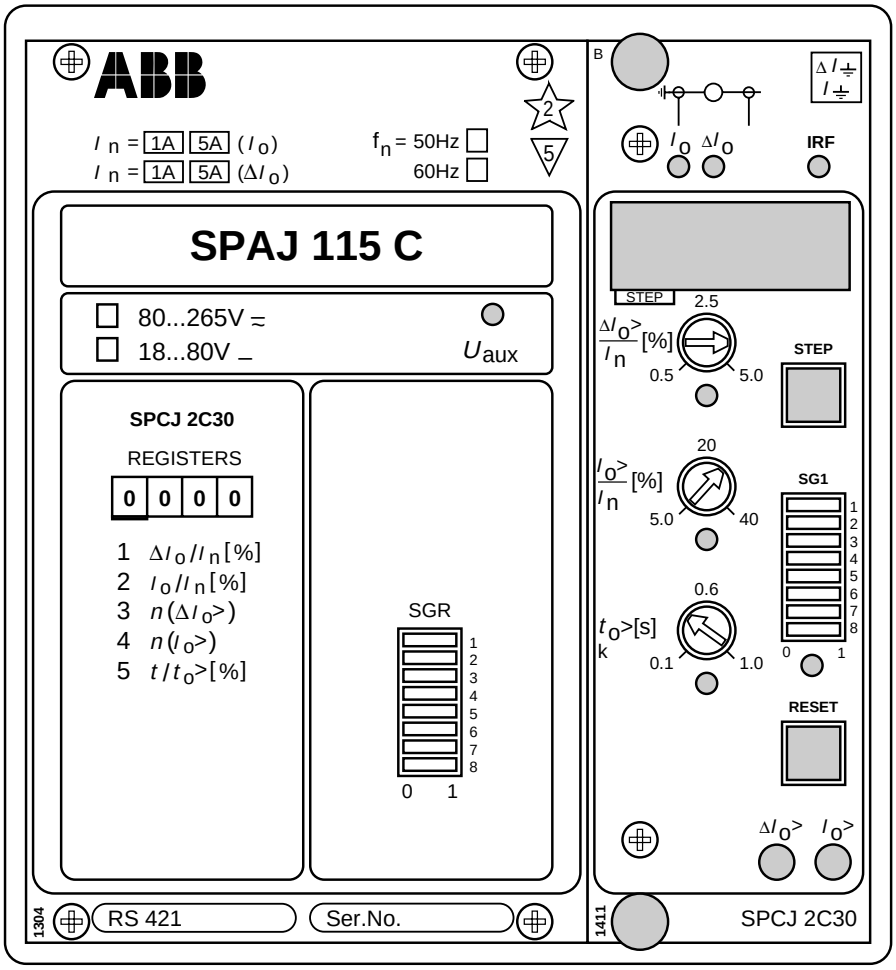
SPAJ 115 C
Restricted earth-fault and residual earth-fault relay

User´s manual and Technical description



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Contents

The complete manual for the combined restricted earth-fault and residual earth-fault relay SPAJ 115 C includes the following submanuals:

Restricted earth-fault and residual earth-fault relay SPAJ 115 C	1MRS 750658-MUM EN
Combined restricted earth-fault and residual earth-fault relay module SPCJ 2C30	1MRS 750659-MUM EN
General characteristics of C type relay modules	1MRS 750328-MUM EN

Features

Sensitive restricted earth-fault protection stage for fast, selective earth-fault protection

Sensitive definite time or inverse time earth-fault stage for back-up residual earth-fault protection

Output relay functions freely configurable for desired relay operations

Flexible adaptation of the relay to a certain application

Accurate settings and stable functions due to fully digital relay design

Local numerical display of setting values, measured values and recorded fault values

Serial interface for two-way data communication over fibre-optic bus between relay level and superior system levels

High immunity to electrical interference and robust aluminium case to class IP54

Continuous self-supervision of hardware and software, including auto-diagnostics

Powerful optional software support for setting, reading, copying and recording relay parameters

The relay is a member of the SPACOM product family, which is compatible with PYRAMID™, the coordinated protection and control concept of ABB.

Application

The combined restricted earth-fault and residual earth-fault relay SPAJ 115 C is intended to be used for the earth-fault protection of power generators, motors and transformers. The relay contains two energizing input circuits, that is a differential earth-fault current circuit and a residual earth-fault current circuit.

Principle of function

The combined restricted earth-fault and residual earth-fault relay SPAJ 115 C is a secondary relay which measures two energizing currents; the differential current ΔI_0 and the residual current I_0. When an earth-fault is detected the relay operates, alarms and trips the circuit breaker, according to the settings and configuration of the relay.

The differential current is formed with an external circuit, for instance the one shown in Fig. 2.

The main earth-fault protection is formed by the restricted earth-fault current stage ΔI_0, which operates instantaneously, when the differential current exceeds the set start value of the restricted earth-fault stage. The restricted earth-fault stage operates exclusively on earth-faults inside the area of protection. The area of protection is the area limited by the phase current transformers and the current transformer of the neutral earthing circuit. The operation of the restricted earth-fault stage on faults outside the area of protection is prevented with a stabilizing resistor, which is connected in series with the matching transformer of the relay, see Fig. 2.

The operation of the restricted earth-fault stage exclusively on faults inside the area of protection is based on the fact, that the impedance of a transformer decreases as the transformer is saturated. The reactance of the excitation circuit of a fully saturated transformer is zero and in these cases the impedance is composed purely of the resistance of the coil. Under the influence of the stabilizing resistor in the differential current circuit the secondary current of the non-saturated transformer is forced to flow through the secondary circuit of the saturated transformer.

The start current of the restricted earth-fault stage is set so high, that the stage cannot operate on currents caused by external faults into the differential current circuit.

When an earth-fault appears inside the area of protection, both transformers tend to feed current into the differential current circuit and the stage operates. To keep the resistance of the secondary circuit as low as possible, the summing point for the currents should be located as close to the current transformers as possible.

The back-up earth-fault protection is formed by the residual current stage $I_0>$, which can be given definite time or inverse time characteristic.

When the residual current exceeds the set star value of the residual current stage $I_0>$, the residual current stage starts. After the set operate time $t_0>$ at definite time operation or the calculated operate time at inverse time operation the stage operates delivering a trip signal.

When inverse time characteristic has been selected four time/current curve sets according to IEC 60255 and BS 142 are available. The curve sets are referred to as "Normal inverse", "Very inverse", "Extremely inverse" and "Long-time inverse".

The start signal of the relay, obtainable as a contact function, can, for example, be used as a blocking signal for other protection relays.

The relay is provided with one optically isolated control input, which can be used as a blocking input.

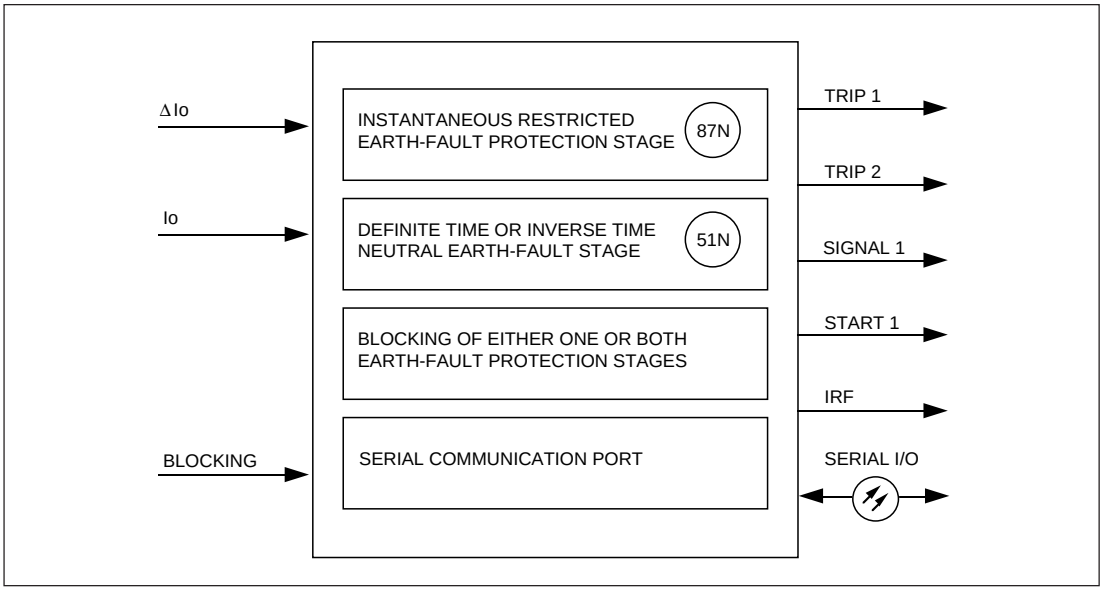


Fig. 1. Protection functions of the combined restricted earth-fault and residual earth-fault relay SPAJ 115 C. The encircled numbers refer to the ANSI (=American National Standards Institute) number of the concerned protection function.

Connections

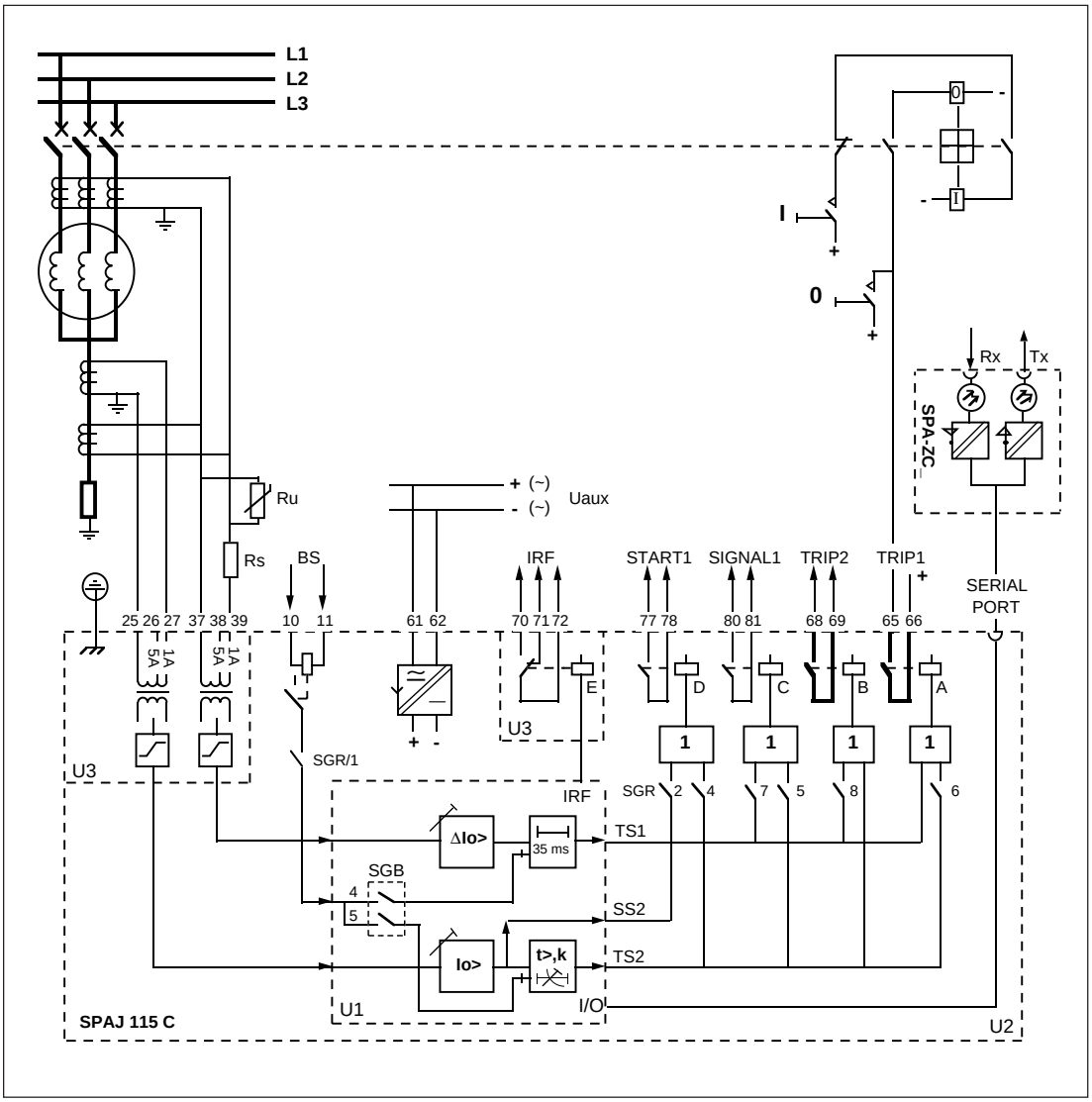


Fig. 2. Connection diagram for the combined restricted earth-fault and residual earth-fault relay SPAJ 115 C

U_{aux}	Auxiliary voltage
A,B,C,D,E	Output relays
IRF	Self-supervision signal
BS	External blocking signal
SS	Start signal
TS	Trip signal
SGR	Switchgroup for configuring trip and alarm signals
SGB	Switchgroup for configuring blocking signals
TRIP_	Trip output
SIGNAL1	Signal on relay operation
START1	Start signal or signal on relay operation
U1	Combined restricted earth-fault and residual earth-fault relay module SPCJ 2C30
U2	Power supply and I/O module SPTU 240S1 or SPTU 48S1
U3	I/O module SPTE 2E17
R_s	Stabilizing resistor
R_u	Voltage dependent resistor
SERIAL PORT	Serial communication port
SPA-ZC_	Bus connection module
Rx/Tx	Optical-fibre receiver terminal (Rx) and transmitter terminal (Tx) of the bus connection module

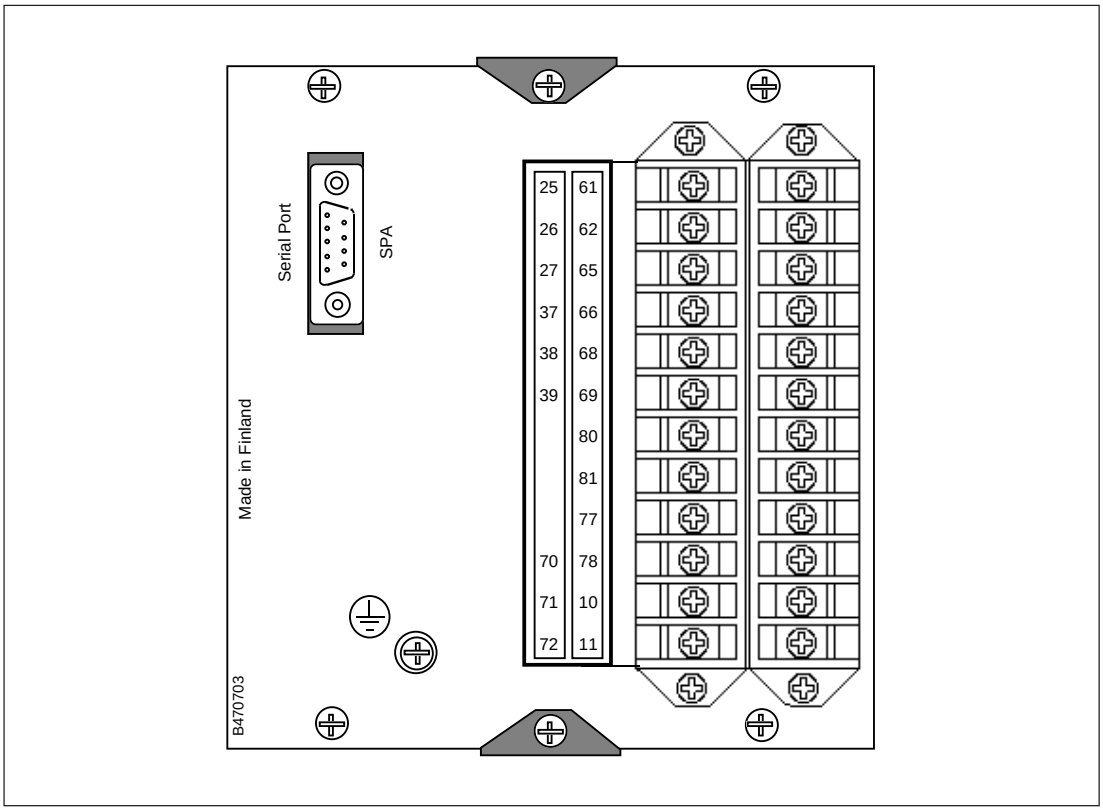


Fig.3. Rear view of the restricted earth-fault and residual earth-fault relay SPAJ 115 C.

Specification of input and output terminals

Contacts	Function
25–26	Residual current I_0 (I_n = 5 A)
25–27	Residual current I_0 (I_n = 1 A)
37–38	Differential current ΔI_0 (I_n = 5 A)
37–39	Differential current ΔI_0 (I_n = 1 A)
10-11	External blocking signal (BS)
61-62	Auxiliary power supply. When the relay is energized from a DC source the positive pole is to be connected to terminal 61.
65-66	Operation output 1 for the ΔI_0> and I_0> stages (TRIP 1)
68-69	Operation output 2 for the ΔI_0> and I_0> stages (TRIP 2)
80-81	Signal on operation of the ΔI_0> and I_0> stages (SIGNAL 1)
77-78	Signal on start or operation of stage I_0> (START1)
70-71-72	Self-supervision (IRF) alarm output. Under normal conditions the contact interval 70-72 is closed. When the auxiliary voltage disappears or an internal fault is detected, the contact interval 71-72 closes.
⏚	Protective earth terminal

The combined restricted earth-fault and residual earth-fault relay SPAJ 115 C connects to the fibre-optic data communication bus by means of the bus connection module SPA-ZC 17 or SPA-ZC 21. The bus connection module is fitted to the D-type connector (SERIAL PORT) on the rear panel of the relay. The opto-connectors of the fibre-optic cables are plugged into the counter connectors Rx and Tx on the bus connection module. The selector switch for the mode of operation of the bus connection module is to be set in position "SPA".

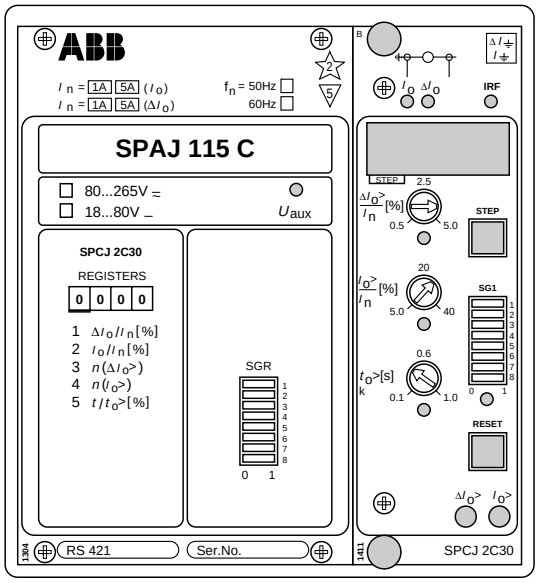
Configuration of output relays

The trip signal of the $\Delta I_0>$ stage is firmly wired to output relay A and the trip signal of the $I_0>$ stage is firmly wired to output relay B. In addition, the following functions can be selected with the switches of the SGR switchgroup on the front panel:

Switch	Function	Factory settings	User's settings
SGR/1	Routes the ext. blocking signal to the E/F module	1	
SGR/2	Routes the start signal of the $I_0>$ stage to output relay D	1	
SGR/3	Not in use	1	
SGR/4	Routes the operate signal of the $I_0>$ stage to output relay D	1	
SGR/5	Routes the operate signal of the $I_0>$ stage to output relay C	1	
SGR/6	Routes the operate signal of the $I_0>$ stage to output relay A	1	
SGR/7	Routes the operate signal of the $\Delta I_0>$ stage to output relay C	1	
SGR/8	Routes the operate signal of the $\Delta I_0>$ stage to output relay B	1	

The circuit breakers can be directly controlled with output relay A or output relay B. Thus either operation stage may have its own trip output relay and two separate circuit breakers can be controlled with the same earth-fault relay.

Start and operation indicators



1. Either earth-fault stage has its own operation indicator (ΔI_0> and I_0>), located in the right bottom corner of the front plate of the relay module. The indicator of the residual current stage I_0> turns yellow as the stage starts and turns red as the stage operates (trips). The indicator of the restricted earth-fault current stage ΔI_0> turns red as the stage operates (trips).

   With the SG2 software switchgroup the start and trip indicators can be given a latching function, which means that the LEDs remain lit, although the signal that caused operation returns to normal. The indicators are reset with the RESET push-button. An unreset indicator does not affect the operation of the relay.

2. The yellow LEDs (ΔI_0 and I_0) on the upper black part of the front plate indicate, when lit, that the value of the energizing current of the concerned protection stage is being dis- played.

3. The red IRF indicator of the self-supervision system indicates, when lit, that a permanent internal relay fault has been detected. The fault code appearing on the display once a fault has been detected should be recorded and notified when service is ordered.

4. The green U_{aux} LED on the front panel is lit when the power supply module operates properly.

5. The LED indicator below a setting knob indicates, when lit, that the setting value is being displayed.

6. The LED of the SG1 switchgroup indicates, when lit, that the checksum of the switchgroup is being displayed.

The start and operation indicators, the function of the SG2 software switchgroup and the functions of the LED indicators during setting are described more detailed in the relay module manual of the combined restricted earth-fault and residual earth-fault relay module SPCJ 2C30.

Power supply and I/O module

The combined power supply and I/O module (U2) is located behind the system front panel of the protection relay and can be withdrawn from the relay case after removal of the system front panel. The power supply and I/O module incorporates a power unit, four output relays, the control circuits of the output relays and the electronic circuitry of the external control input.

The power unit is transformer connected, that is, the primary circuit and the secondary circuits are galvanically isolated. The primary circuit is protected by a slow 1 A fuse F1, placed on the PC board of the module. When the power source operates properly, the green U_{aux} LED on the front panel is lit.

The power supply and I/O module is available in two versions which have different input voltage ranges:

- type SPTU 240S1 U_{aux} = 80...265 V ac/dc
- type SPTU 48S1 U_{aux} = 18...80 V dc

The input voltage range of the power supply and I/O module incorporated in the relay on delivery is marked on the system front panel of the relay.

Technical data
(modified 2002-04)

Energizing inputs

	1 A	5 A
Terminals	25–27, 37–39	25–26, 37–38
Rated current I_n	1 A	5 A
Thermal withstand capability		
Continuous carry	4 A	20 A
Make and carry for 10 s	25 A	100 A
Make and carry for 1 s	100 A	500 A
Dynamic current withstand capability, half-wave value	250 A	1250 A
Input impedance	<100 mΩ	<20 mΩ
Rated frequency f_n acc. to order	50 Hz or 60 Hz	

Output contact ratings

Control contacts	
Terminals	65-66, 68-69
Rated voltage	250 V ac/dc
Continuous carry	5 A
Make and carry for 0.5 s	30 A
Make and carry for 3 s	15 A
Breaking capacity for dc, when the control circuit time constant L/R ≤ 40 ms, at the control voltages	
- 220 V dc	1 A
- 110 V dc	3 A
- 48 V dc	5 A

Signalling contacts	
Terminals	70-71-72, 77-78, 80-81
Rated voltage	250 V ac/dc
Carry continuously	5 A
Make and carry for 0.5 s	10 A
Make and carry for 3 s	8 A
Breaking capacity for dc, when the signalling circuit time constant L/R ≤ 40 ms, at the signalling voltages	
- 220 V dc	0.15 A
- 110 V dc	0.25 A
- 48 V dc	1 A

External control input (Blocking input)

Terminals	10-11
Control voltage level	18...265 V dc or 80...265 V ac
Current consumption when input activated	2...20 mA

Auxiliary supply voltage

Power supply and I/O modules and voltage ranges:	
- type SPTU 240S1	80...265 V ac/dc
- type SPTU 48S1	18...80 V dc
Power consumption under quiescent/operating conditions	~4 W/~6 W

Combined restricted earth-fault and residual earth-fault relay module SPCJ 2C30

Restricted earth-fault current stage $\Delta I_0>$	
Start current $\Delta I_0>$, setting range	0.5...5% x I_n
Operate time	35 ms
Residual earth-fault current stage $I_0>$	
Start current $I_0>$, setting range	5…40% x I_n
Selectable operation characteristic	
- definite time characteristic	
- operate time $t_0>$	0.1…100 s
- inverse definite minimum time (IDMT) characteristic	
- curve sets acc. to IEC 60255-3 and BS 142	Normal inverse Very inverse Extremely inverse Long-time inverse
- time multiplier k	0.05...1.00

Data communication

Transmission mode	Fibre-optic serial bus
Data code	ASCII
Selectable data transfer rates	300, 1200, 2400, 4800 or 9600 Bd
Fibre-optic bus connection module, powered from the host relay	
- for plastic fibre cables	SPA-ZC 21 BB
- for glass fibre cables	SPA-ZC 21 MM
Fibre-optic bus connection module, powered from external power source	
- for plastic fibre cables	SPA-ZC 17 BB
- for glass fibre cables	SPA-ZC 17 MM

Insulation Tests *)

Dielectric test IEC 60255-5	2 kV, 50 Hz, 1 min
Impulse voltage test IEC 60255-5	5 kV, 1.2/50 μs, 0.5 J
Insulation resistance measurement IEC 60255-5	>100 MΩ, 500 Vdc

Electromagnetic Compatibility Tests *)

High-frequency (1 MHz) burst disturbance test IEC 60255-22-1	
- common mode	2.5 kV
- differential mode	1.0 kV
Electrostatic discharge test IEC 60255-22-2 and IEC 61000-4-2	
- contact discharge	6 kV
- air discharge	8 kV
Fast transient disturbance test IEC 60255-22-4 and IEC 61000-4-4	
- power supply	4 kV
- I/O ports	2 kV

Environmental conditions

Specified ambient service temperature range	-10...+55°C
Long term damp heat withstand acc. to IEC 60068-2-3	<95%, +40°C, 56 d/a
Relative humidity acc. to IEC 60068-2-30	93...95%, +55°C, 6 cycles
Transport and storage temperature range	-40...+70°C
Degree of protection by enclosure for panel mounted relay	IP 54
Weight of relay including flush mounting case	3.0 kg

*) The tests do not apply to the serial port, which is used exclusively for the bus connection module.

Current transformer requirements

The sensitivity and reliability of a resistor-stabilized restricted earth-fault protection depends to a great extent on the current transformers to be used. The number of turns of all the current transformers of the same differential circuit must be equal.

In the differential protection systems class X current transformers are used, and the important parameters of the current transformers are the knee-point voltage and the resistance of the secondary circuit. The knee-point voltage is the secondary voltage value, from which a 10% voltage increase causes the excitation current to grow by 50%.

When the sensitivity of the protection is considered the excitation current of the current transformers and the current through a possible stabilizing resistor must be noted.

The knee-point voltage of the current transformers must be about 2 times the stabilizing voltage to secure a safe operation and a fast operate time of the relay. The stabilizing voltage U_s can be calculated as follows:

$$U_s = \frac{I_{kmax} \times (R_{in} + R_m)}{n}$$

I_{kmax} = Maximum through-fault current, for which the relay must not operate
R_{in} = Resistance of the CT secondary circuit
R_m = Total resistance of the longest measuring circuit (to and from)
n = CT transforming ration

It is recommended that current transformers with a secondary resistance of the measuring circuit are used. In this way the knee-point voltage requirements imposed to the current transformer can be kept within reasonable values.

The sensitivity of the protection can be determined with the stabilizing resistor; the higher the selected resistor value the lower a relay setting can be used and the more sensitive a protection is obtained. The sensitivity of the protection can be calculated as follows:

$$I_{prim} = n \times (I_r + m \times I_e + I_u)$$

During faults inside the zone of protection the voltage of the measuring circuit may grow so high that it can exceed the isolation level of the circuit. This can be avoided by installing a voltage dependent resistor into the circuit.

Three types of voltage dependent resistors are available, see Fig. 4.

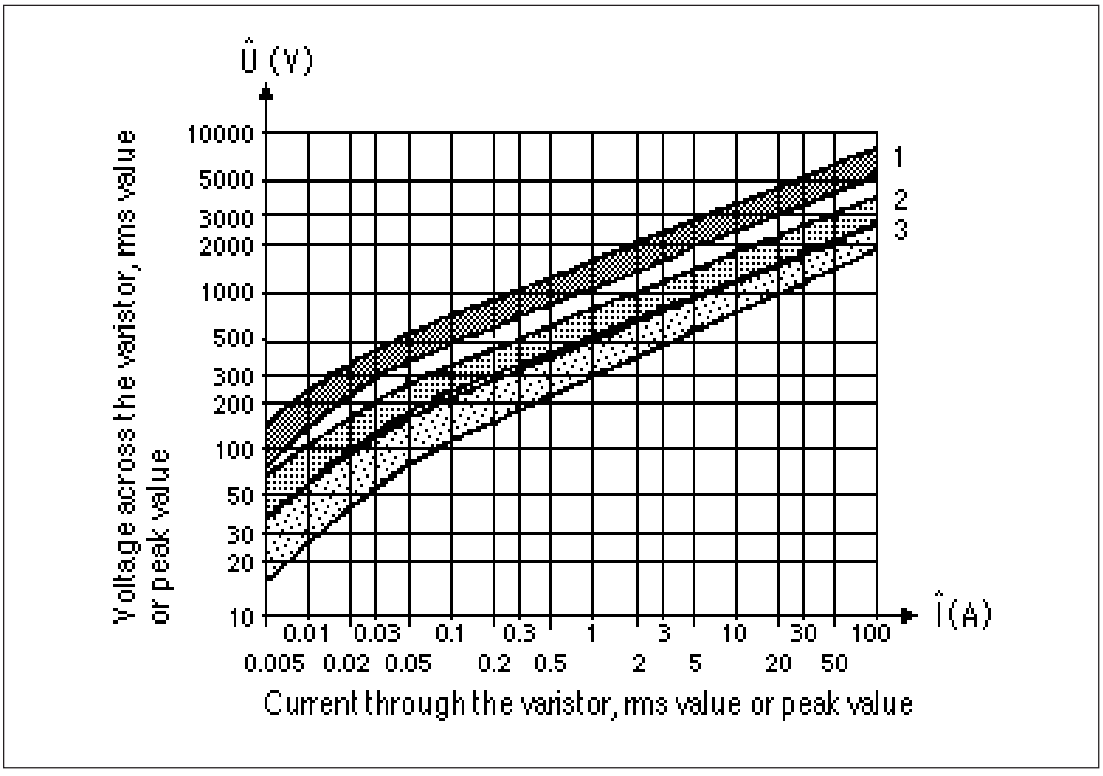


Fig. 4. Operation characteristic of the voltage dependent resistors.

1 Voltage dependent resistor type 5248 831-D
2 Voltage dependent resistor type 5248 831-C
3 Voltage dependent resistor type 5248 831-B

Examples of application

Example 1.
Generator earth-fault protection

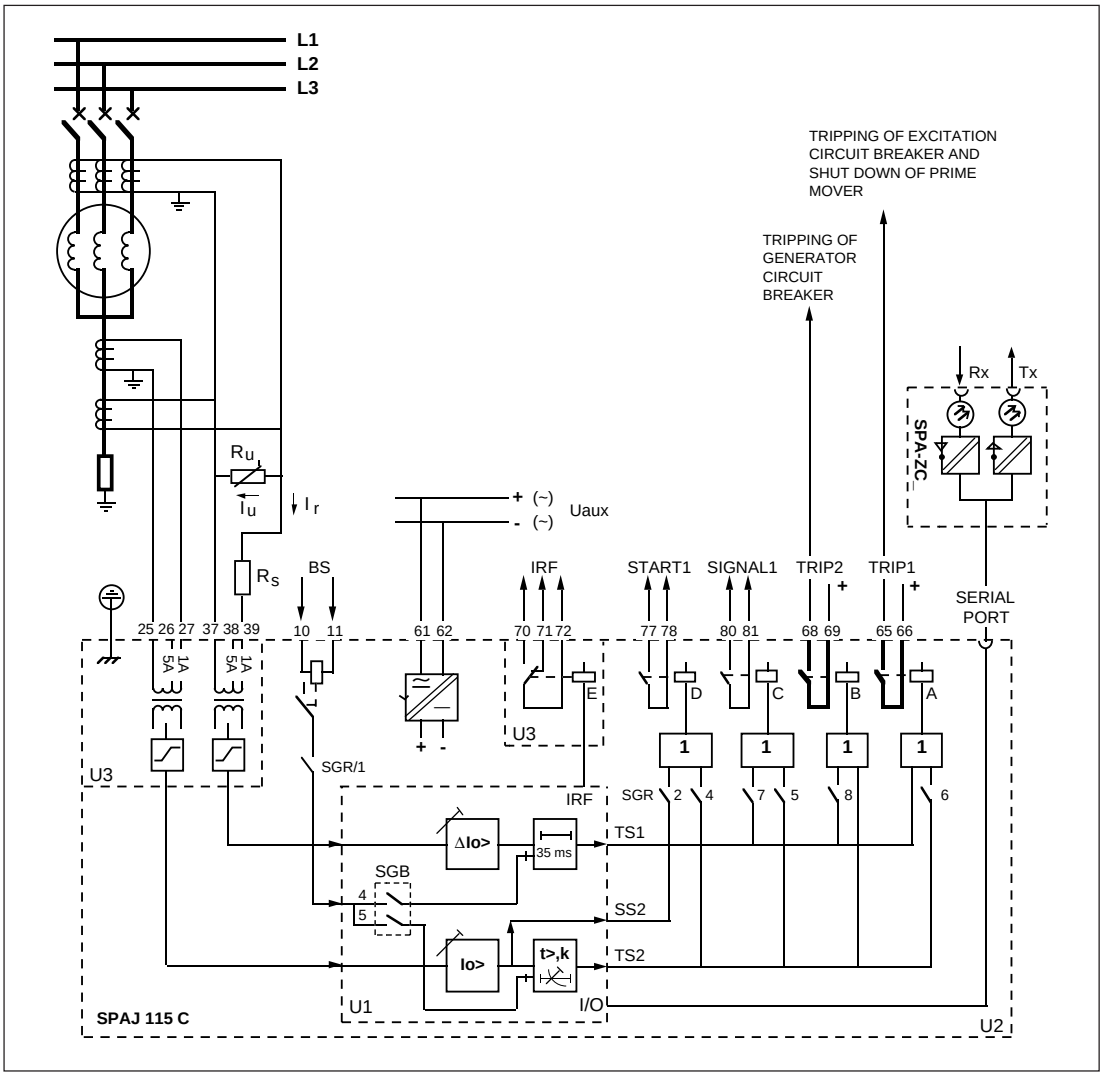


Fig. 5. Generator earth-fault protection using the restricted earth-fault and residual earth-fault relay SPAJ 115 C. The selector switch positions are shown in the table on the following page.

The restricted earth-fault stage $\Delta I_0>$ acts as main earth-fault protection. The residual earth-fault stage $I_0>$ acts as busbar earth-fault protection and back-up earth-fault protection for the network.

The stability of the restricted earth-fault protection stage is based on the fact that the impedance of a current transformer decreases when the transformer saturates. The reactance of the excitation circuit of a fully saturated current transformer is zero and thus the impedance is purely composed of the winding resistance. The stabilizing resistor in the differential current circuit forces the secondary current of the unsaturated current transformer to flow through the secondary circuit of the saturated current transformer. The start current of the restricted earth-fault stage is set so high, that the protection does not operate on currents induced in the circuit during faults outside the zone of protection.

When the earth-fault appears outside the zone of protection limited by the current transformers, the current flows through the current transformers and causes no relay operation. When the earth-fault arises inside the area of protection the current transformers feed current through the differential current circuit and the relay operates.

An external stabilizing resistor R_s is needed in the differential current measuring circuit. The purpose of the stabilizing resistor is to prevent the relay from operating on faults outside the area of protection. The short time power withstand capability of the stabilizing resistor must be high enough to stand for the power appearing in the differential current circuit. The most suitable resistor type is an open wire-wound resistor.

The purpose of the voltage dependent resistor is to prevent the voltage from exceeding the insulation voltage level during in-zone faults. The voltage dependent resistor must be so selected that the current through the resistor at the stabilizing voltage level is as low as possible.

Current transformers with the same transforming ratios and equal numbers of winding turns are selected. In order to minimize the length of the CT secondary circuits the summing point of the secondary currents is to be located as close to the CT terminals as possible.

The calculations for the restricted earth-fault protection are performed using an iteration method. First the current transformers are defined and then their suitability for the intended application is checked.

The stabilizing voltage U_s required by the protection in through-fault situations is determined according to the following expression:

$$U_s = \frac{I_{kmax} \times (R_{in} + R_m)}{n}$$

I_{kmax} = Maximum through-fault current, for which the relay must not operate. If the current is unknown the generator is given the value $I_{kmax} \approx 6 \times I_n$
R_{in} = Resistance of the CT secondary circuit
R_m = Total resistance of the longest measuring circuit, i.e. from the summing point to the current transformer
n = CT transforming ration, for example n = 2000/5 A = 400

In order to secure a safe operation of the protection at in-zone faults the stabilizing voltage U_s must not exceed half the value of the knee-point voltage U_k of the current transformers.

The excitation current I_e corresponding to the stabilizing voltage U_s is determined either from the excitation curves provided by the CT manufacturer or by assuming a linear excitation curve for voltage values below the knee-point voltage.

The value of the stabilizing resistor can be calculated from the expression:

$$R_s = \frac{U_s}{I_r}$$

The start current I_r can be changed, if needed, by changing the value of R_s. It is recommended that the start current I_r is greater than the sum of the excitation currents of the CTs. That is, the start current is to be $I_r \geq m \times I_e$, where m is the number of CTs in the differential current circuit.

The primary current value corresponding to the start current I_r is obtained from the expression:

$$I_{prim} = n \times (I_r + m \times I_e + I_u)$$

I_u = current through the varistor at U_s, see Fig. 5.

The selector switches of the relay SPAJ 115 C can be given the following settings:

Switch	SG1/SPCJ 2C30	SGB/SPCJ 2C30	SGR
1	0 Not in use	0 Not in use	0 No external blocking signal
2	0 Not in use	0 Not in use	0 No stage I_0> start to relay D
3	1 Stage ΔI_0>; latching	0 Not in use	0 Not in use
4	1 Stage I_0>; latching	0 No blocking of Δt>	1 Stage I_0> trip to relay D
5	0 Not in use	0 No blocking of t_0>	0 No stage I_0> trip to relay C
6	1 Inverse time	0 Not in use	0 No stage I_0> trip to relay A
7	0 } Normal inverse	0 Not in use	1 Stage ΔI_0> trip to relay C
8	1 } Normal inverse	0 Not in use	1 Stage ΔI_0> trip to relay B
Σ	172		

With the above settings of relay SPAJ 115 C the following output relay functions are obtained:

Contact	Function
65-66	Trip signal from the restricted earth-fault stage; opens the excitation CB and stops the prime mover of the generator
68-69	Trip signal from the restricted earth-fault stage or the residual earth-fault stage; opens the generator CB
80-81	Signal on operation of the restricted earth-fault stage
77-78	Signal on operation of the residual earth-fault stage
70-71-72	Self-supervision alarm signal

Example 2.
Earth-fault protection of the high-voltage side of a power transformer

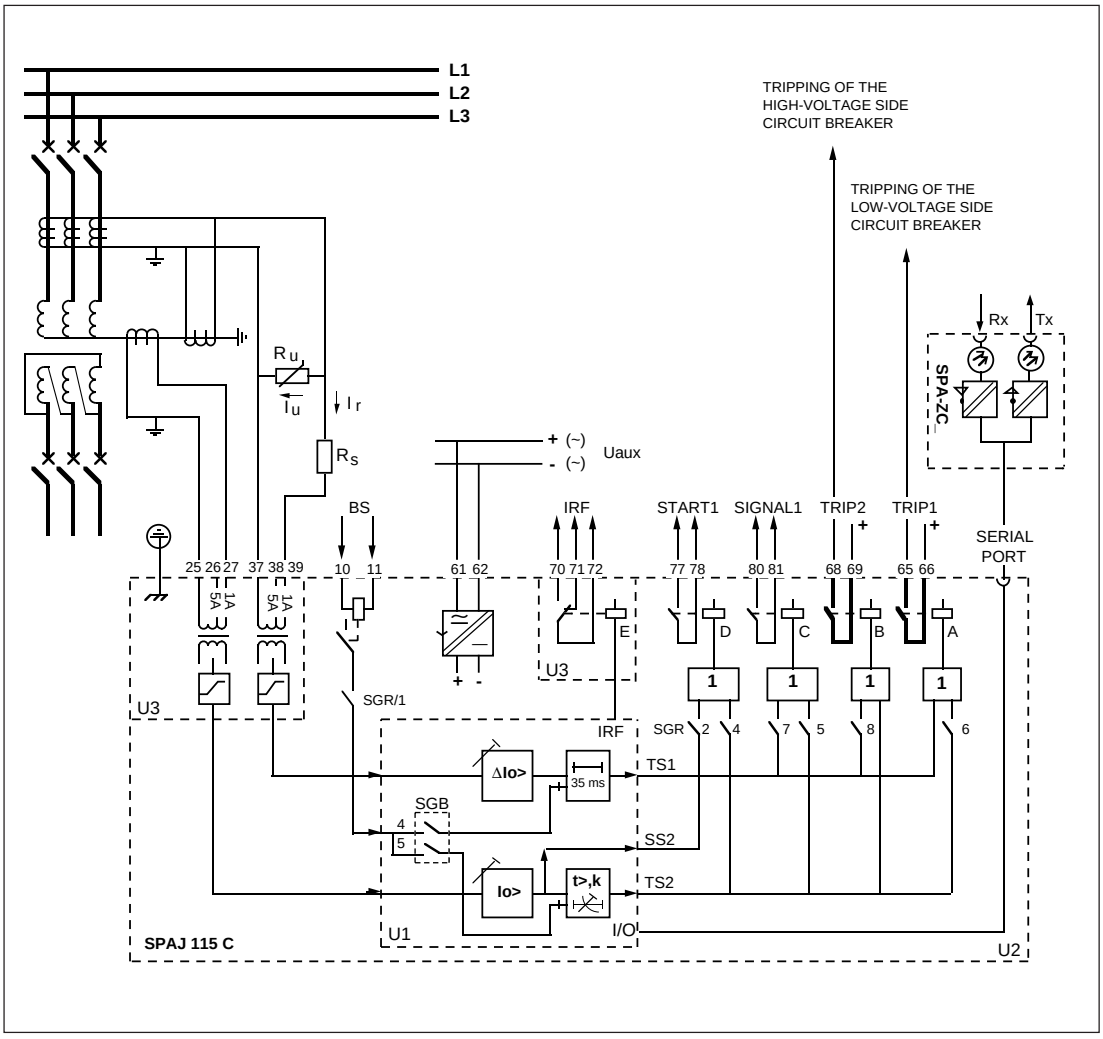


Fig. 6. Transformer earth-fault protection using the restricted earth-fault and residual earth-fault relay SPAJ 115 C. The selector switch positions are shown in the table on the next page.

The calculations are performed in the same way as in the previous example. If the maximum through-fault current I_{kmax} is not known, the value 16 x I_n can be used when the settings for the transformer protection are calculated.

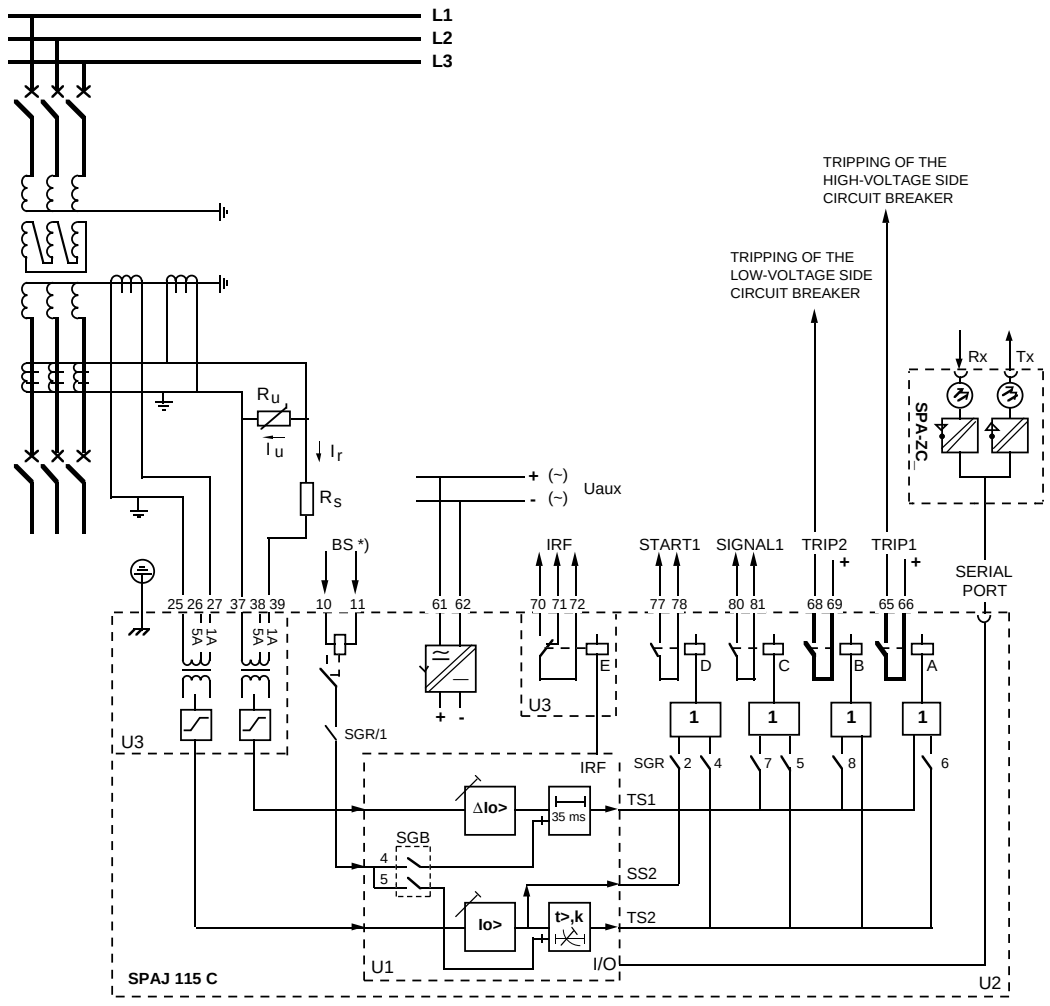
The selector switches of the relay SPAJ 115 C can be given the following settings:

Switch	SG1/SPCJ 2C30	SGB/SPCJ 2C30	SGR
1	0 Not in use	0 Not in use	0 No external blocking signal
2	0 Not in use	0 Not in use	0 No stage I_0> start to relay D
3	1 Stage ΔI_0>; latching	0 Not in use	0 Not in use
4	1 Stage I_0>; latching	0 No locking of Δt>	1 Stage I_0> trip to relay D
5	0 Not in use	0 No blocking of t_0>	0 No stage I_0> trip to relay C
6	1 Inverse time	0 Not in use	0 No stage I_0> trip to relay A
7	0 } Normal inverse	0 Not in use	1 Stage ΔI_0> trip to relay C
8	1 } Normal inverse	0 Not in use	1 Stage ΔI_0> trip to relay B
Σ	172		

With the above settings of relay SPAJ 115 C the following output relay functions are obtained:

Contact	Function
65-66	Trip signal from the restricted earth-fault stage; opens the low-voltage side CB
68-69	Trip signal from the restricted earth-fault stage or the residual earth-fault stage; opens the high-voltage side CB
80-81	Signal on operation of the restricted earth-fault stage
77-78	Signal on operation of the residual earth-fault stage
70-71-72	Self-supervision alarm signal

Example 3.
Earth-fault protection of the low-voltage side of a power transformer



*) Blocking signals from the earth-fault relays of the outgoing feeders

Fig. 7. Transformer earth-fault protection using the restricted earth-fault and residual earth-fault relay SPAJ 115 C. The selector switch positions are shown in the table on the next page.

In this example the residual earth-fault stage is used as a fast feeder cubicle and busbar earth-fault protection. Should the fault appear on the feeder, the feeder earth-fault relay transmits a blocking signal to the residual earth-fault stage of the infeeder cubicle. Should the earth-fault, however, appear in the infeeder cubicle or on the busbars, no blocking signal will be obtained and the residual earth-fault stage operates. An incoming blocking signal is routed to the residual earth-fault stage by means of switch SGB/5 in the relay module SPCJ 2C30.

The selector switches of the protection relay module SPAJ 115 C can be set as follows:

Switch	SG1/SPCJ 2C30	SGB/SPCJ 2C30	SGR
1	0 Not in use	0 Not in use	1 External blocking signal
2	0 Not in use	0 Not in use	0 No stage I_0> start to relay D
3	1 Stage ΔI_0>; latching	0 Not in use	0 Not in use
4	1 Stage I_0>; latching	0 No locking of Δt>	1 Stage I_0> trip to relay D
5	0 Not in use	1 Blocking of t_0>	0 No stage I_0> trip to relay C
6	0 Definite time	0 Not in use	0 No stage I_0> trip to relay A
7	0 } t_0> = 0.1…1.00 s	0 Not in use	1 Stage ΔI_0> trip to relay C
8	0 }	0 Not in use	1 Stage ΔI_0> trip to relay B
Σ	12		

With the above settings of relay SPAJ 115 C the following output relay functions are obtained:

Contact	Function
65-66	Trip signal from the restricted earth-fault stage; opens the high-voltage side CB
68-69	Trip signal from the restricted earth-fault stage or the residual earth-fault stage; opens the low-voltage side CB
80-81	Signal on operation of the restricted earth-fault stage
77-78	Signal on operation of the residual earth-fault stage
70-71-72	Self-supervision alarm signal

Recorded information

The data registered by the relay can be used to analyze the faults and the behaviour of the protection.

Register 1 contains the maximum value of the differential current as a percentage of the rated current of the used energizing input. The register is updated, if
- the value of the measured current exceeds the value already in the register
- the relay operates. At relay operation the value of the current at operation is recorded.

The value of the differential current measured during a fault shows the magnitude of the earth-fault current. When the earth-fault current of the total network is known, the probable location of the fault inside tha transformer can be judged. The value in register 1 shows how close the set relay start current value is to the real fault current value. Correspondingly, the set start current values can be compared with the differential current values measured by the relay under normal operation conditions.

Register 2 contains the maximum value of the residual current as a percentage of the rated current of the used energizing input. The register is updated, if
- the value of the measured current exceeds the value already in the register
- the relay operates. At relay operation the value of the current at operation is recorded.

The value of the residual current measured during a fault shows the magnitude of the earth-fault current. When the earth-fault current of the total network is known, the degree of development of the earth-fault can be judged. The value in register 2 shows how close the set relay start current value is to the real fault current value. Correspondingly, the set start current values can be compared with the residual current values measured by the relay under normal operation conditions.

Register 3 records the number of operations of the differential current stage $\Delta I_0>$.

The number of starts of the the residual earth-fault stage, register 4, provides information about how frequently earth-faults appear in the network. Frequent starts may indicate an imminent earth-fault caused, for instance, by a broken isolator or some kind of disturbance apt to cause an earth-fault. The reason may also be too low a start current setting. The residual earth-fault stage, unlike the restricted earth-fault stage, also detects faults outside the zone of protection.

The values recorded in register 5 shows the duration of the latest start of the residual earth-fault stage, expressed as a percentage of the set operate time. Any new start resets the counter, which always starts counting from zero. If the stage operates, the value of the register will be 100 [%].

Register 5 provides information on the duration of the earth-fault and the safety margins of the grading times of the protection. Should, for instance, the duration recorded by the earth-fault relay, functioning as a back-up relay for the feeder earth-fault relay show the value 75 [%] after that the feeder earth-fault relay has tripped, the safety margin of the selective protection has been 25% counted on the operate time of the residual earth-fault relay.

The registers 1…5 are reset, either by pressing the STEP and RESET push-buttons simultaneously or with a command, V102, over the SPA bus.

Secondary injection testing

The secondary testing should always be performed in accordance with national regulations and instructions.

The protection relay incorporates an IRF function that continuously monitors the internal condition of the relay and produces an alarm signal on detection of a fault. According to the manufacturer's recommendations the relay should be submitted to secondary injection testing at five years' intervals. These tests should include the entire protection chain from the instrument transformers to the circuit breakers.

The secondary testing described in this manual is based on the relay's setting values in the concerned application. If necessary, the secondary testing can be extended by testing the protection stages throughout their setting ranges.

As switch positions and setting values may have to be altered during the test the correct positions of switches and the setting values of the relay during normal operation conditions have to be recorded, for instance, on the reference card accompanying the relay.

To enable secondary injection testing the relay has to be disconnected, either through disconnectable terminal blocks or a test plug fitted on the relay.

DANGER!
Do not open the secondary circuit of a current transformer during testing, if the primary circuit is live. The high voltage produced by an open CT secondary circuit could be lethal and may damage measuring instruments and insulation.

When the auxiliary voltage is connected to the protection relay, the relay performs a self-testing program. The self-testing does not include the matching transformers and the contacts of the output relays. The operational condition of the relay is tested by means of ordinary relay test equipment and such a test also includes the matching transformers, the output relays and the accuracy of the operate values.

Equipment required for testing:
- adjustable voltage transformer 0...260 V, 1 A
- current transformer
- ammeter, accuracy ±0.5%
- stop watch or counter for time measurement
- dc voltage source for auxiliary supply
- switches and indicator lamps
- supply and pilot wires
- calibrated multimeter

The secondary current of the current transformer is to be selected on the basis of the rated current, 1 A or 5 A, of the relay energizing input to be tested. The energizing inputs are specified under the heading "Technical data, Energizing inputs".

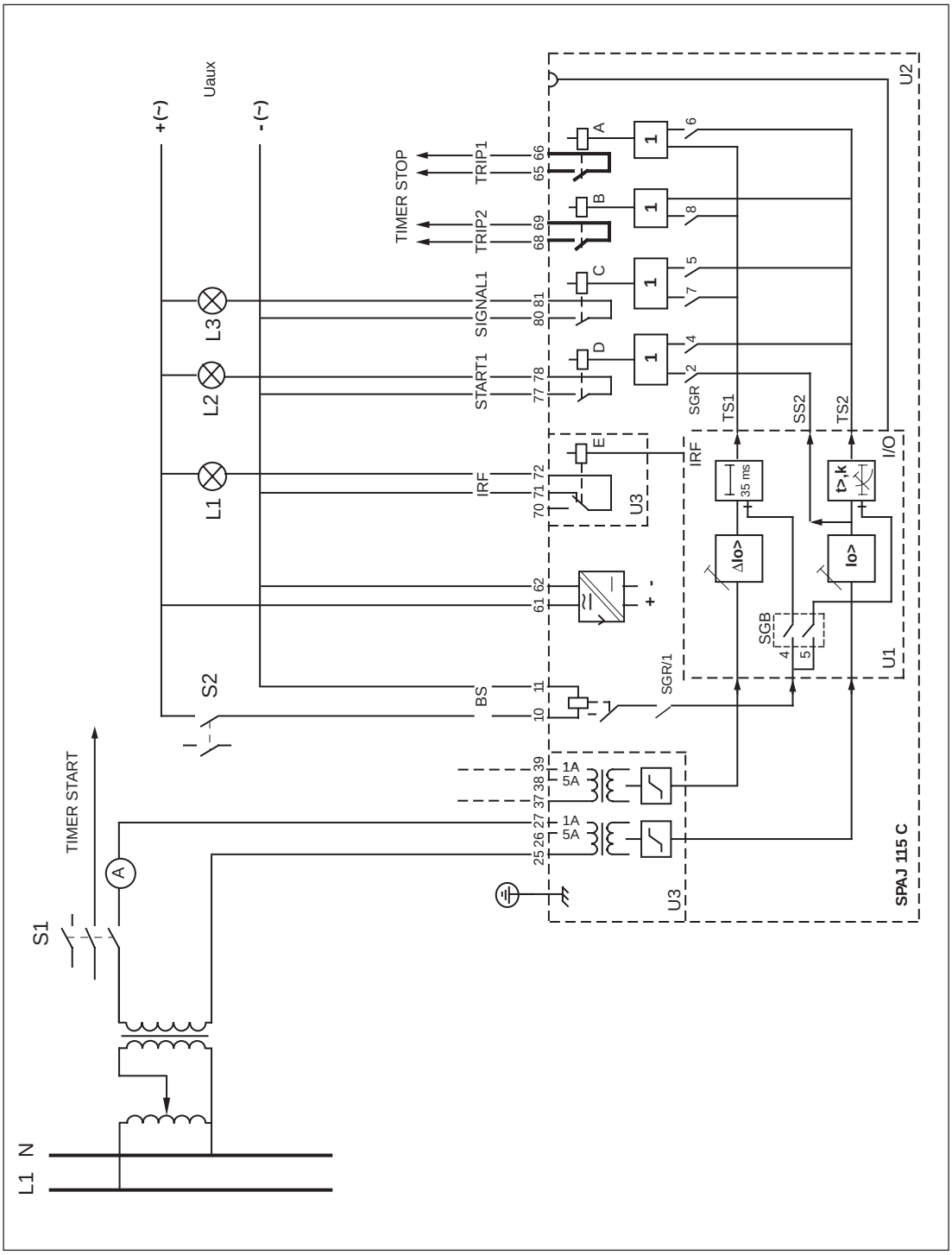


Fig. 8. Secondary test circuit for the earth-fault relay SPAJ 115 C.

The auxiliary voltage can be connected to the relay, as the test connection has been finished and the selector switches properly set.

The correctness of the test connection can be verified by using a multimeter.

Checking the matching transformers

Pure sinusoidal energizing current is fed to the relay. Compare the current value shown in the display with the current reading of the ammeter.

The measurement can be made at the rated current of the relay. The matching transformers are tested separately.

Checking the restricted earth-fault stage $\Delta I_0>$

The switches of switchgroup SGR should be set as follows:

Switch	Position
1	1
2	0
3	-
4	0
5	0
6	0
7	1
8	0

The output relays have the following functions:

Output (terminals)	Function
A (65-66)	Trip signal of stage $\Delta I_0>$
B (68-69)	Not in use
C (80-81)	Signal on tripping of stage $\Delta I_0>$ (L3)
D (77-78)	Not in use
E (71-72)	Self-supervision alarm signal (L1)

Start function

Close switch S1 and slowly increase the test current until the relay operates, indicator L3 is lit. Read the start current value from the ammeter.

Operate time

The operate time of the restricted earth-fault stage is measured at a test current equal to 2 times the set start value of stage $\Delta I_0>$. The timer is started when switch S1 is closed and stopped by contact 65-66 on operation of output relay A.

The operation of output relay C is indicated by LED L3.

When the relay operates, the indicator $\Delta I_0>$ in the right bottom corner of the front panel of the relay module turns red.

Blocking

Switch 4 and 5 of switchgroup SGB on the PC board of the relay module and switch SGR/1 on the front panel are to be set in position 1 (ON).

The blocking function is tested by applying a control voltage of the auxiliary voltage level to input 10-11 via switch S2. At first switch S2 is closed and then the test current is increased well above the set start current level.The relay must not operate, i.e. L3 remains dark.

Checking the restricted earth-fault stage I_0>

The switches of switchgroup SGR should be set as follows:

Switch	Position
1	1
2	1
3	0
4	0
5	1
6	0
7	0
8	0

The output relays have the following functions:

Output (terminals)	Function
A (65-66)	Not in use
B (68-69)	Trip signal of stage I_0>
C (80-81)	Signal on tripping of stage I_0> (L3)
D (77-78)	Start signal of stage I_0> (L2)
E (71-72)	Self-supervision alarm signal (L1)

Start function

The measuring current is slowly increased until the stage starts and indicator L2 is lit. The start current is read from the ammeter.

Operate time

Definite time characteristic

The operate time of the residual earth-fault stage is measured at a test current equal to 2 times the set start value of I_0> stage. The timer is started by closing switch S1 and stopped by contact 68-69 on operation of output relay B.

Inverse time characteristic

At inverse time characteristic the operate time of the stage is measured at two current values (2 x I_0> and 10 x I_0>). The operate times thus received are compared with the operate times shown in the current/time curves for the corresponding inverse time characteristic.

Checking the self-supervision system

The self-supervision system and its operation indicator IRF and output relay E can be tested in the Trip-Test mode described in section "General characteristics of C-type relay modules" of this manual. The operation of output relay E is indicated by the LED indicator L1.

Maintenance and repair

When used under the conditions specified in the section "Technical data", the relay requires practically no maintenance. The relay includes no parts or components that are liable to abnormal physical or electrical wear under normal operating conditions.

If the environmental conditions on site differ from those specified, as to temperature and humidity, or if the atmosphere around the relay contains chemically active gases or dust, the relay should be visually inspected during the relay secondary testing. The visual inspection should focus on:

- Signs of mechanical damage on relay case and terminals
- Dust accumulated inside the relay cover or case; remove carefully with compressed air or a soft brush
- Signs of corrosion on terminals, case or components inside the relay

If the relay fails to operation or if the operation values considerably differ from those stated in the relay specifications, the relay should be given a proper overhaul. Minor measures, such as exchange of a faulty module, can be undertaken by personnel from the customer's instrument work-shop, but major measures involving measures in the electronic circuitry are to be taken by the manufacturer. Please contact the manufacturer or his nearest representative for further information about checking, overhaul and recalibration of the relay.

Note!
The protection relays contain electronic circuits which are liable to serious damage due to electrostatic discharge. Before withdrawing a module from the relay case, ensure that you are at the same electrostatic potential as the equipment by touching the case.

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

Exchange and spare parts

Combined restricted earth-fault and residual earth-fault relay module	SPCJ 2C30
Combined power supply and I/O module	
- U_{aux} = 80...265 V ac/dc	SPTU 240S1
- U_{aux} = 18...80 V dc	SPTU 48S1
Case (including I/O module)	SPTK 2E17
I/O module	SPTE 2E17
Bus connection module	SPA-ZC 17_ or SPA-ZC 21_

Ordering numbers

Combined restricted earth-fault and residual earth-fault relay SPAJ 115 C

SPAJ 115 C	RS 421 012 -AA, CA, DA, FA

Combined restricted earth-fault and residual earth-fault relay SPAJ 115 C with test adapter RTXP 18

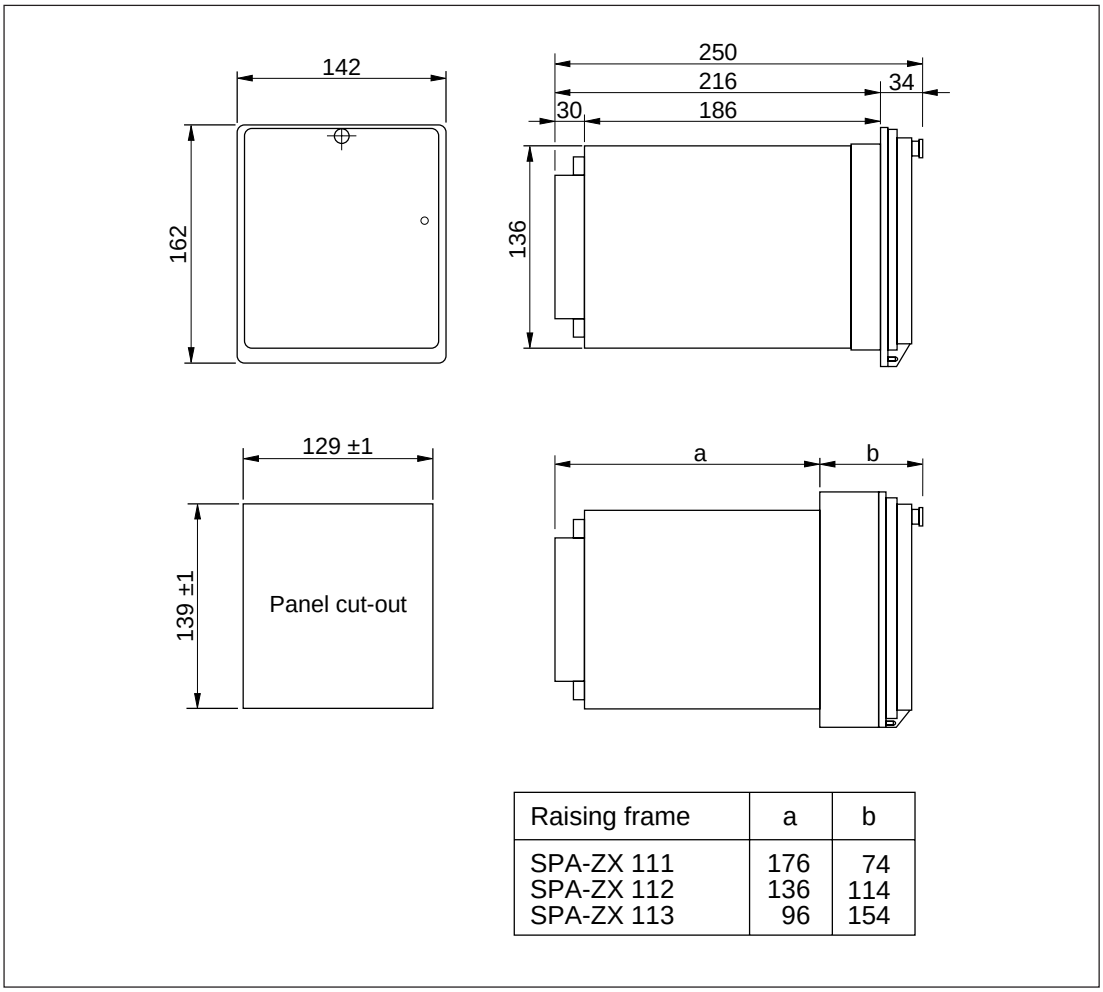
SPAJ 115 C	RS 421 212 -AA, CA, DA, FA

The two last letters of the ordering number designate the rated frequency f_n and the U_{aux} voltage range of the relay as follows:

AA: f_n = 50 Hz and U_{aux} = 80...265 V ac/dc
CA: f_n = 50 Hz and U_{aux} = 18...80 V dc
DA: f_n = 60 Hz and U_{aux} = 80...265 V ac/dc
FA: f_n = 60 Hz and U_{aux} = 18...80 V dc

Dimensions and instructions for mounting

The relay case is basically designed for flush-mounting. The mounting depth can be reduced by the use of a raising frame: type SPA-ZX 111 reduces the depth behind the mounting panel by 40 mm, type SPA-ZX 112 reduces the depth by 80 mm and type SPA-ZX 112 reduces the depth by 120 mm. The relay can also be mounted in a case for surface mounting, type designation SPA-ZX 115.



Raising frame	a	b
SPA-ZX 111	176	74
SPA-ZX 112	136	114
SPA-ZX 113	96	154

Fig. 9. Dimensions of the restricted earth-fault and residual earth-fault relay SPAJ 115 C.

The relay case is made of profile aluminium and finished in beige.

A rubber gasket fitted on the mounting collar provides an IP54 degree of protection between relay case and mounting panel, when the relay is flush mounted.

The hinged cover of the relay case is made of a clear, UV stabilized polycarbonate, and provided with a sealable fastening screw. A gasket along the edge of the cover provides an IP54 degree of protection between the case and the cover.

All input and output wires are connected to the screw terminal blocks on the rear panel. Each terminal is dimensioned for one max. 6 mm^2 wire or two max. 2.5 mm^2 wires. The D-type connector connects to the serial communication bus.

Order information

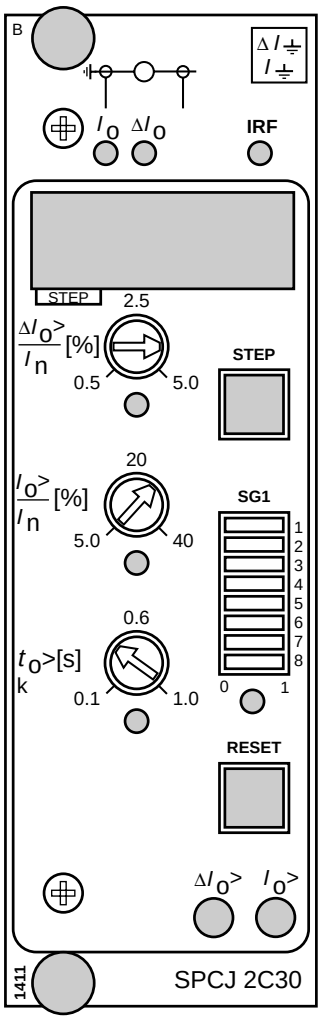
1. Quantity and type designation
2. Order number
3. Rated frequency
4. Auxiliary voltage
5. Accessories

6. Special requirements

Example
15 pces relay SPAJ 115 C
RS 421 012-AA
f_n = 50 Hz
U_{aux} = 110 V dc
15 bus connection modules SPA-ZC 21 MM
2 fibre optic cables SPA-ZF MM 100
14 fibre optic cables SPA-ZF MM 5
–

SPCJ 2C30
Differential current and neutral current module

User´s manual and Technical description



1MRS 750659-MUM EN

Issued 1997-02-26
Modified 2002-05-15
Version B (replaces 34 SPCJ 11 EN1)
Checked MK
Approved OL

SPCJ 2C30
Differential current and neutral current module

Contents

Features

Sensitive differential current stage $\Delta I_0>$ with short operate time, 35 ms. Setting range 0,5…5 % x I_n

Neutral overcurrent stage $I_0>$ with definite time characteristic or inverse time characteristic. Setting range 5…40% x I_n

The operation of both protection stages can be blocked with an external control signal

Local display of measured currents, set start values, recorded fault data and other parameters

Flexible configuration of the relay module to obtain the desired protection functions

All settings may be entered using the push-buttons and the display on the front panel of the module or they may be set using a personal computer

Continuous self-supervision including both module hardware and software. At a permanent fault the alarm output relay operates and the other relay outputs are blocked.

Operation principle

The combined differential current and neutral current module SPCJ 2C30 measures two currents; the differential current ΔI_0 and the neutral current I_0. The differential current is formed with an external connection. The relay module holds two protection stages, one for each current.

The differential current stage $\Delta I_0>$ operates instantaneously and provides an operate signal TS1, if the measured differential current exceeds the set start current.

The neutral current stage $I_0>$ starts if the measured neutral current exceeds the set start current. On starting the stage provides a start signal SS2 and at the same time the operation indicator turns yellow. After the set or calculated operate time $t_0>$ the stage provides an operate signalTS2, if the fault still persists.

The indicator of the stage that operates turns red. The start and operation indications can be given self-reset or manual-reset mode of operation, see switch SG2. The latched indications are reset locally by pressing the RESET push-button on the front panel or remotey by means of the commands V101 or V102 via the SPA bus.

The operation of stage $\Delta I_0>$ can be blocked by means of an external control signal to input BTS1. Correspondingly the operation of stage $I_0>$ can be blocked by means of an external control signal to input i BTS2. The incoming blocking signals are distributed to the desired protection stages with switches of switcgroup SGB.

The switches of switchgroup SGB are also used for defining start signals for a possible cooperating auro-reclose relay. The function of switchgroup SGB is described in the general description of the different relay manuals.

The setting range of the differential stage $\Delta I_0>$ is 0,5…5% x I_n. The operate time is fixed and typically 35 ms.

The setting range of the neutral current stage $I_0>$ is 5…40% x I_n. The neutral current stage can be assigned definite time or inverse time characteristic. The selection is made with switch SG1/6. At definite time characteristic three operate time ranges are available; 0.1…1s, 1…10 s and 10…100 s. The operate time setting range is set with switch SG1/7 and SG1/8.

At inverse time characteristic of the $I_0>$ stage four time-current characteristic curve groups can be selected. The selection is made with switches SG1/7 and SG1/8.

The two protection stages can separately be given a latching function, which means that the operate output remains high, althoug the fault, which caused the relay to operate, has disappeared. The lached state is reset locally by pressing the STEP and RESET push-buttons simultaneously or remotely by means of the commands V101 or V102 via the SPA bus. The latching function of stage $\Delta I_0>$ is selected with switch SG1/3 and the latching function of stage $I_0>$ with switch SG1/4.

The differential current input and the neutral current input are provided with low-pass filters which suppress harmonics of the input current, see. Fig. 1.

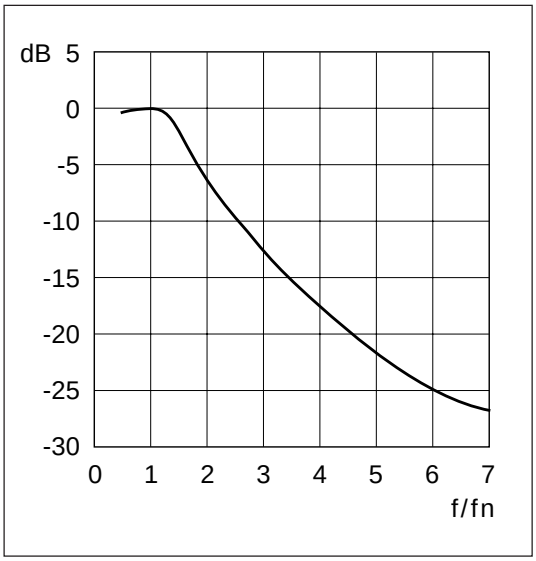


Fig. 1. Filter characteristics of the measuring current inputs of the SPCJ 2C30 module.

Block diagram

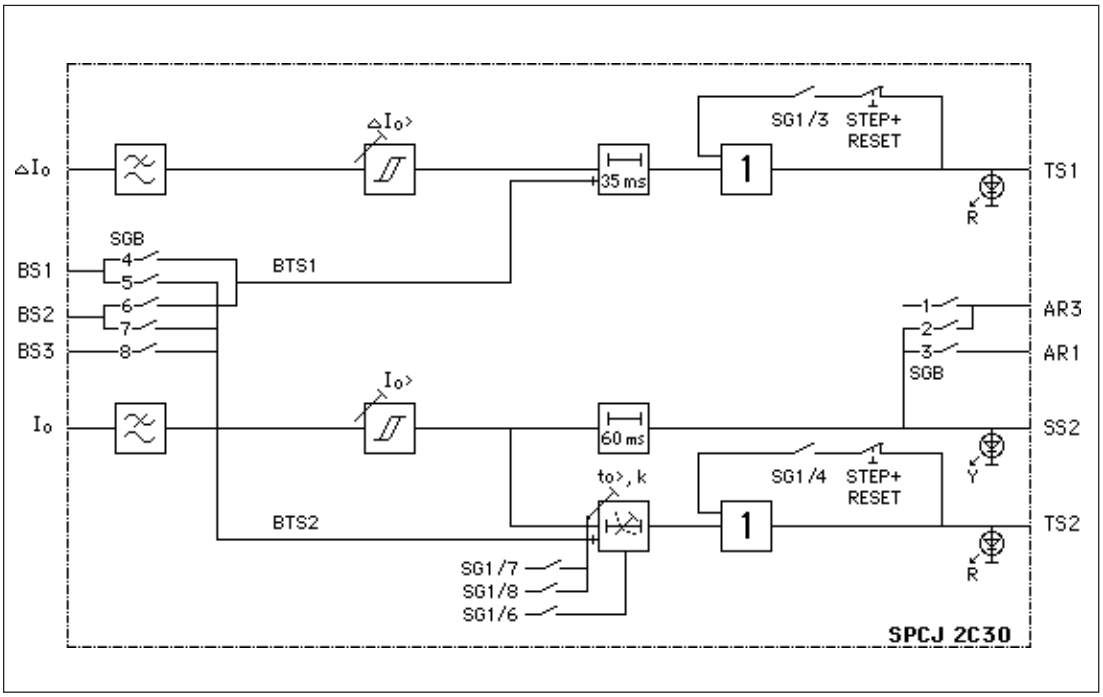


Fig. 2. Block diagram of the differential current and neutral current relay module SPCJ 2C30.

ΔI_0	Measured differential current
I_0	Measured neutral current
BS1, BS2, BS3	External blocking signals
BTS1	Blocking signal of stage $\Delta I_0>$
BTS2	Blocking signal of stage $I_0>$
SG1	Switchgroup on the front panel
SG2	Indicator programming switchgroup (not shown in figure)
SGB	Blocking signal and auto-reclose start signal programming switchgroup on the circuit board
TS1	Operate (trip) signal of stage $\Delta I_0>$
SS2	Start signal of stage $I_0>$
TS2	Operate (trip) signal of stage $I_0>$
AR1, AR3	Auto-reclose start signals
$\Delta I_0>$	Differential current stage
$I_0>$	Neutral current stage
$t_0>$	Operate (trip) time of stage $I_0>$
Y	Yellow indicator, starting
R	Red indicator, operation (tripping)

NB!
All input and output signals of the relay module are not necessarily wired to the terminals of any protection relay incorporating the above relay module. The signals wired to the terminals of a particular protection relay are shown in section "Signal diagram" in the general manual of the concerned protection relay.

Front panel

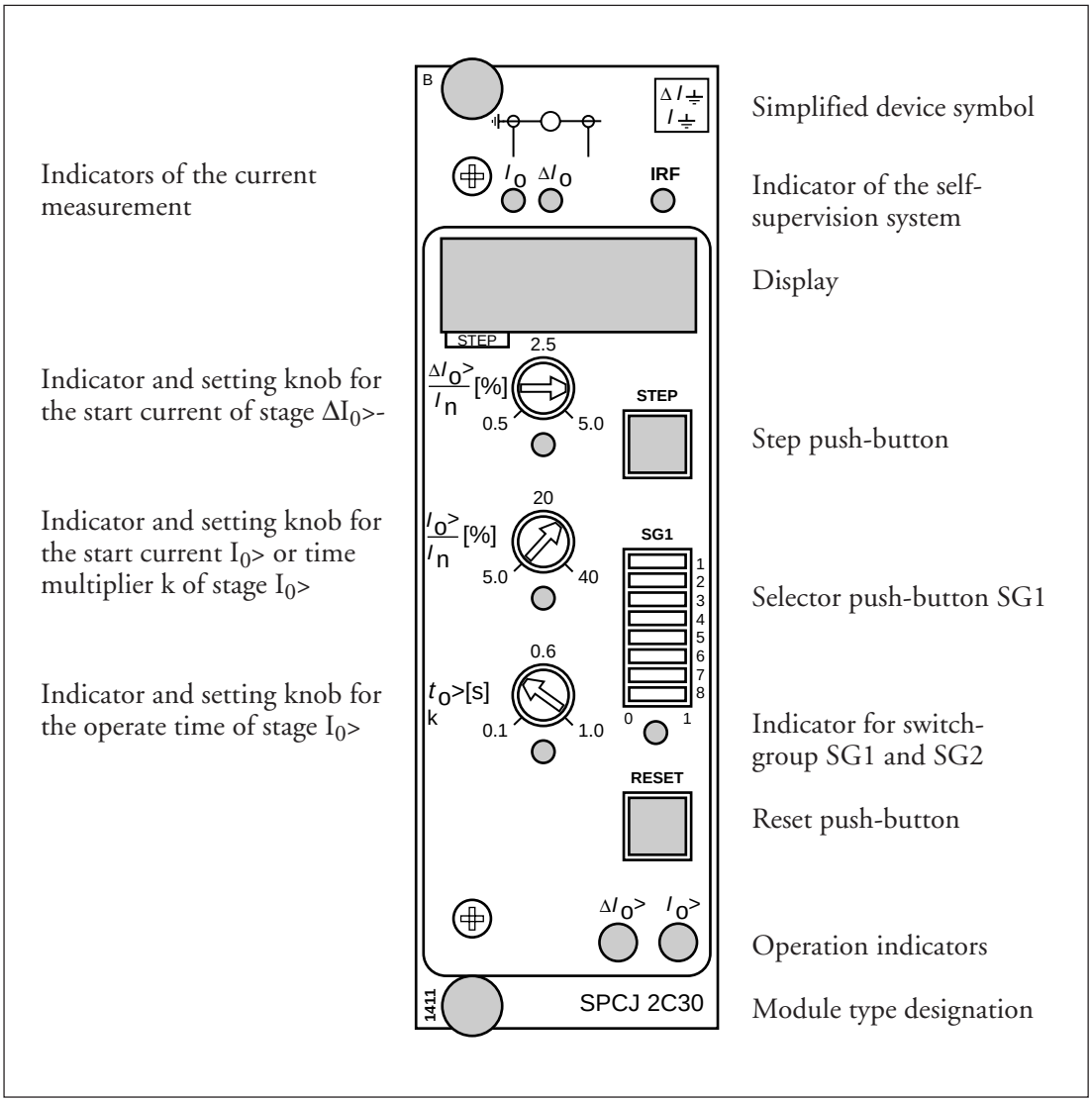


Fig. 3. Front panel of the differential current and neutral current relay module SPCJ 2C30.

Indicators

The operation indicator of the differential current stage $\Delta I_0>$ is lit with red colour, when the stage operates. The operation indicator of the neutral current stage $I_0>$ is lit with yellow colour when the stage starts and with red colour, when the stage operates.

The indicators can separately be assigned a latching function, which means that the indicator will remain lit, although the fault that caused the indication has disappeared. If, for example, the trip indication of stage $I_0>$ has been assigned the latching function, the indicator normally turns yellow when the stage starts and turns red when the stage operates. When the stage resets the red indicator remains lit. The latched indicators are reset locally by pressing the RESET push-button on the front panel or remotely by means of commands V101 or V102 via the SPA bus.

An unreset operation indicator does not affect the protection functions of the relay module. The relay module is always operative, whether the indicators have been reset or not.

The self-supervision alarm indicator IRF indicates that the self-supervision system has detected a permanent internal relay module fault. The IRF indicator is lit with red light shortly after the fault has been detected. At the same time the relay module delivers a control signal to the self-supervision system output relay of the protection relay unit.

Additionally, in most fault cases, a fault code showing the fault type appears on the display of the relay module. The fault code consists of a red figure one (1) and a green three-digit code number. When a fault message appears on the display, the code number should be noted to facilitate trouble-shooting and repair.

Settings

The setting values are shown by the three rightmost digits of the display. When lit, the LED indicator below a setting knob shows that the concerned setting value is being displayed.

$\Delta I_0>/I_n$	Start current of stage $\Delta I_0>$ in percent of the rated current of the used relay energizing input, setting range 0,5…5% x I_n
$I_0>/I_n$	Start current of stage $I_0>$in percent of the rated current of the used relay energizing input, setting range 5…40% x I_n
$t_0>$	Operate time of stage $I_0>$ at definite time characteristic. The setting range is k> selected with switche SG1/7and SG1/8 , setting ranges 0.1...1.0 s, 1…10 s and 10...100 s. Time multiplier k> at inverse time characteristic, setting range 0.1…1.0.

Further, the checksum of the selector switchgroup SG1 is indicated on the display when the LED indicator under the switchgroup is lit. In this way a check can be carried out to prove that the switchgroup has been set and that the individual switches work properly. An example of a checksum calculation is given in manual "General characteristics of C type relay modules".

Selector switches

Additional fuctions required in different applications are selected with the switches of switchgroup SG1 on the front panel. The switch numbers 1...8 and the switch positions 0 or 1 are marked on the front panel

Switch	Function
SG1/1	Not in use. To be in position 0.
SG1/2	Not in use. To be in position 0.
SG1/3	Selection of the latching function for the operate signal TS1 of stage $\Delta I_0>$ When SG1/3=0, the operate signal TS1 returns to normal (= output relay drops), when the measured current falls below the set start current of the stage. When SG1/3=1, the operate signal TS1 remains high (=output relay picked up), although the measured current falls below the set start current of the stage. The operate signal is reset locally by pressing the STEP and RESET push-buttons simultaneously or remotely by means of the command V101 via the SPA bus. When the STEP- and RESET push-buttons are used the recorded information is also erased.
SG1/4	Selection of the latching function for the operate signal TS2 of stage $I_0>$ When SG1/4=0, the operate signal TS2 returns to normal (= output relay drops), when the measured current falls below the set start current of the stage. When SG1/4=1, the operate signal TS2 remains high (=output relay picked up), although the measured current falls below the set start current of the stage. The operate signal is reset locally by pressing the STEP and RESET push-buttons simultaneously or remotely by means of the command V101 via the SPA bus. When the STEP- and RESET push-buttons are used the recorded information is also erased.
SG1/5	Not in use. To be in position 0.

Switch	Function
SG1/6 SG1/7 SG1/8	With switch SG1/6 definite or inverse time characteristic is selected for stage I_0>. With switches SG1/7 and SG1/8 the operate time setting range is selected at definite time characteristic and the time multiplier setting range at inverse time characteristic.

SG1/6	SG1/7	SG1/8	Characteristic	Operate time t_0> or time/current curve
0	0	0	Definite time	0.10…1.00 s
0	1	0	Definite time	1.00…10.0 s
0	0	1	Definite time	1.00…10.0 s
0	1	1	Definite time	10.0…100 s
1	0	0	Inverse time	Extremely inverse
1	1	0	Inverse time	Very inverse
1	0	1	Inverse time	Normal inverse
1	1	1	Inverse time	Long time inverse

The software switchgroup SG2 is located in the third submenu of the checksum register of switchgroup SG1. The operation principle of the operation indicators is defined with switchgroup SG2. The operation indicators can be defined to be self-reset or latching. The setting is performed by defining a checksum for the switchgroup as described in the table below. As a default setting the start signal is set to be self-reset and the operate signals to be latching.

	Weighting factor	Factory default
Red indication, ΔI_0> operated Yellow indication, I_0> started. Red indication, I_0> operated	2 4 8	2 0 8
Checksum Σ	14	10

The possible external blocking signals applied to the relay are routed to the protection stages with switches SGB/4…8. Any start signals to be routed to a cooperating auto-reclose relay are configured with switches SGB/2 and SGB/3. Switch SGB/1 is not in use.

The alternatives, which can be selected with the switches of switchgroup SGB, are shown in the general part of the maual of the different relays which incorporate the differential current and neutral current module SPCJ 2C30.

Measured data

The measured values are displayed with the rightmost three digits of the display. The currently displayed value is indicated by an illuminated LED indicator on the front panel.

Indicator	Measured data
I_0	Neutral current displayed in percent of the rated current I_n of the relay
ΔI_0	Differential current displayed in percent of the rated current I_n of the relay. If the measured current exceed about 60% x I_n, a symbol "- - -" will be shown in the display.

Recorded information

The leftmost digit of the display indicates the number of the register and the three rightmost digits show the content of the register.

Register/ STEP	Recorded information
1	Measured maximum differential current ΔI_0 in percent of the relay rated current. The register content is updated if on of the following conditions is fulfilled: 1) The measured current exceeds the value currently in the register. 2) The relay issues an operate signal. When the relay operate the value at the moment of operation is recorded in the register. If the value of the measured differential current exceeds approximately 60% x I_n, the register content will be shown as "- - -".
2	Measured maximum neutral current I_0 in percent of the relay rated current. The register content is updated if on of the following conditions is fulfilled: 1) The measured current exceeds the value currently in the register. 2) The relay issues an operate signal. When the relay operate the value at the moment of operation is recorded in the register.
3	Number of operations of the differential current stage $\Delta I_0>$, n($\Delta I_0>$) = 0 ... 255
4	Number of operations of the neutral current stage $I_0>$, n($I_0>$) = 0 ... 255
5	Duration of the last start situation of stage $I_0>$ in percent of the set operate time $t_0>$ at definite time characteristic or calculated operate time at inverse time characteristic. The counter always starts counting from zero. When the module operates (trips) the counter reading will be 100 [%].
0	Status of the external blocking inputs. The rightmost digit of the display shows the status of the blocking inputs. The following alternatives are available: 0 = No blocking 1 = The operation of stage $\Delta I_0>$ is blocked 2 = The operation of stage $I_0>$ is blocked 3 = The operation of both stages ($\Delta I_0>$ and $I_0>$) is blocked The middle digit of the register is always zero. The third digit from the right indicates the status of a possible remote reset input. The following alternatives are available: 0 = Remote reset input not activated 1 = Remote reset input activated From register 0 the TRIP TEST mode can be reached. In the TRIP TEST mode the start and operate signal of the module can be activated on by one. A detailled description of the TRIP TEST mode is to be found in the manual "General characteristics of C type relay modules".

Register/ STEP	Recorded information
A	Module address code for the communication system. If the register value is zero the serial communicatio is not in use. The subregisters of register A are: 1) Selection of the data transfer speed. Selectable values 300, 1200, 2400, 4800 or 9600 Bd. Default setting 9600 Bd 2) Bus communication monitor. If the module is connected to a data communication device and the communication system is working, the communcation counter is 0. If the communication is interrupted the numbers 0…255 are scrolling in the display. 3) Password required for remote setting of relay parameters

When the display is dark you can proceed to the beginning of the display menu by pressing the STEP push-button once.

The content of the registers 1...5 are erased by pressing push-buttons STEP and RESET simultaneously or with the remote control command V102. The register values are also erased if the auxiliary power supply to the module is interrupted. The address code of the relay module, the value of the data transfer rate of the serial communication and the password are not erased by an auxiliary voltage interruption. Instructions for setting the address and the data transfer rate are given in the user's manual "General characteristics of C-type relay modules".

Menu chart

The diagram below shows the main menu and the submenus of the differential current and neutral current relay module SPCJ 2C30. The general principles for navigating in the menues are described in the user's manual "General characteristics of C type relay modules".

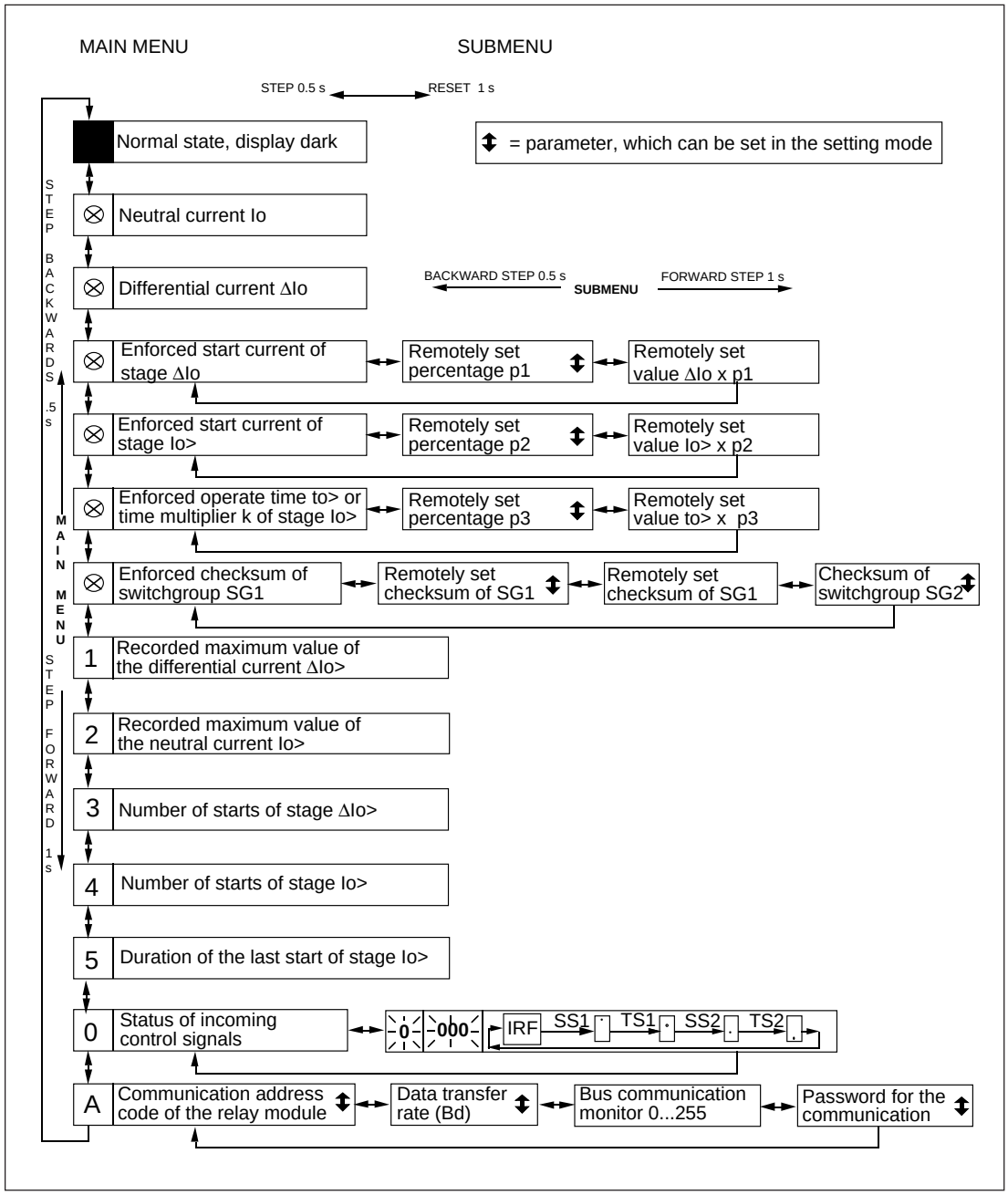


Fig. 4. Menu chart of the differential current and neutral current relay module SPCJ 2C30.

Inverse time characteristic

(modified 2002-05)

The operation of the neutral current stage $I_0>$ is based on either definite time or inverse time characteristics. The desired characteristic is selected with switch SG1/3, see chapter "Selector switches".

At inverse time characteristic the operate time of stage $I_0>$ is a function of the current; the higher the current the shorter the operate time. The relationship between time and current is defined in the BS 142.1966 and IEC 60255-3 standards as follows:

$$t = \frac{k \times \beta}{\left(\frac{I}{I_{0>}}\right)^{\alpha} - 1}$$

where,
t = operate time in seconds
k = time multiplier
I = measured current
$I_0>$ = set start current

The relay module includes four standard curve groups. The desired curve group is selected with switch SG1/7and SG1/8, see chapter "Selector switches".

The slope of the characteristic curve is defined by parameter α and β as follows:

Slope of the characteristic curve	α	β
Normal inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long time inverse	1.0	120.0

According to the standard BS 142.1966 the normal current range is defined as 2...20 times the setting current. Additionally the relay must start at the latest when the measurd current exceeds 1.3 times the set sarting value, when the time/current characteristic is normal inverse, very inverse or extremely inverse. When the characteristic is long time inverse, the normal range accordance to the standards is 2...7 times the set starting value and the relay must start when the current exceeds 1.1 times the set starting value.

The following requirements regarding tolerances of the operation time are specified in the standard (E denotes accuracy in percent, - = not specified):

$I/I_0>$	Normal inverse	Very inverse	Extremely inverse	Long time inverse
2	2,22 E	2,34 E	2,44 E	2,34 E
5	1,13 E	1,26 E	1,48 E	1,26 E
7	-	-	-	1,00 E
10	1,01 E	1,01 E	1,02 E	-
20	1,00 E	1,00 E	1,00 E	-

The accuracy of the operation time of the inverse time curves of the neutral current stage of the relay module SPCJ 2C30 comply with the tolerances of class 5.

The standardi inverse time curve groups are shown in Figs. 5, 6, 7 and 8.

Note.
The actual operate time of the relay, presented in the graphs in Fig. 3…6, includes an additional filter and detection time plus the operate time of the trip output relay. When the operate time of the relay is calculated using the mathematical expression above, these additional times of about 30 ms in total have to be added to the time received.

Time/current characteristic of the combined differential current and neutral current module SPCJ 2C30

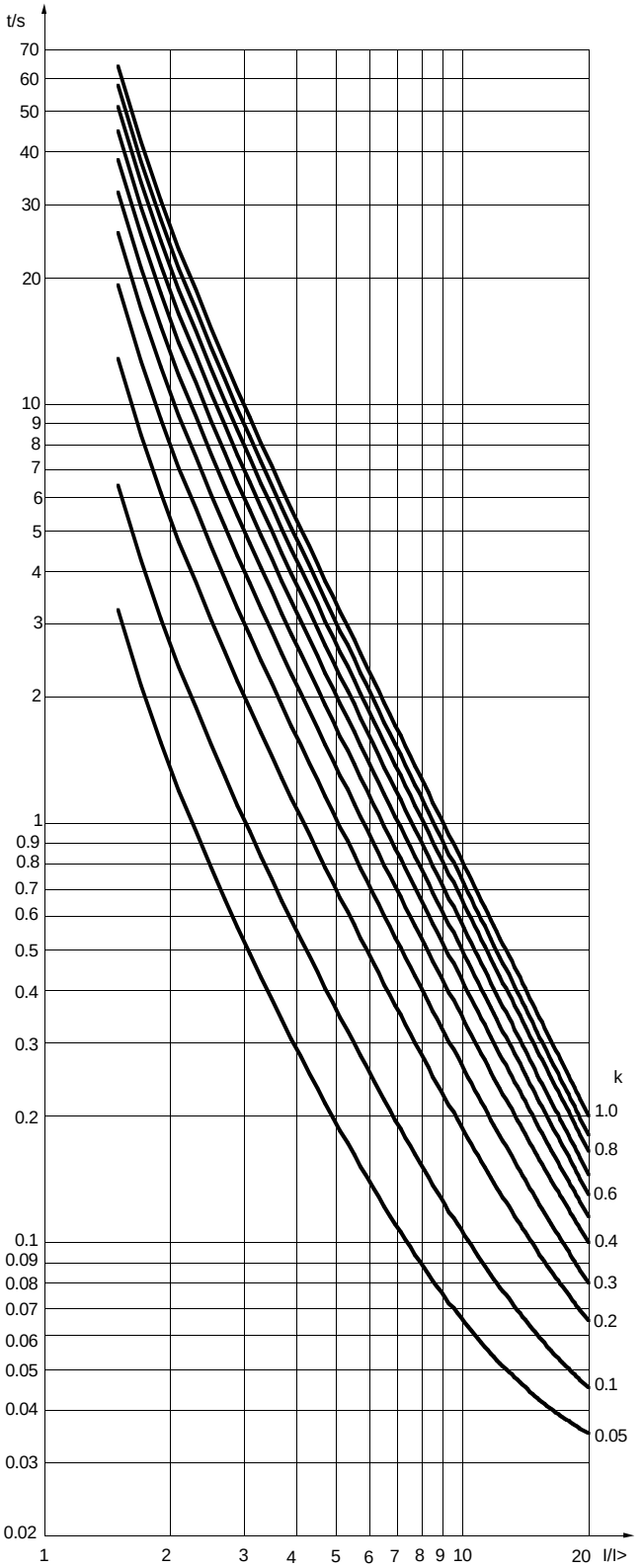


Fig. 5. Extremely inverse characteristic

I = measured current
$I_{0}>$ = set start current
t = operate time
k = time multiplier

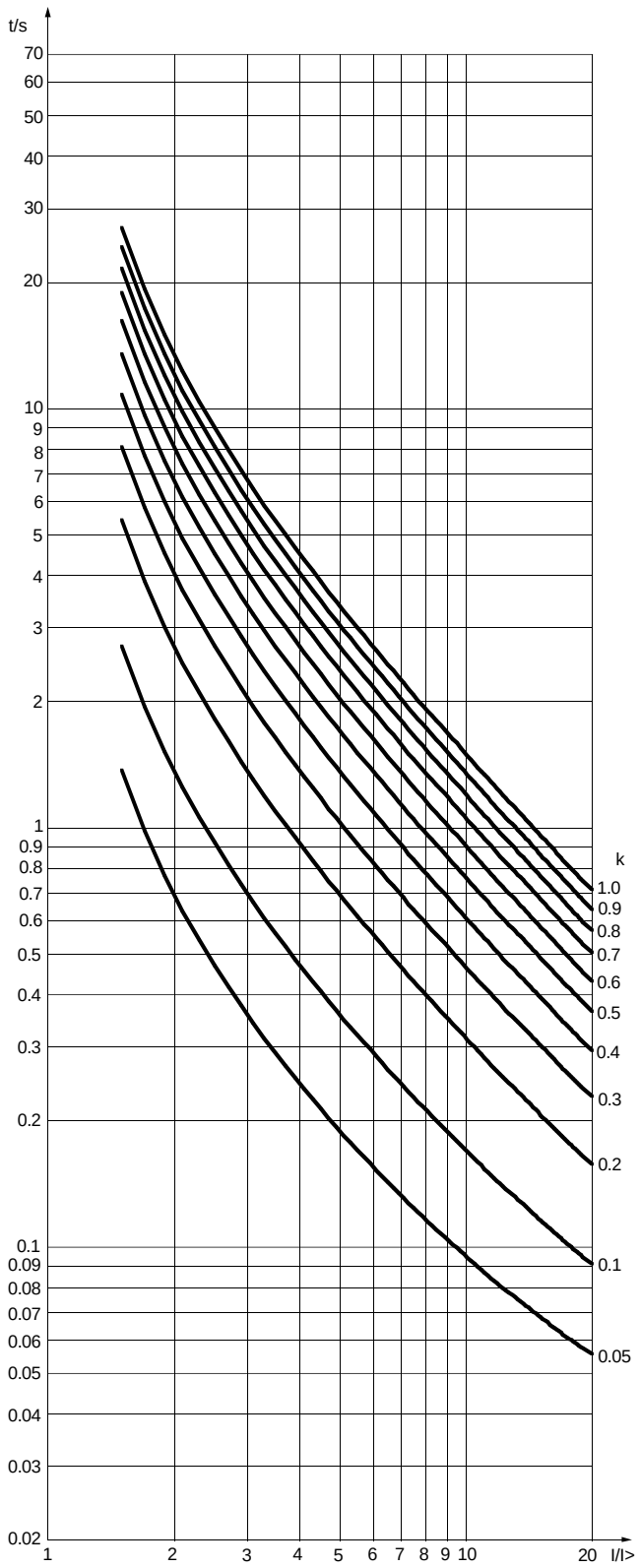


Fig. 6. Very inverse characteristic

I = measured current
$I_0>$ = set start current
t = operate time
k = time multiplier

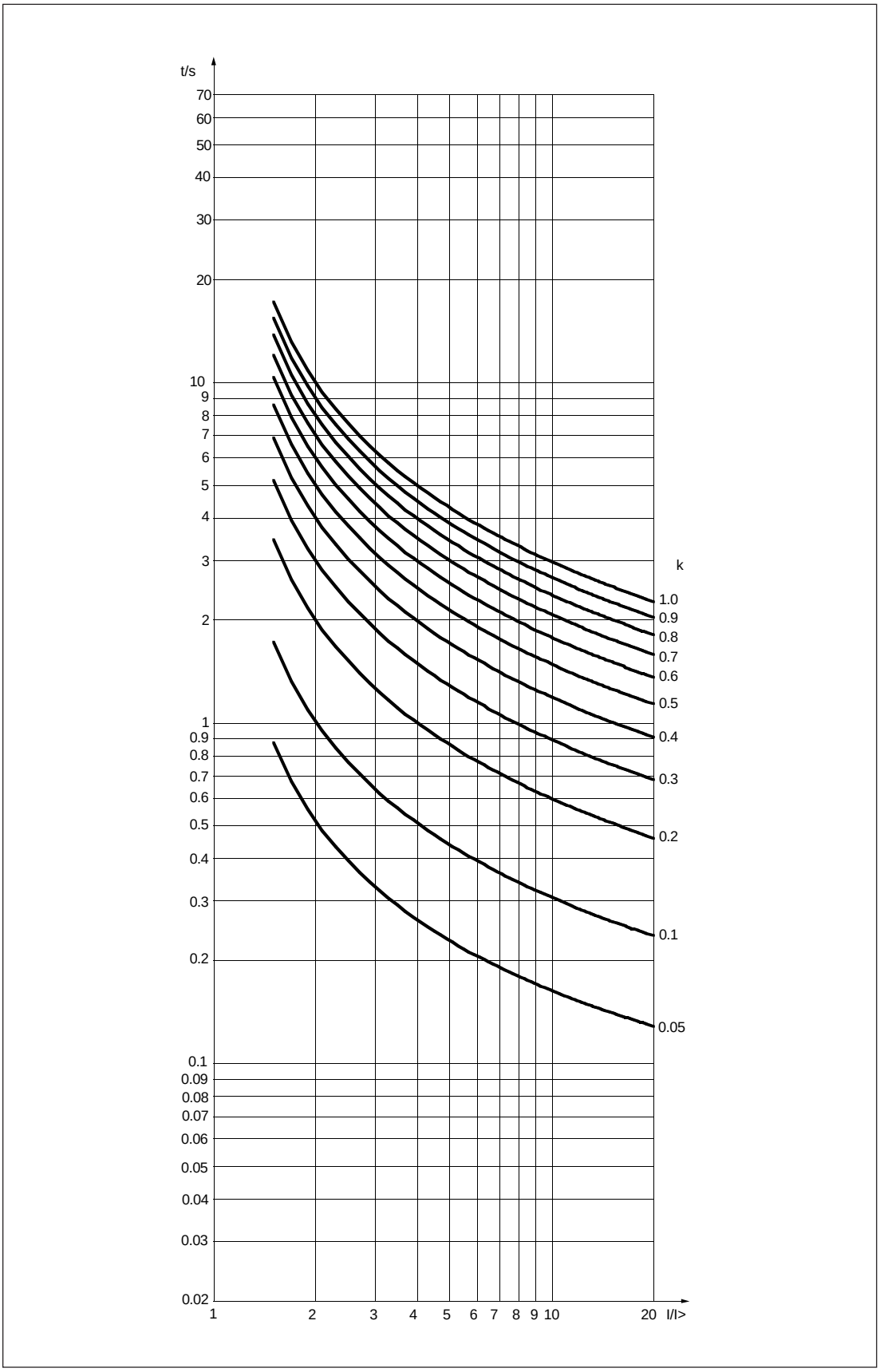


Fig. 7. Normal inverse characteristic

I = measured current
I_0> = set start current
t = operate time
k = time multiplier

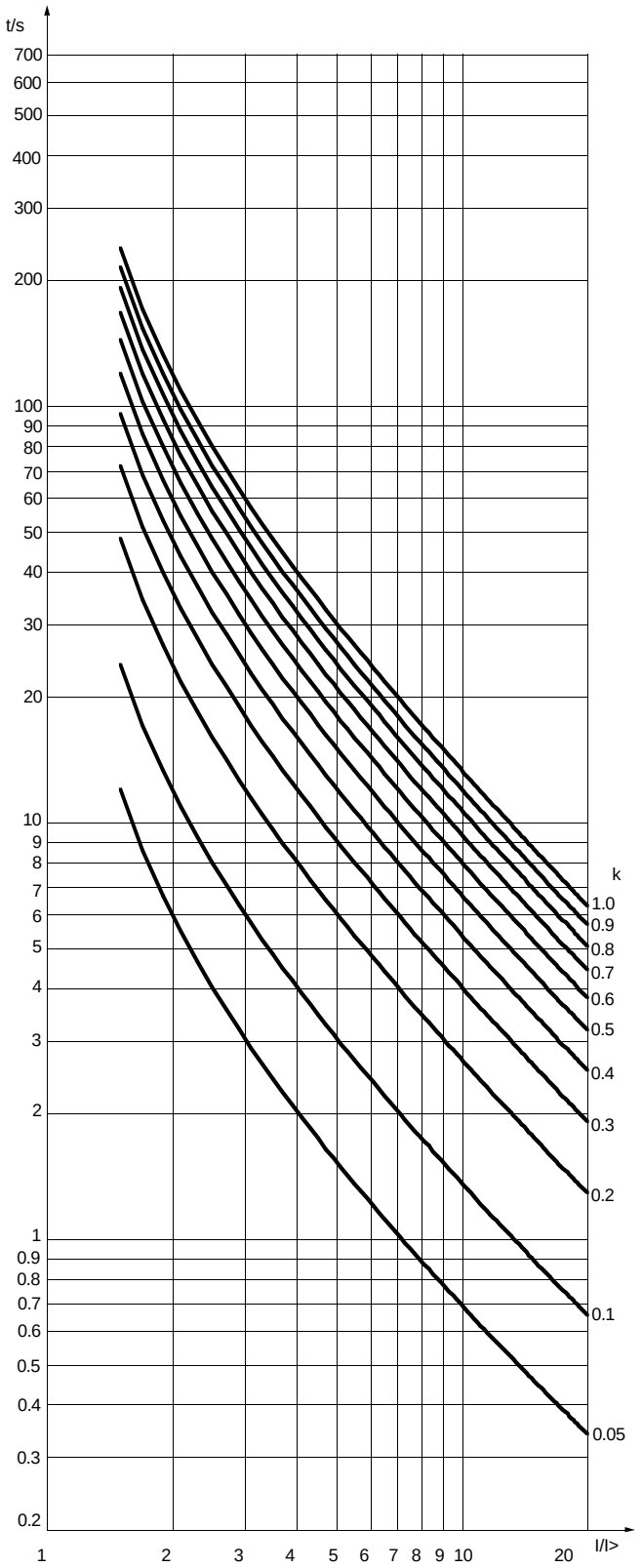


Fig. 8. Long time inverse characteristic

I = measured current
$I_{0>}$ = set start current
t = operate time
k = time multiplier

Differential current stage $\Delta I_0>$

Start current	0.5…5% x I_n
Fixed operate time, typ.	35 ms
Reset time, typ.	60 ms
Reset ratio, typ.	0.97
Operate time accuracy	±25 ms
Operation accuracy	
- within the setting range 0.5…1.5% x I_n	±5% of the set value
- within the setting range 1.5…5% x I_n	±3% of the set value

Neutral current stage $I_0>$

Start current	5...40% x I_n
Start time, typ.	60 ms
Operate time $t_0>$, at definite time characteristic	0.1...1.00 s, 1...10 s or 10…100 s
Time/current curves at inverse time characteristic	Extremely inverse Very inverse Normal inverse Long time inverse
Time multiplier k	0.1…1.0
Reset time, typ.	60 ms
Reset ratio, typ.	0.96
Operate time accuracy at definite time characteristic	±2% of the set value ± 25 ms
Operate time accuracy class index E at inverse time characteristic	5
Operation accuracy	±3% of the set value

Event codes

A substation level communication device can read event messages via the SPA bus from the combined differential current and neutral current relay module SPCJ 2C30. On request the module transmits its event messages in the form; time (ss.sss) and event code. The event codes of the module are E1…E6, E50 and E51. The communication device may also form event messages related to the data communication system.

The events represented by the codes E1...E6 can be included or excluded from the event reporting. This is done via the SPA bus by writing a so called event mask (V155) to the relay module. The event mask is a binary number coded to a decimal number.The even codes E1…E6 correspond with the weighting factors 1, 2, 4…32. The event mask is formed by multiplying the above numbers by 0, event not included in reporting or 1, event included in reporting and by adding the numbers received.

The event mask may have a value within the range 0…255. The factory set default value is 21, that is all the sart and operate events are, on request, tranmitted to the communication device,but the resettings are not transmitted. The events represented by the codes E50…E54 cannot be excluded from the reporting.

The event codes of the combined differential current and neutral current relay module SPCJ 2C30 :

Code	Event	Weighting factor	Factory default
E3	Stage ΔI_0> has operated	1	1
E4	Stage ΔI_0> has reset after operation	2	0
E5	Stage I_0> has started	4	1
E6	Stage I_0> has reset after starting	8	0
E7	Stage I_0> has operated	16	1
E8	Stage I_0> has reset after operation	32	0
E50	Restarting	*	-
E51	Overflow of event register	*	-
E52	Temporary data communication disturbance	*	-
E53	No response from the relay module over the bus	*	-
E54	Relay module responds again over the bus	*	-

0 not included in the event reporting
1 included in the event reporting
* no weighting factor
- not programmable

NB!
In the SPACOM system the events E52…E54 are generated by the substation level communication device, for instance, type SRIO 1000M.

Remote transfer data

In addition to the event data transfer the SPA bus allows reading of all input data (I data) of the module, setting values (S data), information recorded in the memory (V data), and some other data. Further, part of the data can be altered by commands given over the SPA bus. All the data are available in channel 0.

R = data that can be read from the module
W = data that can be written to the module

Data	Code	Data direction	Value or function
Measured neutral current I_0	I1	R	0…999% x I_n
Measured differential current ΔI_0	I2	R	0…62.5% x I_n 999, if ΔI_0 > 62.5% x I_n
Blocking of the operation of stage ΔI_0>	I3	R	0 = no blocking 1 = stage ΔI_0> blocked
Blocking of the operation of stage I_0>	I4	R	0 = no blocking 1 = stage I_0> blocked

Data	Code	Data direction	Value or function
Operation of stage $\Delta I_0>$	O1	R	0 = stage $\Delta I_0>$ not operated 1 = stage $\Delta I_0>$ operated
Starting of stage $I_0>$	O2	R	0 = stage $I_0>$ not started 1 = stage $I_0>$ started
Operation of stage $I_0>$	O3	R	0 = stage $I_0>$ not operated 1 = stage $I_0>$ operated
Enforced start current of stage $\Delta I_0>$	S1	R	0.5…5% x I_n
Enforced start current of stage $I_0>$	S2	R	5…40% x I_n
Enforced operate time $t_0>$ or time multiplier of stage $I_0>$	S3	R	0.10…100 s or 0.1…1.0
Enforced checksum of switchgroup SG1	S4	R	0...255
Start current of stage $\Delta I_0>$, set with the setting knob	S11	R	0.5…5% x I_n
Start current of stage $I_0>$, set with the setting knob	S12	R	5…40% x I_n
Operate time $t_0>$ or time multiplier k, set with the setting knob	S13	R	0.10…100 s or 0.1…1.0
Checksum of switchgroup SG1, set with the switches	S14	R	0…255
Start current of stage $\Delta I_0>$, remotely set percentage	S21	R,W	0…999%
Start current of stage $I_0>$, remotely set percentage	S22	R,W	0…999%
Operate time $t_0>$ or time multiplier k, remotely set percentage	S23	R,W	0…999%
Checksum of switchgroup SG1, remotely set checksum	S24	R,W	0…255
Start current of stage $\Delta I_0>$, executed second setting	S31	R	0.5…5% x I_n
Start current of stage $I_0>$, executed second setting	S32	R	5…40% x I_n
Operate time $t_0>$ or time multiplier k, executed second setting	S33	R	0.10…100 s or 0.1…1.0
Checksum of switchgroup SG1, second setting	S34	R	0…255
Maximum measured differential current or differential current at opertion	V1	R	0…62.5% x I_n 999, if ΔI_0 > 62.5% x I_n
Maximum measured neutral current or neutral current at opertion	V2	R	0…999% x I_n
Number of operations of stage $\Delta I_0>$	V3	R	0…255
Number of starts of stage $I_0>$	V4	R	0…255
Duration of the last start situation of satge $I_0>$	V5	R	0…100%
Remote resetting of the operation indicators	V101	W	1 = resetting of output relays and indicators
Remote resetting of output relays and indicators and erasing of recoded data	V102	W	1 = resetting of output relays and indicators, erasig of recoreded data (codes V1...V5)

Data	Code	Data direction	Value or function
Remote selection of settings	V150	R,W	0 = potentiometersettings S11…S14 enforced 1 = remote settings S31…S34 enforced
Event maskfor the reporting	V155	R,W	0…63, see chaper "Event codes"
Operation principle of the start and	V156	R,W	0…14, see chaper " Selector switches"
Opening of password for remote setting	V160	W	1…999
Changing or closing of password for remote setting	V161	W	0…999
Activation of the self-supervision system	V165	W	1 = self-supervision output is activated and IRF indicator switched on in about 5 s, whereafter the self-super-vision system and the IRF indicator reset
Address code of the relay module	V200	W	1...254
Software version	V205	R	e.g. 091 A
Relay module type designation	F	R	SPCJ 2C30
Reading of event register	L	R	time, channel number and event code
Re-reading of event register	B	R	time, channel number and event code
Reading of relay module status dat	C	R	0 = normal status 1 = module has been subject to automatic reset 2 = overflow of event register 3 = events 1 and 2 together
Resetting of module status data	C	W	0 = resetting
Clock time reading and setting	T	R,W	00.000...59.999 s

The data transfer codes L, B, C and T have been reserved for the event data transfer between the relay module and the substation level communication device.

The event register can be read only once by the L command. Should a fault occur, for instance, in the data transfer, it is possible, by using the B command, to re-read the contents of the event register once read by means of the L command. When required the B command can be repeated. Normally the event register is empty.

Parameters S1...S4 contain the enforced set values currently used by the relay module. These values may originally have been set by means of the setting knobs and selector switches or by remote control. The main settings S11...S14 are given with the setting knobs and the selector switches of the relay module. The values S21...S24 are percentage factors to be multiplied by the set values given with the setting knobs. The settings S21...S24 can be both read and written. A condition for writing is that the password, V160, for remote setting has been opened and the potentiometer settings are alerted, V150=0. The variables S31...S34 contain the actual remotely set values

The remote setting percentage of variables S21...S23 can be given a percentage value within the range 0...999. This means that certain parameters can be given set values outside the limits of the specified setting range. However, proper operation of the relay is guaranteed only for set values within the limits of the setting range specified in section "Technical data".

When the self-supervision system is activated (V165) the operation of the relay module is blocked and the IRF indicator is lit.

Fault codes

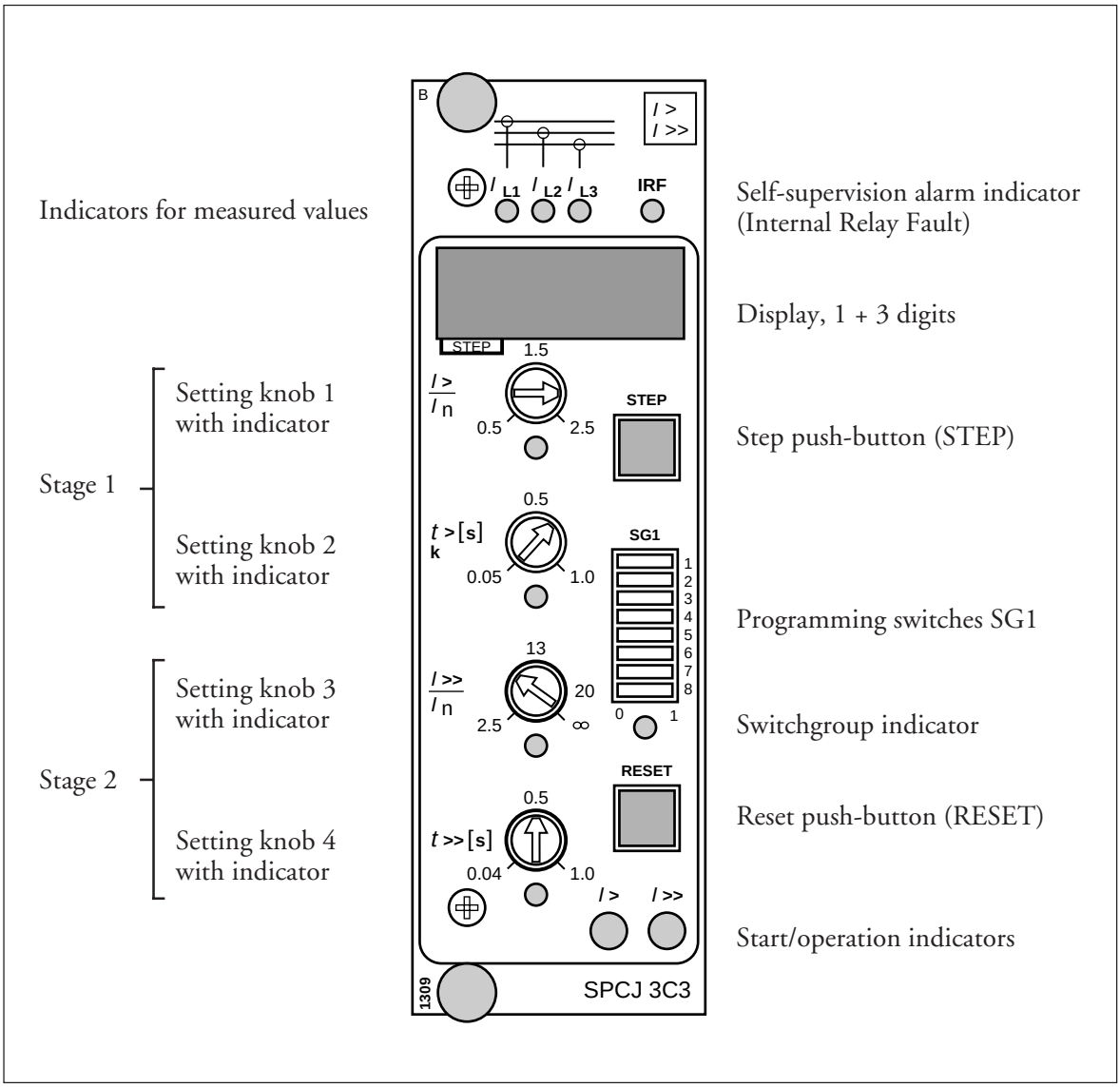
Shortly after the self-supervision system has detected a permanent internal fault the red fault indicator IRF on the relay module front panel is lit. At the same time the self-supervision system generates a control signal to the output relay of the self-supervision system. Further, in most fault situations a self-diagnostic fault code is shown on the display of the relay module. The fault code is composed of a red figure one (1) and a green, one-, two- or three-digit code number. It is recommended that the fault code number is noted down and passed forward to the service shop when overhaul and repair of a faulty relay module is ordered.

The combined differential current and neutral current relay module SPCJ 2C30 displays the following fault codes:

Fault code	Fault description
4	Trip relay control circuit broken or trip relay board missing
30	Faulty program memory (ROM)
50	Faulty work memory (RAM)
195	Too low a value on reference channel, factor 1
131	Too low a value on reference channel, factor 5
67	Too low a value on reference channel, factor 25
203	Too high a value on reference channel, factor 1
139	Too high a value on reference channel, factor 5
75	Too high a value on reference channel, factor 25
253	No interruptions from the A/D converter

General characteristics of C-type relay modules

User´s manual and Technical description



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General characteristics of C-type relay modules

Contents

Push-buttons

The front panel of the relay module contains two push-buttons. The STEP button is used for stepping forward in the display and the RESET button for resetting the red indicators. Additionally, the push-buttons are used for certain settings, e.g. for setting the address of the relay module and the data transfer rate for the serial communication when the modules are used in relay packages provided with this quality. (See section Display).

Programming switches SG1

Part of the settings and the selections of the operating characteristics for the relay modules in various applications are made with the programming switches SG1 on the front panel. The indicator of the switchgroup glows when the checksum of the switchgroup is shown on the display. The checksum can be used for checking that the switches are properly set. Fig. 2 gives an example of calculating the checksum.

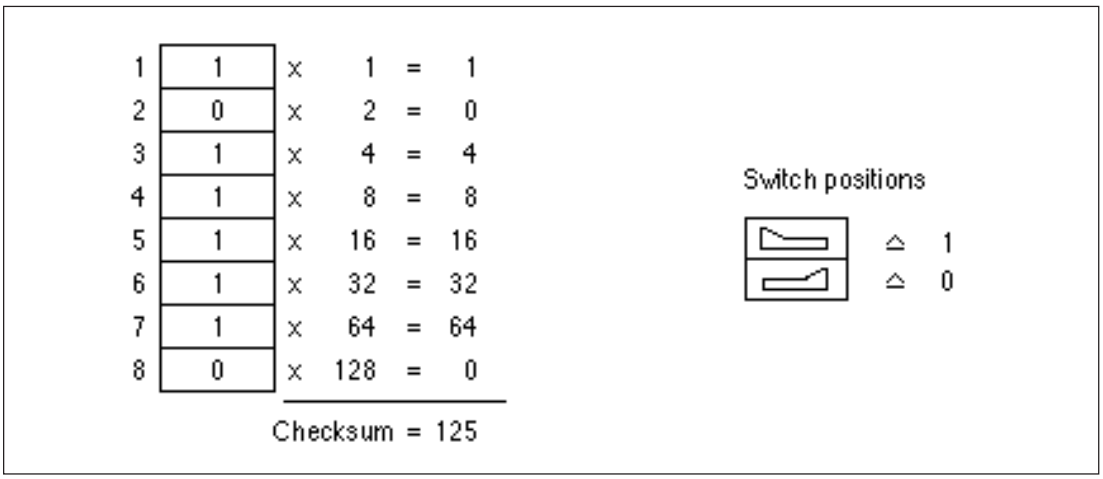


Fig. 2. Example of calculating the checksum of programming switchgroup SG1.

When the checksum calculated according to the example is equal to the checksum indicated on the display of the relay module, the switches are properly set.

The function of the programming switches of the individual measuring relay modules is specified in the description of the module concerned.

Setting knobs

Most of the operating values and operating times are set by means of the setting knobs on the front panel of the relay module. Each setting knob has its own (LED) indicator which glows when the concerned setting value is shown on the display.

If a setting knob is turned while the display is showing another measured or set value, the value being set automatically appears on the display. Simultaneously, the indicator for the concerned setting starts glowing.

In addition to the settings made with the setting knobs, most modules allow so called remote setting. This means that the settings made by means of the setting knobs of the module and the checksum of the programming switchgroup may be altered through an instruction over the serial communication bus. Remote setting is possible if the password in the register A is known, and the remote settings are not activated, i.e. parameter V150=0. The circumstance that the remote settings are activated is shown with a flashing light of the indicator of the setting knob, the value of which currently is being displayed.

Display

The measured and set values as well as the data recorded are shown on the display of the measuring relay module. The display consists of four digits. The three digits (green) to the right indicate the measured, set or stored value and the digit at the extreme left (red) the number of the register. The measured or set value displayed is indicated by a yellow LED indicator. The number of the register glows only when a stored value is displayed.

When the auxiliary voltage is connected to a measuring relay module, the module initially tests the display by stepping through the digits 1...9 for about 15 seconds. When the test is finished the display turns dark. The testing can be interrupted by pressing the STEP button. The protective functions of the module are operative throughout the testing.

Display main menu

All the data required during normal operating conditions are accessible from the main menu which presents the measured values in real-time, the normal setting knob settings as well as the most important memorized data.

The data to be shown in the main menu are selected to the display in a certain sequence by means of the STEP button. When pressing the STEP button for about one second, the display moves forward in the display sequence. When pressing it for about 0.5 seconds, the display moves backwards in the display sequence.

From a dark display only forward movement is possible. When keeping the STEP button depressed, the display is continuously moving in forward direction stopping for a while at the dark point.

Unless the display is switched off by stepping to the dark point, it remains activated for about 5 minutes from the last pressing of the STEP button and then goes out.

Display submenu

Less important values and values not very often set are displayed in the submenus. The number of submenus varies with different relay module types. The submenus are presented in the description of the concerned module.

A submenu is entered from the main menu by pressing the RESET button for about one second. When the button thereafter is released, the red digit (STEP) of the display starts flashing, indicating that one is in a submenu. Going from one submenu to another or back to the main menu follows the same principle as when moving from the main menu display to another; the display moves forward when pressing the STEP button for one second and backward when pressing it for 0.5 seconds. The return to the main menu has taken place when the red STEP display turns dark.

When entering a submenu from a measured or set value indicated by a LED indicator, the indicator remains glowing and the address window (STEP) of the display starts flashing. A flashing address window when no LED indicator is lit indicates that the submenu of a register has been entered.

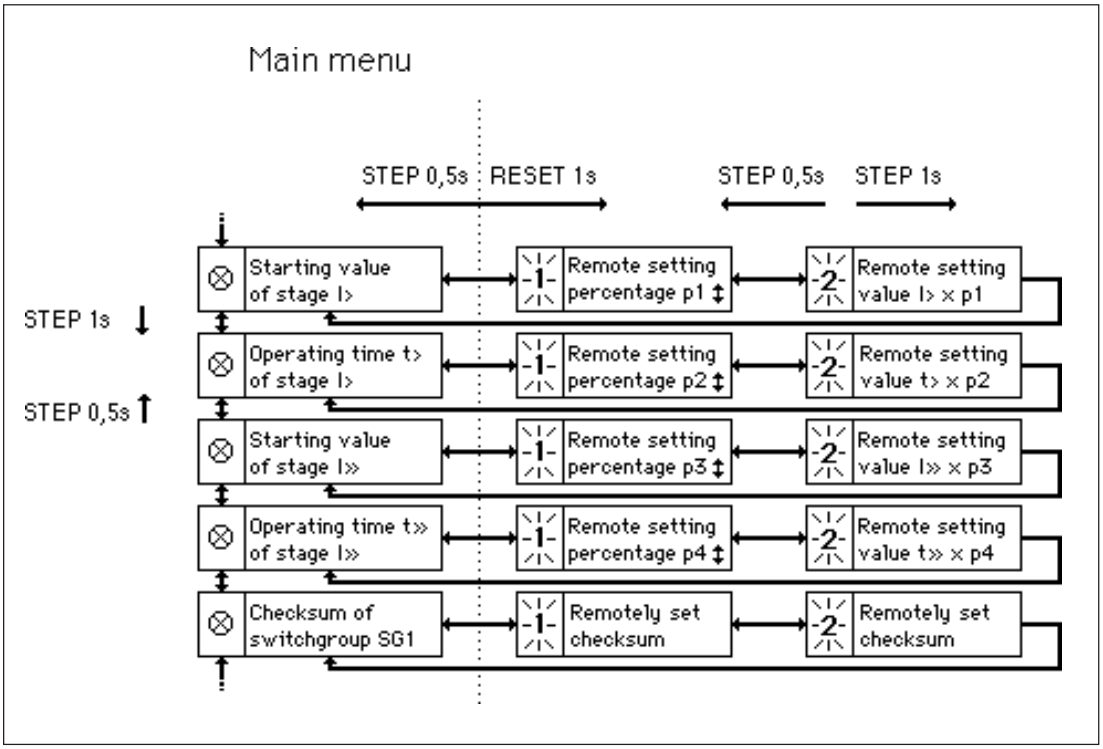


Fig. 3. Example of the main and submenus for the settings of the overcurrent relay module SPCJ 3C3. The settings made with the setting knobs are in the main menu and they are displayed by pressing the STEP button. In addition to the setting knob settings the main menu contains the measured current values as well as the registers 1…5, as well as 0 and A. The remote setting percentage and remote setting value are located in the submenus for the settings and are activated on the display by pressing the RESET button.

Setting mode

The registers of the main menu and the submenus also contain parameters to be set. The settings are made in the so called setting mode, which is accessible from the main menu or a submenu by pressing the RESET button, until the digit at the extreme right starts flashing (about 10 s). The flashing digit is set by means of the STEP button. The flashing is moved on from digit to digit by pressing the RESET button.

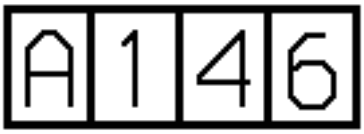
A set value is stored in the memory by pressing the push-buttons STEP and RESET simultaneously. In practice the RESET button must be pressed slightly in excess of the STEP button. Return from the setting mode to the main menu or submenu is possible by pressing (for about 10 s) the RESET button until the green digits on the display stop flashing. If the module is left in the setting mode, it will return automatically to the start condition after about 5 minutes.

The values to be set in the setting mode are for instance the address code of the relay module and the data transfer rate for the serial communication. Further the percentage values for the remote settings can be changed.

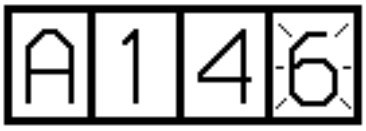
Example 1:

Function in the setting mode. Manual setting of the address code of a relay module and the data transfer rate for the serial communication. The initial value for the address code is 146.

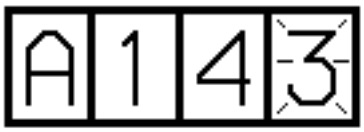
a)
Press push-button STEP until register address A appears on the display.



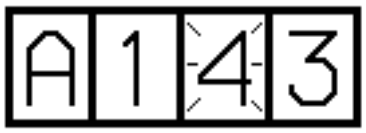
b)
Press the RESET button for about 10 s until the right most digit starts flashing.



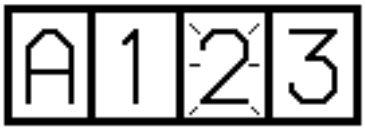
c)
Press the STEP button repeatedly to set the digit to the value desired.



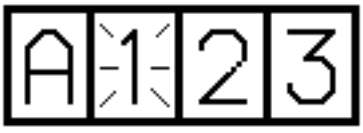
d)
Press the RESET button to make the middle of the green digits flash.



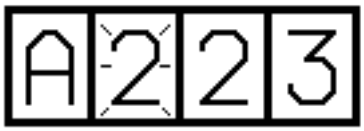
e)
Set the middle address digit by means of the STEP button.



f)
Press the RESET button to make the left most green digit flash.

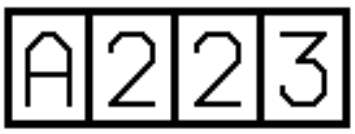


g)
Set the digit by means of the STEP button.



h)
Store the set address number in the memory of the relay module by pressing the RESET and STEP button simultaneously. At the moment the information enters the memory, the three green dashes flash in the display, i.e. A—.

i)
Leave the setting mode by pressing the RESET button for about 10 s, until the display stops flashing.



j)
Then enter submenu 1 of register A by pressing the RESET button for approx. one second. The register address A is then replaced by a flashing 1. This submenu is used for setting the data transfer rate of the serial communication.

k)
The data transfer rate for the serial communication is set and stored in the same way as the address, see sections b...i, except that the continuously glowing register address has been replaced by a flashing 1.

l)
After storing the data transfer rate for the serial communication you may return to the main menu of register A by pressing the STEP button for about 0.5 second.

Stored information

The parameter values measured at the moment when a fault occurs are recorded in the registers, in some modules also the setting values. The recorded data, except for some setting parameters, are set to zero by pressing the push-buttons STEP and RESET simul-taneously. The data in normal registers are erased if the auxiliary voltage supply to the relay is disrupted, only the set values and the number of autoreclosings are maintained in the registers at a voltage failure.

The number of the registers varies with different module types. The function of the registers are illustrated in the descriptions of the separate relay modules. Additionally, the system panel contains a simplified list of the data recorded by the various relay modules of the relay assembly.

All C-type relay modules are provided with two general registers: register 0 and register A.

Register 0 contains, in coded form, the information about e.g. external blocking signals and status information for the circuit breaker. The codes are explained in the descriptions of the relay modules.

Register A contains the address code of the relay module as required by the serial communication system. Example 1 on page 4 shows how the address code is altered. Submenu 1 of register A contains the data transfer rate value expressed in kilobaud for the serial communication.

Submenu 2 of register A contains a bus traffic monitor for the SPACOM system. If the protective relay, which contains the relay module, is linked to a system including the control data communicator and the data communication system is operating, the counter reading of the monitor will be zero. Otherwise the digits 1...255 are continuously rolling in the monitor.

Submenu 3 contains the password required for changing the remote settings. The address code, the data transfer rate for the serial communication and the password can be set manually or via the serial communication bus. For manual setting see example 1.

The start value for the address code and the password is 001 and that for the data transfer rate 9.6 kilobaud.

Trip-test mode

Register 0 also allows access to the so called Trip-test function, which allows the output signals of the relay module to be activated one by one. If the auxiliary relay module of the protection assembly is in place, the auxiliary relays will be included in the testing.

When pressing the RESET button for about 10 seconds, the three green digits to the right start flashing to indicate that the relay module is in test position. The indicators of the setting knobs indicate by flashing which output signal can be activated. The required output function is selected by pressing the RESET button for about 1 second, until the following LED indicator starts flashing.

The indicators of the setting knobs refer to the following output signals:

Setting knob 1	SS1	Starting of stage 1
Setting knob 2	TS1	Tripping of stage 1
Setting knob 3	SS2	Starting of stage 2
Setting knob 4	TS2	Tripping of stage 2
No indication	IRF	Self-supervision

The selected starting or tripping is activated by simultaneous pressing of the push-buttons STEP and RESET. The signal remains activated as long as the two push-buttons are being pressed.

The self-supervision output is activated by pressing the STEP button once when no setting knob indicator is flashing. The IRF output is activated in about 5 seconds after pressing of the STEP button, and resets after that. Simultaneously, the display returns to the main menu and performs the initial testing indicated by rolling digits 0...9 in the display several times.

The signals are selected in the order illustrated in fig. 4.

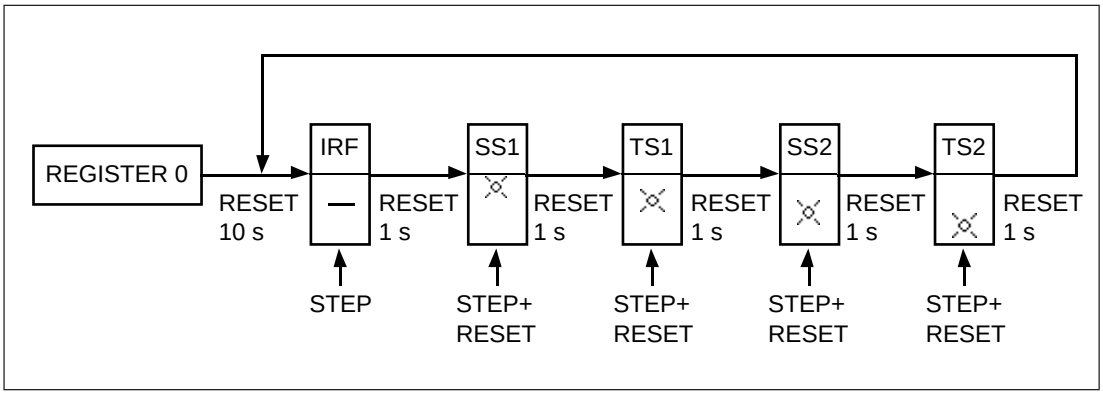


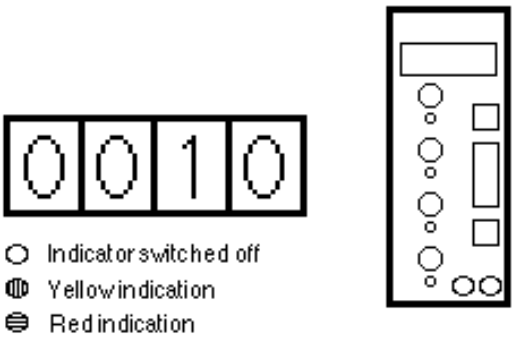
Fig. 4. Sequence order for selecting the output signals in the Trip-test mode.

If e.g. the indicator of the setting knob 2 (second from the top) is flashing, and the push-buttons STEP and RESET are being pressed, the signal TS1 (tripping of stage 1) is activated. Return to the main menu is possible at any stage of the Trip-test sequence scheme, by pressing the RESET button for about 10 seconds. If the module is left in the Trip-test mode, it will return automatically after approx. 5 minutes.

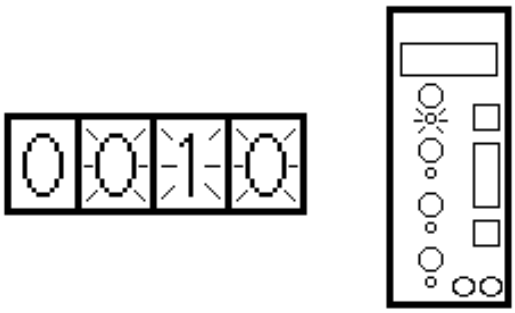
Example 2:

Trip-test function. Forced activation of the outputs is made as follows:

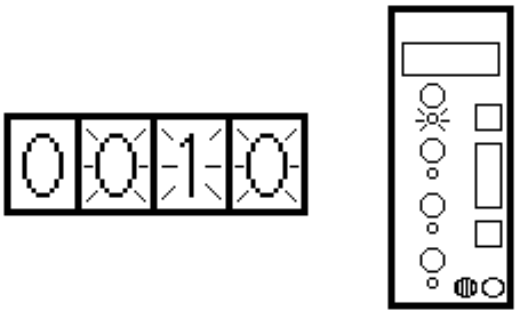
a)
Step forward on the display to register 0.



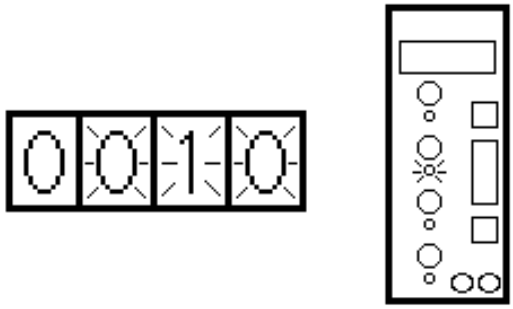
b)
Press the RESET button for about 10 seconds until the three green digits to the right and the LED indicator of the uppermost setting knob start flashing.



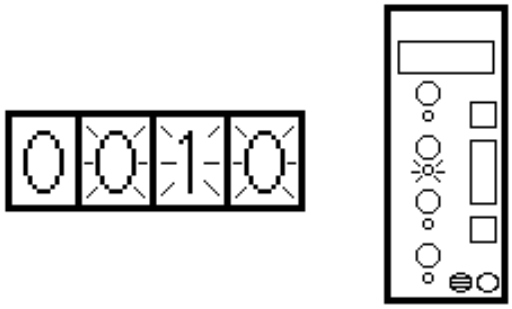
c)
Press the push-buttons RESET and STEP simultaneously. Then the starting of stage 1 (e.g. the I>-stage of the overcurrent module SPCJ 3C3) is activated and, simultaneously, the indicator of the stage starts glowing yellow.



d)
Press the RESET button for about 1 second until the indicator of the second setting knob starts flashing.



e)
Press the push-buttons RESET and STEP simultaneously to activate tripping of stage 1 (e.g. the I>-stage of the overcurrent module SPCJ 3C3). The indicator of the concerned stage starts glowing red.



f)
Starting and tripping of the second stage is activated in the same way as stage 1. The indicator of the third or fourth setting starts flashing to indicate that the concerned stage has been activated.

g)
To activate the self-supervision output step towards the test position, where no indicator is flashing. Press the STEP button once. In about 5 seconds the red IRF indicator starts glowing and the IRF output is activated. Shortly thereafter the indicator goes out and the output automatically resets. At the same time the module leaves the test position.

h)
It is possible to leave the trip test mode at any step of the sequence scheme by pressing the RESET button for about 10 seconds until the three digits to the right stop flashing.

Operation indicators

A measuring relay module is provided with two separate operating stages, each of which with its own yellow/red operation indicator on the lower part of the front plate of the relay module.

The operation indicator starts glowing yellow when the operating stage starts and red when a delayed tripping operates. The functions of the start and operation indicators are described in detail in the different protection relay module manuals.

Fault codes

In addition to the protective functions the relay module is provided with a self-supervision system which continuously supervises the function of the microprocessor, its program execution and the electronics.

When the self-supervision system has detected a permanent fault in the relay module, the red IRF indicator on the panel starts glowing soon after the fault was discovered. At the same time the module puts forward a signal to the self-supervision contact of the relay assembly.

In most fault situations a fault code, indicating the nature of the fault, appears on the display of the module. The fault code, which consists of a red digit (1) and a three digit green code number, cannot be removed from the display by resetting. When a fault occurs, the fault code should be recorded and stated when service is ordered.

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