption:	at 24 V	standby approx. 3 W operating approx. 6 W	
	at 110 V	standby approx. 3 W operating approx. 6 W	

9.3 General data

Permissible interuption of the supply voltage without influence on the function:	50 ms
Dropout to pickup ratio:	>95 %
Returning time:	30 ms
Minimum operating time:	30 ms

9.4 Output relays

The output relays have the following characteristics:

maximum breaking capacity: 250 V AC / 1500 VA / continuous current 6 A

for DC-voltage:

	ohmic	L/R = 40 ms	L/R = 70 ms
300 V DC	0.3 A / 90 W	0.2 A / 63 W	0.18 A / 54 W
250 V DC	0.4 A / 100 W	0.3 A / 70 W	0.15 A / 40 W
110 V DC	0.5 A / 55 W	0.4 A / 40 W	0.2 A / 22 W
60 V DC	0.7 A / 42 W	0.5 A / 30 W	0.3 A / 17 W
24 V DC	6 A / 144 W	4.2 A / 100 W	2.5 A / 60 W

Max. rated making current:	64 A (VDE 0435/0972 and IEC 65/VDE 0860/8.86)
mechanical life span:	30 x 10^6 operating cycles
electrical life span:	2 x 10^5 operating cycles at 220 V AC / 6 A
Contact material:	silver cadmium oxide (AgCdO)

9.5 System data

Design standard:	
Generic standard:	EN 50082-2, EN 50081-1
Product standard:	EN 60255-6, IEC 255-4, BS 142
Specified ambient service	
Storage temperature range:	- 40°C to + 85°C
Operating temperature range:	- 20°C to + 70°C
Environmental protection class F as per DIN 40040 and per DIN IEC 68 2-3:	relative humidity 95 % at 40°C for 56 days
Insulation test voltage, inputs and outputs between themselves and to the relay frame as per EN 60255-6 and IEC 255-5:	2.5 kV (eff.), 50 Hz; 1 min
Impulse test voltage, inputs and outputs between themselves and to the relay frame as per EN 60255-6 and IEC 255-5:	5 kV; 1.2 / 50 µs; 0.5 J
High frequency interference test voltage, inputs and outputs between themselves and to the relay frame as per EN 60255-6 and IEC 255-22-1:	2.5 kV / 1MHz
Electrostatic discharge (ESD) test as per EN 61000-4-2 and IEC 255-22-1:	8 kV air discharge, 6 kV contact discharge
Electrical fast transient (Burst) test as per EN 61000-4-8 and IEC 801-4:	4 kV / 2.5 kHz, 15 ms
Power frequency magnetic field test as per ENV 50141:	electric field strength 10 V/m
Surge immunity EN 61000-4-5:	4 kV
Radio interference suppression test as per EN 55011:	limit value class B
Radio interference radiation test as per EN 55011:	limit value class B

Mechanical tests:

Shock:	class 1 acc. to DIN IEC 255 part 21-2
Vibration:	class 1 acc. to DIN IEC 255 part 21-1
Degree of protection:	IP54 by enclosure of the relay case and front panel (relay version D)
Weight:	approx. 1.5 kg
Pollution degree:	2 where design A is used 3 where design D is used
Overvoltage class:	III

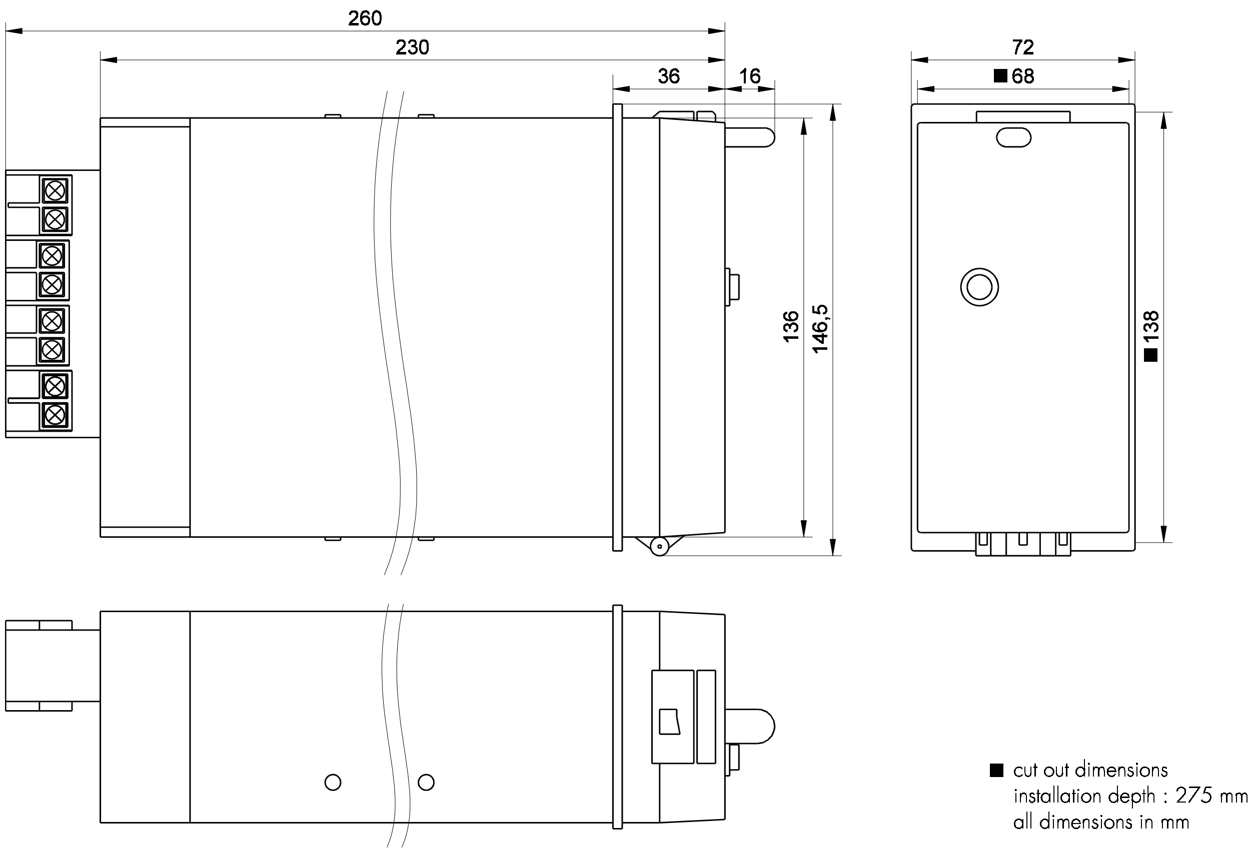
Influencing parameters:

Frequency:	40 Hz < f < 70 Hz: <3% of the set value
Temperature:	-20°C bis +70°C
Aux. voltage:	no influence in the permissible range

9.6 Setting ranges and graduation

Parameter	Setting range	Graduation	Tolerance
P_{R1} and P_{R2}	2% … 17.5% x P_N	0.5%	±5% of setting value
t_{PR1} and t_{PR2}	0.1 s … 3.1 s 2.0 s … 62 s	0.1 s 2.0 s	±3% or ±20 ms

9.7 Dimensional drawing



Please observe:
A distance of 50 mm is necessary when the units are mounted one below the other for the housing bonnet to be easily opened. The front cover can be open downwards.

10 Order form

Reverse power relay	IRP1 -	1	I		U			
Power measuring single phase								
Rated current: 1 A				1				
5 A				5				
Rated voltage: 100 V						1		
230 V						2		
400 V						4		
Auxiliary voltage (AC/DC):								
24 V (16 V to 60 V AC / 16 V to 80 V DC)							L	
110 V (50 V to 270 V AC / 70 V to 360 V DC)							H	
Housing (12TE): 19"- rack								A
Flush mounting								D

Setting list *IRP1*

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

Project: ______________________________ SEG job.-no.: ______________________

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

Relay functions: ______________________________

Setting of parameters

Parameter		Unit	Default settings	Actual settings
Δ/Y	Adjustment	-	Δ	
P_{R1}	Pickup value	%	2.0	
t_{PR1}	Trip delay of the first reverse power element	s	0.1	
P_{R2}	Pickup value of the second reverse power element	%	2.0	
t_{PR2}	Trip delay of the second reverse power element	s	0.1	
–	Phase angular displacement	°	0°	

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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