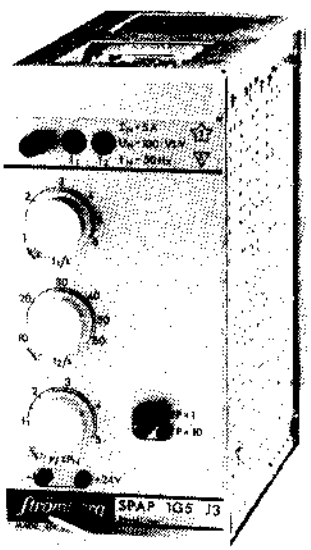
Definite time
REVERSE POWER RELAY

SPAP 1G1 J3
SPAP 1G5 J3

Static power relay
Number of phases
Spacing letter
Rated current in amps
Mechanical construction code

Main features

- reverse power protection for any type of a.c. power generators and their prime movers
- wide setting ranges and accurate measurement
- the relay operates satisfactorily down to 50 % of nominal voltage and maintains accuracy for power factors down to 0,01
- two separate output stages, one with a short time-lag and the other with a longer time-lag
- mechanically solid design and resistant against electrical and electro-magnetical interference
- effectively protected against maloperation caused by harmonics in the energizing quantities



The relay plug-in unit type SPAP 1G5 J3

Contents

Area of application

The reverse power relays SPAP 1G1 J3 and SPAP 1G5 J3 are applied for protection of a.c. power generators, their prime movers and their power transmission systems against injury and damage, caused by a reversal of power flow. The reverse power relay also trips the generator from the network, if the prime mover, i.e. a gas, steam or hydro turbine or a diesel engine, is disturbed in its operation and power output, resulting in a power flow reversal and a risk for the generator starting motoring.

The first stage of the reverse power relay can be used for bringing the generating set to a standstill rapidly and softly, if the prime mover is shut down before the reverse power relay has operated. When the prime mover is shut down, the kinetic energy of the power set is fed into the network in the form of electric energy, whereafter the generator breaker is tripped without risks for overspeeding the generator. The tripping signal from the first stage of the reverse power relay is linked over an auxiliary contact of the prime mover shut down valve to the generator breaker trip coil. The second stage of the reverse power relay operates as back-up tripping stage.

The reverse power relay is also applied in other applications, e.g. for supervision of the flow of power in network interconnections or for supervision of certain power levels.

If the reverse power relay is to be given a very low setting, i.e. < 2 % rated power, the instrument transformers should as to their angular displacement comply with the requirements of class 0,5 instrument transformers.

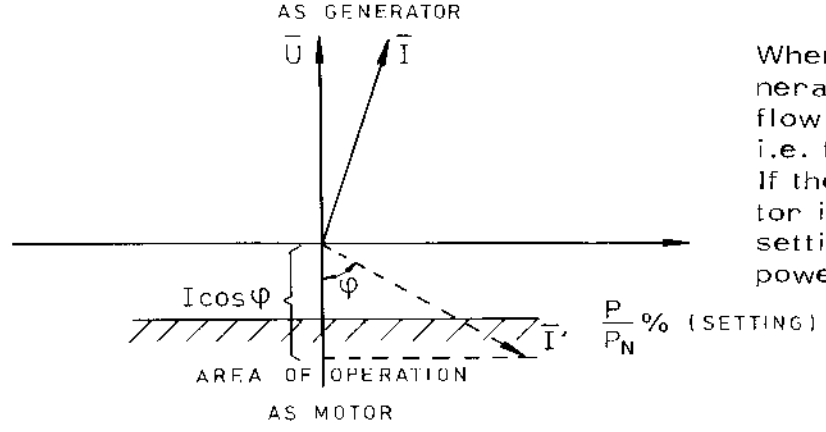
Principle of operation

The reverse power relay measures the phase to neutral voltage and the line current of the same phase. The power measurement and the determination of the direction of the power flow are based on multiplying the line current and the power factor, i.e. on I x cosφ. The relay assumes the voltage to be constant and variations in the voltage level only influence the accuracy of the I cosφ measurement.

The relay operating value is set as a relative value to the relay rated power, i.e. P/P_N expressed in percent. The setting is accurate, as long as the energizing voltage equals the relay rated voltage. If the energizing voltage differs from the relay rated voltage, the setting P/P_N expressed in percent is corrected with a factor k, see example on page 5.

The relay starts, when the power exceeds the set starting level and the power flows in the direction measured by the relay, or:

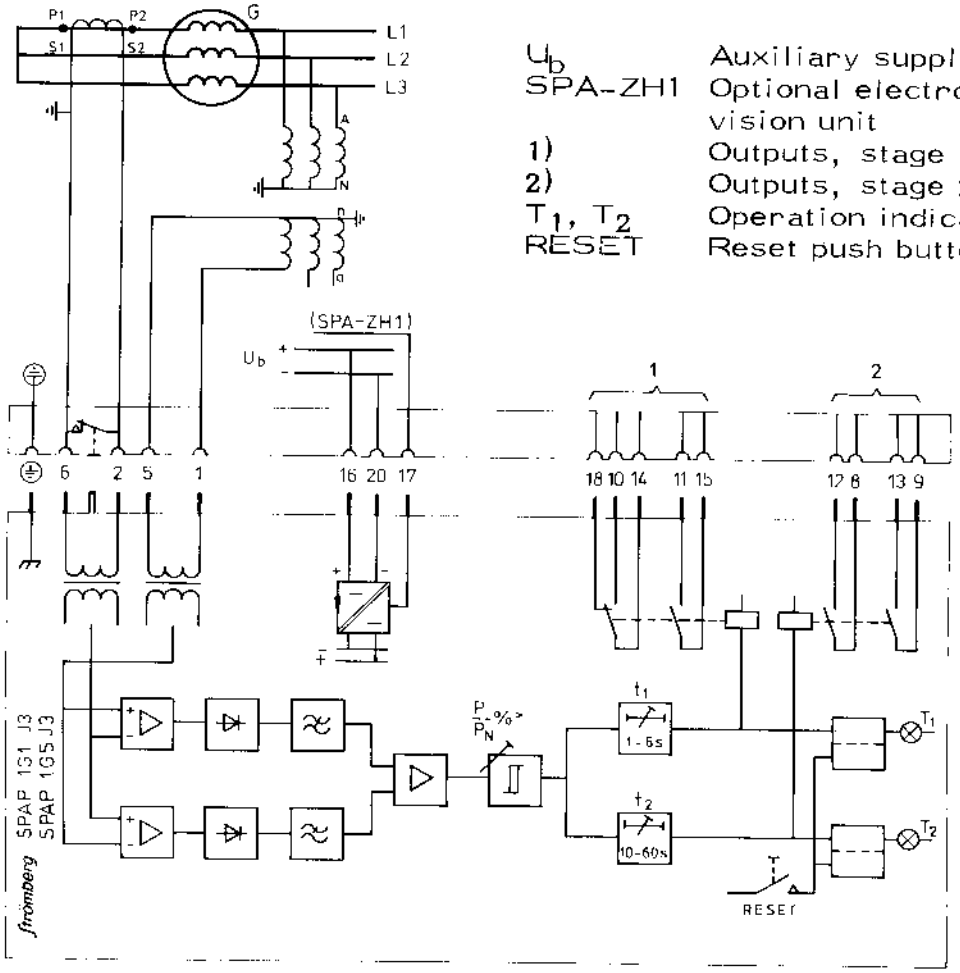
$$\frac{(I \cdot \cos\varphi) \cdot U_N}{I_N \cdot U_N} \cdot 100\ \% > \frac{P}{P_N}\ \%$$



When the prime mover of the generator is disturbed, the power flow of the generator is reversed, i.e. the generator starts motoring. If the power drawn by the generator in this situation exceeds the setting of the relay, the reverse power relay operates.

Fig. 1. The operating characteristic of the reverse power relays

Block schematic diagram



U_b	Auxiliary supply voltage
SPA-ZH1	Optional electronics' voltage supervision unit
1)	Outputs, stage 1
2)	Outputs, stage 2
T_1, T_2	Operation indicators
RESET	Reset push button

Block schematic diagram and typical connection of the reverse power relays SPAP 1G1 J3 and SPAP 1G5 J3

Connections

The reverse power relays are provided with two energizing inputs, one for the phase current, input 2-6, and the other for the phase to neutral voltage, input 1-5. The rated voltage of the voltage input is $100/\sqrt{3}$ V and the rated current is 1 A for the relay SPAP 1G1 J3 and 5 A for the relay SPAP 1G5 J3. The relay plug-in unit can be withdrawn from and inserted into its case with the relay in operation. For this reason the energizing current input is provided with an automatically operating bridge contact, which short-circuits the current transformer secondary, when the relay plug-in unit is withdrawn from its case.

The auxiliary supply voltage is fed to the relay terminals 16 and 20, the terminal 16 being positive and the terminal 20 negative. The relay is not damaged by a reversed polarity, but the internal supply unit of the relay does not start. If the relay is a.c. supplied, the polarity of the supply is free. A label on the left-hand side of the relay plug-in unit states the auxiliary supply voltage range, for which the relay is intended.

The first operating stage is provided with a heavy-duty output relay with one normally open contact 11-15 and one change-over contact 10-14-18. The second operating stage is also provided with one heavy-duty output relay with two normally open contacts. The contacts have a making and breaking capability dimensioned for a direct control of a circuit-breaker trip circuit.

An optional electronics' voltage supervision unit can be connected to the terminal 17 and to the earth terminal ⏚. The supervision unit provides an alarm signal over a normally closed contact, if the level of the internal electronics' voltage turns abnormal.

Operation indicators and reset push button

Indications and resetting

When the reverse power relay has started and the set time-lag t_1 has run out, the first stage operates, i.e. its output relay picks up and the indicator T_1 turns on, glowing with red colour. If also the time-lag t_2 runs out, the second stage of the relay operates and the indicator T_2 turns on also glowing red. The indications persist, until they are acknowledged by pushing the common reset push button on the relay front panel, adjacent to the indicators. An auxiliary voltage cut-off also resets the indicators.

The operation indicators, whether reset or not after a fault, do not in any way interfere with the basic relay functions. The relay is always prepared to operate, even if a previous fault indication has not been acknowledged.

Electronics' voltage checking

The operation indicator T_1 and the common reset push button can be used for a rapid check of the internal electronics' voltage. Whenever the relay is connected to a proper auxiliary supply and the reset push button is pressed, the indicator T_1 should glow weakly, thus indicating a correct internal voltage level. The check of the internal electronics' voltage does not interfere with the basic relay functions and the check is not to be regarded as a complete relay test.

Auxiliary supply voltage

For proper operation the protective relay requires a continuous supply of auxiliary energy, taken from a suitable d.c. or a.c. source. The level and the type, i.e. a.c. or d.c., of the auxiliary supply voltage, which will be used for supply of the relay, is to be included with the order information.

Normally, the protective relays are equipped with an internal d.c./d.c. converter, which permits any station battery voltage level within the range 40... 275 V d.c. to be used as auxiliary supply voltage for the relay. This standard power unit covers most of the battery voltage levels used in substations and power plants. A relay provided with the standard supply unit is interchangeable between different stations, as long as their battery voltage levels are within the above range.

On request, the relay is provided with an internal d.c./d.c. power unit for supply from a 17...40 V d.c. source. On request, the relay also is delivered with a power unit for a.c. supply from a 187...242 V, 50/60 Hz source.

A label on the left-hand side of the relay plug-in unit states the supply voltage range, for which the relay is specified.

The internal d.c./d.c. converter galvanically isolates the auxiliary supply network from the electronics of the relay and forms a stabilized 24 V d.c., which is the internal feed level of the electronics.

The internal 24 V d.c. can roughly be checked by pushing the reset push button on the relay front panel, also see section "Operation indicators and reset push button" on this page. When testing the relay, the internal voltage of the relay is measured in the output, marked -⊙⊙+ 24 V, on the relay front panel. The measuring outlet is short-circuit and overload protected. The voltmeter used for measuring should have an input impedance of $\geq 20\ k\Omega/V$ to provide an accurate meter reading. Too low an input impedance renders too low a meter reading. The internal voltage level is to be 23...25 V d.c.

The internal electronics' voltage can be continuously supervized by means of an optional supervision unit type SPA-ZH 1. The supervision unit delivers an alarm

signal through a normally closed contact, if the monitored voltage takes an abnormal level, if the relay supply voltage disappears or if the relay unit is withdrawn from its case during operation.

Relay settings

The reverse power relay is accurately set by means of continuously adjustable setting knobs and with a range selector plug on the relay front panel.

The operation level of the reverse power relay is set in percent of the rated power P_N. The total setting range is 0,5...50,0 % of P_N divided in two partial ranges, i.e. 0,5... 5,0 % corresponding to the range selector plug position P x 1, and 5...50 % corresponding to the range selector plug position P x 10. If the range selector plug is missing, the dial multiplier is P x 1.

The time-lag t_1 of the first output stage is continuously adjustable within the range 1...6 s.

Draw-out handle

Reset push button, operation indicators and relay ratings

Time-lag t_1 setting knob, stage 1

Locking screw

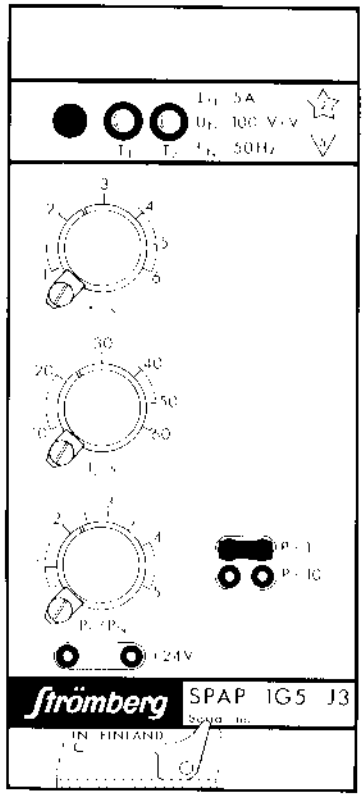
Time-lag t_2 setting knob, stage 2

Power level setting knob and range selector plug

Electronics' voltage measuring outlet

Type specification and serial number

Draw-out handle and locking latch



The time-lag t_2 of the second output stage is continuously adjustable within the range 10...60 s.

The operation level P in percent of the rated power P_N corresponds to the "relay rated power", which is defined by the relay rated voltage U_N and the relay rated current I_N. Thus the actual energizing voltage and the actual energizing current should be considered, when the relay is set.

Example of setting:
A generator rated P_N = 40 MW and U_N = 10 kV is provided with a reverse power relay, which is to operate at 3 % reverse power. The transforming ratios for the instrument transformers are 3000/5 A and $10000 : \sqrt{3}/100 : \sqrt{3}$ V. The relay operation level setting is:

$$\frac{P}{\%P_N} = \frac{P_N}{I_N \cdot U_N \cdot \sqrt{3}} \cdot 3\,\% = \frac{40 \cdot 10^6}{3 \cdot 10^3 \cdot 10^4 \cdot \sqrt{3}} \cdot 3\,\% \approx 2,3\,\%$$

The relay in the figure above has been given this setting.

Note! If the relay has been energized from voltage transformers with a rated secondary of $110 : \sqrt{3}$ V or any other level, the setting calculated above should be corrected with a factor k defined:

$$k = \frac{U}{U_N}$$ where U = the rated secondary energizing voltage, max. 110 V
U_N = the relay rated voltage $100 : \sqrt{3}$ V ≈

The corrected setting is: $k \cdot \frac{P}{P_N} = \frac{110 : \sqrt{3}}{100 : \sqrt{3}} \cdot 2,3\,\% \approx 2,5\,\%$

Technical data

	SPAP 1G1 J3	SPAP 1G5 J3
Energizing inputs		
Rated current I_N	1 A	5 A
Thermal current withstand, continuous/for 10 s/for 1 s	3 A/30 A/100 A	15 A/150 A/500 A
Dynamic current withstand, half-wave	250 A	1250 A
Input impedance	≤ 1,0 Ω	≤ 50 mΩ
Rated voltage U_N	$100/\sqrt{3}$ V	$100/\sqrt{3}$ V
Continuous withstand	110 V	110 V
Rated burden at U_N	≤ 0,2 VA	≤ 0,2 VA
Rated frequency f_N	50/60 Hz	50/60 Hz

Measuring circuits	
Setting range for the operation power P	0,5...50,0 % of P_N
Dial accuracy, applies over full setting range	± 5 %
Repetitive accuracy	± 2 %
Drop-out/pick-up ratio	≥ 0,95
Timing circuits	
Setting range for the time-lag t_1 of the first operating stage	1,0...6,0 s
Setting range for the time-lag t_2 of the second operating stage	10,0...60,0 s
Dial accuracy, applies over full setting range	± 5 %
Repetitive accuracy	± 2 %
Reset including drop-out time of the output relays	≤ 0,3 s
Auxiliary supply voltage	
Standard relay	40...275 V d.c.
Relay on request	17...40 V d.c. or 187...242 V, 50/60 Hz
Auxiliary supply burdens, relay under standby/tripping conditions	~ 4 W/~ 12 W
Influence on the relay operating values of the auxiliary supply within its permitted range of variation	± 0,5 %
Permitted ripple in d.c. supply as per IEC 255-11	≤ 12 %
Output contact ratings	
Make and carry for 0,5 s	30 A
Continuous carry	10 A
Rated voltage, make and break	250 V d.c./a.c.
Breaking capability for d.c., with the time constant L/R ≤ 40 ms, at the voltage levels 48/110/220 V d.c.	7 A/3 A/1 A
Contact numbers	8-12, 9-13, 11-15, 10-14-18
Contact material	$AgCdO_2$

Test voltages

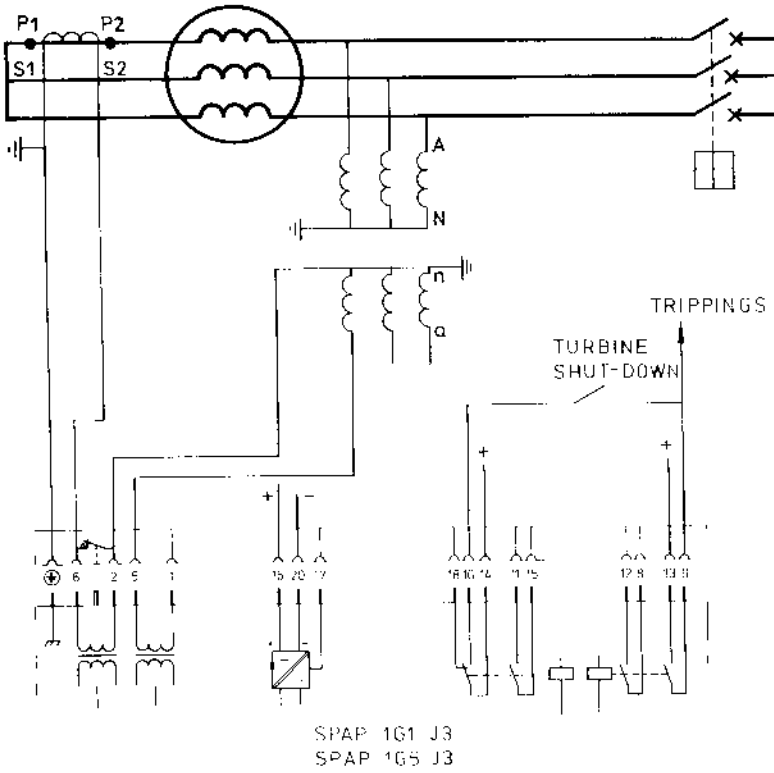
Insulation test voltage, inputs and outputs between themselves, inputs/outputs to the framework as per IEC 255-5, series C	2 kV, 50 Hz, 1 min
Impulse test voltage, inputs and outputs between themselves, inputs/outputs to the framework as per IEC 255-4, appendix E, class III	5 kV, 1,2/50 µs, 0,5 J
High frequency test voltage, inputs and outputs between themselves, inputs/outputs to the framework as per IEC 255-6, appendix C, class III	2,5 kV, 1 MHz
Spark interference test voltage, inputs and outputs between themselves, inputs/outputs to the framework as per SEN 36 15 03 class 3	4...8 kV

Environmental conditions

Relative humidity as per DIN 40040 class F	≤ 95 %, max. 30 d/a at +35°C
Specified operation temperature range	-10...+55°C
Temperature influence on the operating values of the relay over the operation temperature range	< 0,2 %/°C
The relay maintains its operating capability over the ambient temperature range	-25...+55°C
Storage temperature range	-40...+70°C
Degree of protection of the relay cases	IP 40
Mass of the relay unit	3,2 kg

Examples of applications

Example 1. Reverse power protection for steam turbine driven generator

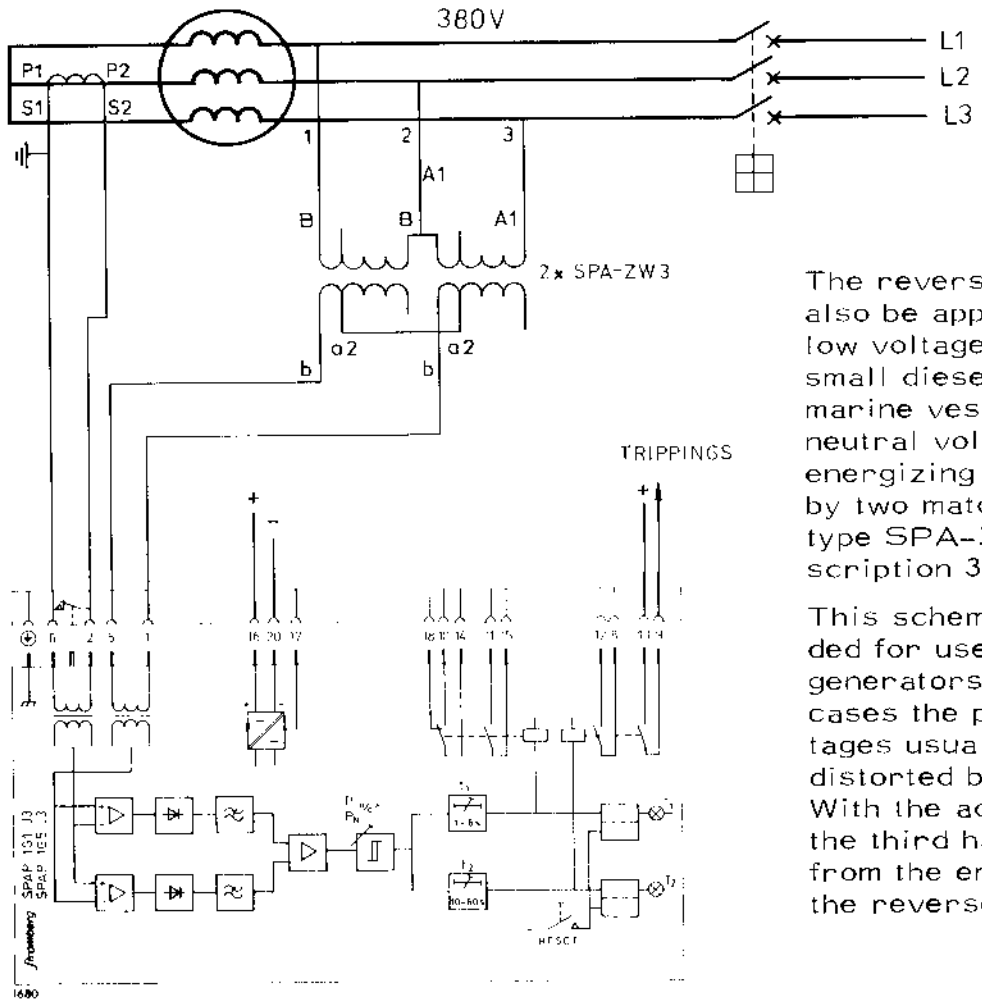


The tripping signal of the first stage is wired over an auxiliary contact of the turbine shut-down valve, while the tripping signal of the second stage is wired directly to the generator circuit-breaker trip coil.

The solution above enables the generator to be softly brought to a standstill and tripped by the first stage, if a shut-down has been carried out. If no shut-down has been carried out, the second stage trips the generator in a reverse power situation.

The solution can be used also for other types of prime movers than steam turbines.

Example 2. Reverse power protection for low voltage generator



The reverse power relay can also be applied for protection of low voltage generators, e.g. on small diesel generating sets on marine vessels. The phase to neutral voltage required for energizing the relay is formed by two matching transformers type SPA-ZW 3, see also description 34 SPA 32 EN 1.

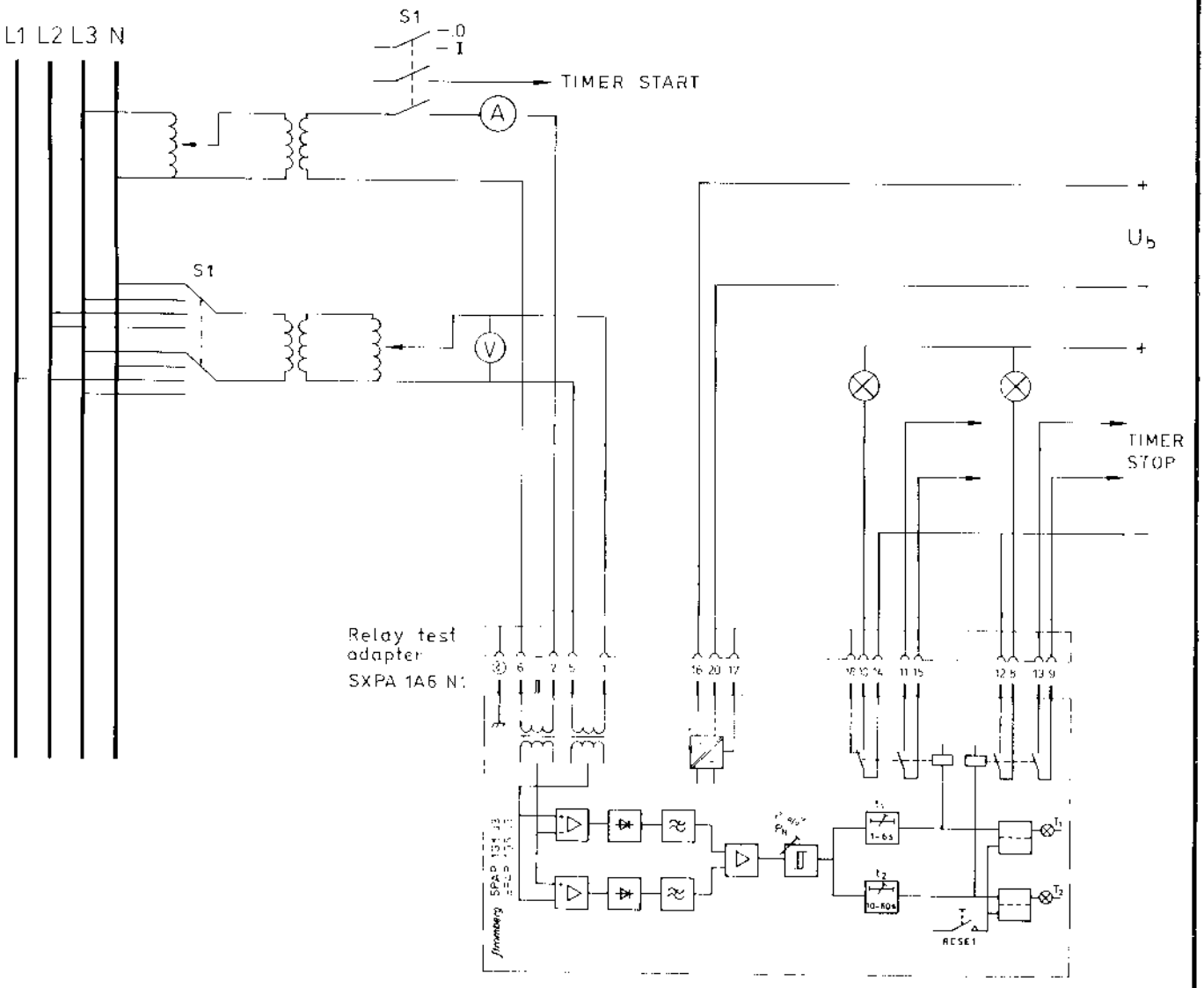
This scheme is also recommended for use with asynchronous generators, because in these cases the phase to phase voltages usually are more or less distorted by a third harmonic. With the adjacent connection the third harmonic is eliminated from the energizing voltage of the reverse power relay.

Secondary testing

The ability of a protective relay to properly perform its task is best verified by testing the relay at certain intervals. If not otherwise prescribed by local authority regulations or by the general practice of the company, it is recommended that the relays are tested every third year. Relays operating under abnormal environmental conditions are tested every second year or a visual check of the relay is included in the maintenance program of the installation.

For secondary testing of the relays the universal relay test adapter type SXPA 1A6 N1 and a conventional relay test set, e.g. the type SXPA 260A120 N1 by Strömberg or any other suitable manufacture, is used. The relay test set is, if necessary, supplemented with or completely substituted by the following testing accessories:

- two isolating transformers
- two regulating transformers
- timer with start/stop function
- one ammeter and one voltmeter
- d.c. source for supply of auxiliary voltage (e.g. the station battery)
- switches and indicator lamps



Secondary test circuit for the reverse power relays SPAP 1G1 J3 and SPAP 1G5 J3

Before starting the test procedure, the following prechecks are advisable:

- the test circuit is controlled
- the relay electronics' voltage is measured in the outlet on the relay front panel
- the relay is once brought to operate and the indicators, switches and timers are checked

Control of the operating setting $P/\%$ of P_N

Relay settings: Test switches:

t_1 = 1 s S1 = I
t_2 = – S2 = I

Test voltage:

$U = 100/\sqrt{3}$ V ≈ 57,7 V

Oper. level setting		Test results, measur. and calculat.		
$P/\%P_N$	Multiplier	I/A	SPAP 1G1 J3	SPAP 1G5 J3
0,5	P × 1	=	=	=
3,0	P × 1	=	=	=
5,0	P × 1 x)	=	=	=
1,0	P × 10	=	=	=
5,0	P × 10	=	=	=
Drop-out/pick-up ratio			=	

Note! The output relay 11–15 is delayed 1 s in operation, i.e. the current should be regulated slowly, when approaching the operating level.

x) The drop-out/pick-up ratio is measured at this setting

Control of the operating setting $P/\%$ of P_N for various phase angles between voltage and current

Relay settings: Test switch:

t_1 = 1 s S1 = I
t_2 = –
$P/\%P_N$ = 5

S2	φ	Test results, measur. and calculat.		
		I/A	SPAP 1G1 J3	SPAP 1G5 J3
I	0°	=	=	=
II	180°	=	= no oper.	= no oper.
III	90°	=	= "	= "
IV	30°	=	=	=

The test voltage $U = 100/\sqrt{3}$ V ≈ 57,7 V. The test is performed as above. The current, at which the relay operates, is measured and the power is calculated from the expression $I/I_N \times \cos\varphi \times 100\ \%$. The operating value is to be 5 % as set on the relay.

Control of the time-lags t_1 and t_2

Relay settings: Test switches:

$P/\%P_N$ = 5 S1 = I
S2 = 0→I

The test voltage $U = 100/\sqrt{3} \approx 57,7$ V. The test current I = 0,1 A for relay SPAP 1G1 J3 and I = 0,5 A for relay SPAP 1G5 J3.

The timer is started by closing the switch S1 and stopped by the contact 11–15 closing, when t_1 is measured and by the contact 9–13 closing, when t_2 is measured.

Set time-lags		Measured time-lags
t_1/s	t_2/s	t/s
1	–	=
3	–	=
6 x)	–	=
–	10	=
–	30	=
–	60 x)	=
Drop-out time		=

x) The drop-out time is measured at this setting

When measuring the drop-out time of the output relays, the relay is first made to operate by closing S1, and the timer is started by opening the switch S1 and stopped by the output contacts opening.

Maintenance and repairs

When the protective relay is operating under the conditions specified in the section "Technical data", the relay unit is practically maintenance-free. The relay unit includes no parts or components, which are subject to an abnormal physical or electrical wear under normal operating conditions.

If the environmental conditions at the relay operating site differ from those specified, as to ambient temperature, humidity or if the atmosphere around the relay holds chemically active gases or dust, the relay plug-in unit ought to be visually inspected in association with the relay secondary test being performed or whenever the relay unit is withdrawn from its case. At the visual inspection the following things should be noted:

- Check the relay unit for signs of mechanical damage; framework, contact plugs and also the relay case
- Shake the relay unit carefully to detect loose parts, such as screws, bolts, nuts, auxiliary relays or foreign metal particles. Note! The contact plugs of the relay unit are self-centering and should be loose
- Accumulation of dust inside the relay unit; remove by blowing air carefully
- Rust spots on framework, component legs and cups and signs of erugo on the printed circuit board copper foil
- Signs of tarnish on the silver-coated contact plugs
- Dirt inside the covers of the internal auxiliary relays. May indicate pitted or burned contacts, these should be cleaned or replaced.

On request, the relay can be specially treated for protection of the equipment against the stress on materials caused by abnormal environmental conditions.

If the relay fails in operation or if the operating values are remarkably diverse from the relay specifications, the relay should be given a proper overhaul. Minor measures can be taken by the customer by personnel from the companys instrument repair-shop, i.e. replacement of indicator LED:s, auxiliary output relays, contact plugs or the supply unit. For spare parts, refer to the spare part sets. Major measures, involving overhaul of the electronics, are to be made by the manufacturer. Please, put yourself in contact with the manufacturer or his nearest representative for further information about the checking, overhaul and recalibration of the relay.

Note! Static protective relays are measuring instruments and should be handled with care and protected against moisture and mechanical stress, especially during transport.

Exchange and spare parts

	Type
- supply unit	
U_{in} = 40...275 V d.c.	SPA-ZU 1
U_{in} = 17...40 V d.c.	SPA-ZU 2
U_{in} = 187...242 V, 50/60 Hz	SPA-ZW 1
- set of spare parts (holds mechanical spare parts for the relays)	SPA-ZM 1
- set of spare parts (holds semiconductor spare parts for the relays)	SPA-ZM 2

Dimensions and instructions for mounting

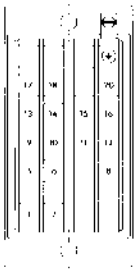
The relay can be supplied with a case for flush mounting, for semi-flush mounting or with a case for projecting mounting. Several relay plug-in units can also be housed in a 19 inch subrack, which can be mounted in a 19 inch framework of an instrument cabinet or flush-mounted as the separate relay cases. All dimensions are in mm.

Terminal arrangement

To the terminals of the cases for flush mounting, semi-flush mounting and projecting mounting with rear connection and to the terminals of the 19 inch subrack one or more wires with the cross section of 1,5...4 sqmm can be connected, see fig. a. These cases are all rear connected.

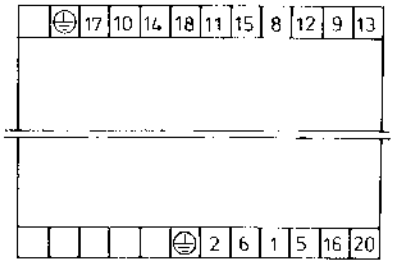
The case for projecting mounting is front-connected and the terminals (max. 4 sqmm) are arranged at the base of the case on the upper and lower side of the case, see fig. b.

Fig a.



Terminal arrangement, see the text

Fig b.

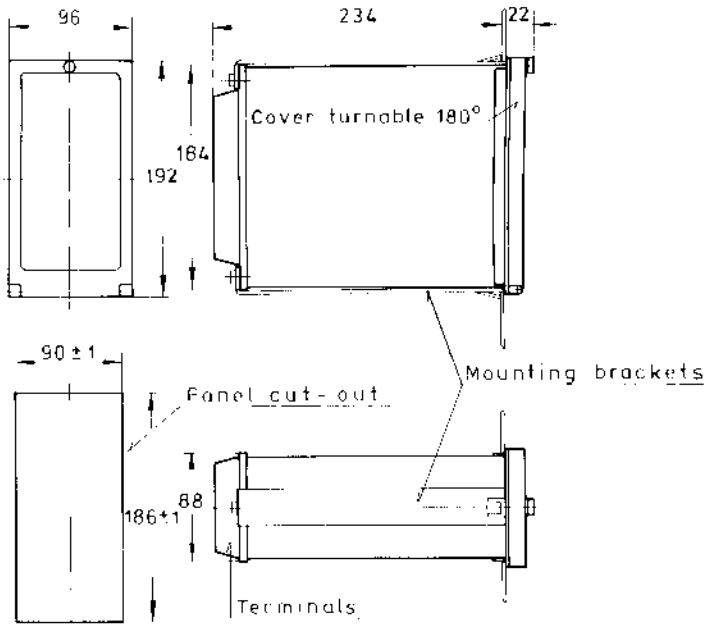


Terminal arrangement, see the text

Case for flush mounting

Case type: SPAP-ZK 1
Mass of the case: 2,0 kg

When the terminals of the relay case are to be protected against accidental touch, please refer to the terminal protection set type SPA-ZX 7.

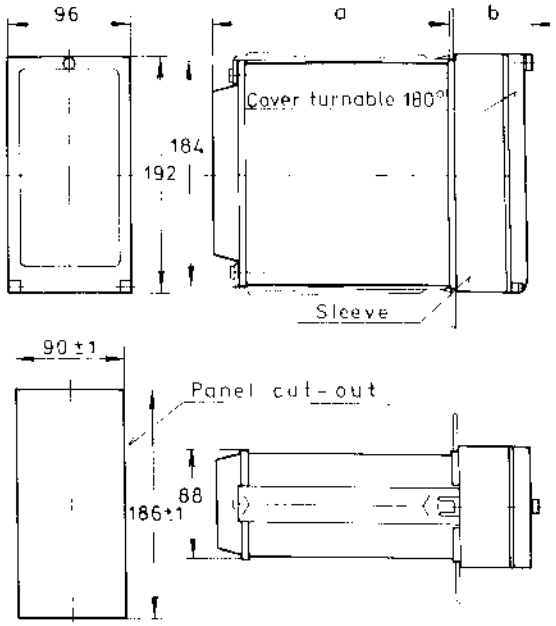


Case for semi-flush mounting

The case for flush mounting type SPAP-ZK 1 is provided with a sleeve type SPA-ZX 1 or type SPA-ZX 9 and their corresponding mounting brackets.

Sleeve type	a	b
SPA-ZX 1	194	62
SPA-ZX 9	154	102

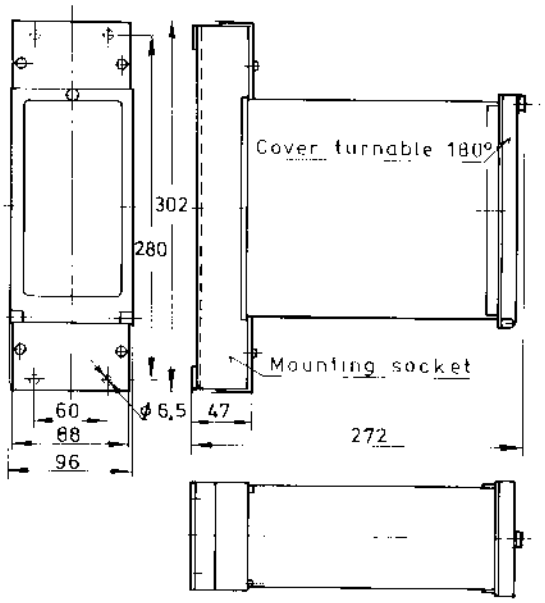
When required, please refer to the terminal protection set type SPA-ZX 7.



Case for projecting mounting with front connection

Case type: SPAP-ZK 2
Mass of the case: 2,6 kg

The block terminals of the relay case are to be found under covers in the upper and lower edge of the mounting socket.

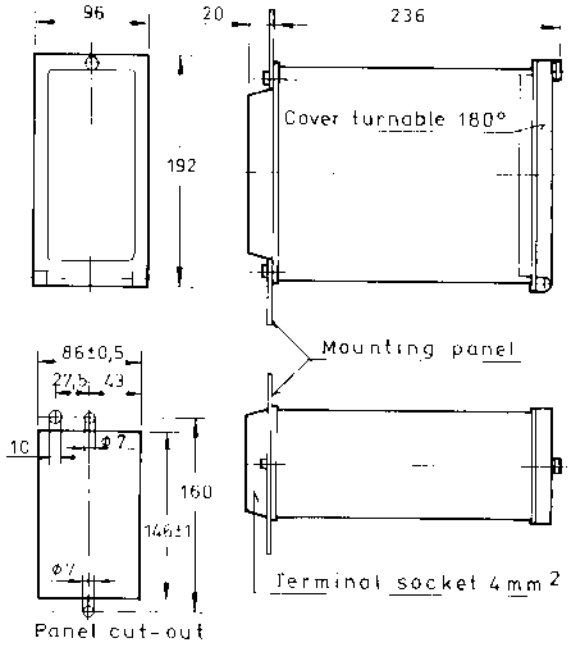


Case for projecting mounting with rear connection

Case type: SPAP-ZK 1
Mass of the case: 2,0 kg

The relay case for flush mounting can also be used for projecting mounting, if rear connection is required. The panel cut-out is illustrated in the adjacent figure.

When the terminals are to be protected, please refer to the terminal protection set type SPA-ZX 7.



19 inch relay subrack

Several protective relays can be enhoused in a common relay case, i.e. a 19 inch relay subrack. This is mainly used, when the protective relays are mounted in 19 inch instrument cabinets according to the IEC Publication 297.

The 19 inch subrack can also be applied for flush mounting or semi-flush mounting, please refer to separate description file No. 34 SPA 21 EN 1.

Information required with order

	Example
1. Amount and type of relay	10 pces relay type SPAP 1G1 J3
2. Amount and type of relay case	10 pces relay case type SPAP-ZK 1
3. Ratings	I_N = 1 A, U_N = 100/√3 V, f_N = 50 Hz
4. Auxiliary supply voltage	110 V d.c.
5. Accessories	E.g. 10 pces electronics' voltage monitor type SPA-ZH 1
6. Special requirements	-