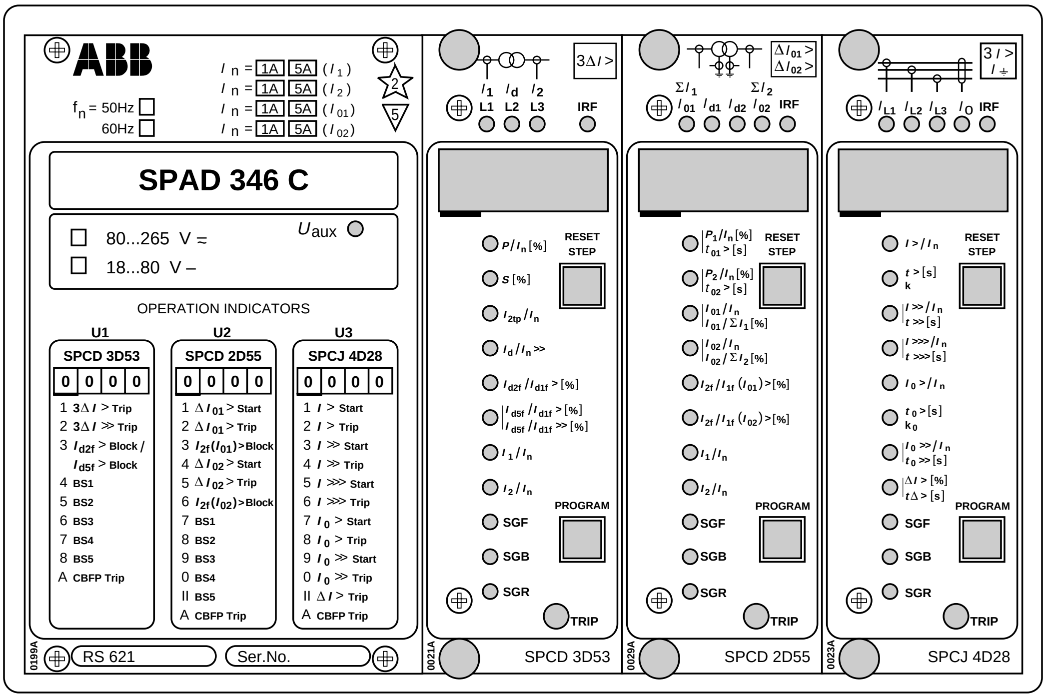
SPAD 346 C
Stabilized Differential Relay

User´s manual and Technical description



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Stabilized Differential Relay

Contents

In addition to this general part the complete manual of the stabilized differential relay includes the following individual documents:

Stabilized differential relay module SPCD 3D53	1MRS 750097-MUM EN
Earth-fault relay module SPCD 2D55	1MRS 750098-MUM EN
Combined overcurrent and earth-fault relay module SPCJ 4D28	1MRS 750093-MUM EN
General characteristics of D-type SPC relay modules	1MRS 750066-MUM EN

Features

Integrated three-phase differential relay, overcurrent relay and earth-fault relay

Stabilized three-phase differential relay providing winding short-circuit and interturn fault protection for two-winding transformers and generator-transformer units and winding short-circuit protection for generators.

Earth-fault protection for transformer HV and LV side windings according to the desired principle: the stabilized differential current principle, the high-impedance principle, the calculated or measured residual current principle or the neutral current principle

Three-stage overcurrent protection for transformers and generators and two-stage back-up protection for earth-fault protection

The operation characteristic of the differential relay easily adapted for different applications

Short operate times, even with partially saturated current transformers

Stabilization prevents unwanted operations at faults outside the protected area and transformer inrush currents

Blocking based on the ratio of the second harmonic and the fundamental component of the differential current prevents unwanted operations at transformer inrush currents

Blocking based on the ratio of the fifth harmonic and the basic frequency component of the differential current prevents operation in harmless situations of transformer overexcitation - can be eliminated if the ratio of the fifth harmonic and the basic frequency component increases at high overvoltages

No interposing transformers are needed for the protection of two-winding transformers - numerical vector group matching on HV and LV side

Wide CT ratio correction range - accurate correction allowed by digital setting

Sensitive phase current and phase angle displays facilitate the checking of measurement circuit connection and vector group matching

Four trip and four signal relay outputs available to the protection design engineer

Five programmable external control inputs intended for the indication and retransmission of alarm and trip signals of gas relays, oil temperature sensors and other sensors of transformer auxiliary devices

Adjustable CBFP operate time to improve reliability of operation

Integrated disturbance recorder capable of recording currents and digital signals - signals to be used for triggering selectable

High immunity to electrical and electromagnetic interference allows the relay to be used in severe environments

High availability and system reliability due to continuous supervision of hardware and software

Application

The stabilized differential relay SPAD 346 C is designed to be used to protect two-winding transformers and generator-transformer units against winding short-circuit, interturn fault, earth fault and short circuit and to protect generators against winding short-circuit and short circuit. The relay can also be used for the protection of a three-winding transformer provided 75% of the short circuit power is fed from the same direction.

Description of operation

The integrated differential relay SPAD 346 C includes three independent relay modules: a three-phase stabilized differential relay module SPCD 3D53, an earth-fault relay module SPCD 2D55 and a combined overcurrent and earth-fault relay module SPCJ 4D28. The rated currents of the relay are 1 A and 5 A. The HV and LV side may use the same or different rated currents.

Below a short description of the features of the protection relay modules. The manuals for the separate relay modules describe the modules more in detail.

Three-phase stabilized differential relay module SPCD 3D53

The differential relay module SPCD 3D53 provides protection for winding short-circuit and interturn faults. The differential relay compares the phase currents on both sides of the object to be protected. Should the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the module, the module provides an operate signal. Different amplitudes or phase difference of the currents may be the reason for the differential current.

Interposing current transformers have normally been used in the differential protection of transformers to obtain vector group matching and to match the secondary currents of the main transformers. Interposing CTs have also been used to eliminate the zero-sequence components of the phase currents at earth faults occurring outside the protected area. The differential current relay SPAD 346 C eliminates the use of interposing transformers for the protection of two-winding transformers as the differential relay module allows the transformer vector group matching, the CT ratio correction and the elimination of the zero-sequence component of the phase currents to be digitally implemented on the HV and/or the LV side.

Stabilized differential current stage

In power transformer protection differential current is caused by CT errors, varying tap changer positions, transformer no-load current, transformer inrush currents, transformer overexcitation in overvoltage and underfrequency situations, and CT saturation at high currents passing through the transformer. Differential current caused by CT errors and tap-changer position grows at the same per cent ratio as the load current increases. In the protection of generators the differential current is caused by CT errors and saturation of the CTs in situations where high currents pass through the transformer.

High currents passing through the object to be protected may be caused by short circuits outside the protected area, large currents fed by the transformer or the generator in motor start-up or transformer inrush situations. Due to these circumstances the operation of the differential relay has been stabilized in respect of the load current. In a stabilized differential relay the differential current required for relay operation is higher, the higher the load current is. The stabilized operation characteristic of the differential relay module and the setting range of the characteristic is presented in the description of the differential relay module SPCD 3D53.

The operation of the differential relay module SPCD 3D53 is based on the fundamental frequency components. Operation based on fundamental frequency components is accurate and stable: the DC component and harmonics of the current do not cause unwanted operation of the protection stage.

Blocking based on the second harmonic of the differential current

Transformer magnetizing inrush currents occur when energizing the transformer after a period of deenergization. The inrush current may be many times the rated current and the halving time may be up to several seconds. To the differential relay inrush current represents differential current, which would cause the relay to operate almost always when the transformer is connected to the network. Typically, the inrush current contains a large amount of second harmonics. Blocking of the operation of the stabilized stage of the relay at magnetizing inrush current is based on the ratio of the amplitudes of the second harmonic digitally filtered from the differential current and the fundamental frequency I_{d2f}/I_{d1f}.

The blocking also prevents unwanted operation at recovery and sympathetic magnetizing inrush. At recovery inrush the magnetizing current of the transformer to be protected increases momentarily when the voltage returns to normal after clearance of a fault outside the protected area. Sympathetic inrush is caused by a transformer, which runs in parallel with the protected transformer already connected to the network, being energized.

The connection of the power transformer against a fault inside the protected area does not delay the operation of the relay module, because in such a situation the blocking based on the second harmonic of the differential current is prevented by a separate algorithm based on the waveform and the rate of change of the differential current.

Blocking based on the fifth harmonic of the differential current

Inhibition of relay operation in situations of overexcitation is based on the ratio of the fifth harmonic and the fundamental component of the differential current I_{d5f}/I_{d1f}. At dangerous levels of overvoltage which may cause damage to the transformer, the blocking can be automatically eliminated by a separate blocking inhibiting setting I_{d5f}/I_{d1f}>>. When required, the blocking based on the second and fifth harmonic of the differential current can be disabled.

Instantaneous differential current stage

In addition to the stabilized stage the differential relay module SPCD 3D53 has a separate adjustable instantaneous stage the operation of which is not stabilized. The instantaneous differential current stage operates when the fundamental component calculated from the differential current exceeds the set operate limit I_d/I_n>> or when the instantaneous value of the differential current exceeds the level 2.5 x I_d/I_n>>. The setting range of the instantaneous stage I_d/I_n>> is 5...30.

Should the stabilizing current be less than 30% of the differential current, there is most certainly a fault in the protected area. In such a situation the set operate value I_d/I_n>> will be halved and the blockings of the stabilized stage are automatically prevented.

Disturbance recorder

The differential relay module SPCD 3D53 is provided with an integrated disturbance recorder that is capable of recording six phase currents, the internal trip and blocking signals of the module and the control input signals. Recording can be triggered by the rising or falling edge of these signal. The recording length is 38 cycles. The recording memory has the capacity of storing one recording at a time. Sampling frequency is 40 samples/cycle. The recording is downloaded by using a PC program. The recording memory has to be reset before a new recording is possible.

Earth-fault relay module SPCD 2D55

When single-phase or two-phase earth faults occur in the area to be protected the sensitivity of the differential protection measuring phase currents may not be sufficient, in particular, if the star point of the transformer is resistance-earthed.

The earth-fault relay module SPCD 2D55 protects the HV and LV side windings of a two-winding transformer. The earth-fault protection can be implemented by four principles: the high-impedance principle, the numerical stabilized differential current principle, the residual overcurrent principle, or the neutral overcurrent principle. The HV and LV side earth-fault protection are quite independent of each other, so the protection principle on the HV side does not have to be the same as that of the LV side.

Numerical stabilized differential current principle

The numerical differential current stage operates exclusively on earth faults occurring in the protected area, i.e. in the area between the phase CTs and the CT of the neutral connection. An earth fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star point of the transformer and earth. The relay measures a differential current as the difference between the residual current of the phase currents and neutral current. An external stabilizing resistor is not required. (See application example 1)

At an earth fault in the protected area the phase difference between the residual current of the phase currents and the neutral current is greater than 90°, i.e. the directions of the residual current and the neutral current are towards the protected area. In the calculation of the differential current the directions of the residual current and the neutral current are so weighted that operation is possible only if the phase difference between the residual current of the phase current and neutral current exceeds 90°. The smaller the phase difference, i.e. the closer it is to 90°, the higher the differential current required for operation.

The operation characteristic for the differential principle is presented in the document describing the earth-fault relay module SPCD 2D55. The setting range of the basic settings P_1/I_n and P_2/I_n is 5...50%. The operation of the numerical differential current principle is stabilized in respect of the phase currents (load current) on the side of the winding to be protected so that the higher the average of the phase currents on the concerned side the higher is the differential current required for starting.

Should the residual current of the phase currents be zero the neutral current exceeding the operate limit, an earth-fault has occurred in the protected area and the relay operates when the preset operate time has elapsed. Such a situation may arise when the transformer is connected to the network on the HV side against an internal earth fault on the LV side. So, in this situation the LV side protection will operate.

When the numerical stabilized differential current principle is used the ratio of the neutral current and the residual current of the phase currents must be greater than the setting $I_{01}/\Sigma I_1$ on the HV side and greater than the setting $I_{02}/\Sigma I_2$ on the LV side to allow starting of the earth-fault protection on the respective side. The settings secure the selectivity of the protection taking into account the distribution of the earth-fault current between the transformer neutral and the network. The distribution of the earth-fault current depends on the ratio of the zero-sequence impedances of the transformer and the supplying network and also on the position of the earth fault in the winding. In addition, the number and the location of the other star-points of the network influence the distribution of the earth fault.

The transformation ratio correction settings I_{01}/I_n and I_1/I_n allow correction of the neutral connection CT and phase CT ratios on the HV side, whereas the settings I_{02}/I_n and I_2/I_n are used for the corresponding ratio corrections on the LV side.

When the stabilized differential current principle is used, the saturation of the current transformers in asymmetrical inrush situations does not cause any problems, if the operation of the earth-fault relay is set to be blocked in inrush situations. This blocking is based on the ratio of the second harmonic and the fundamental frequency component of the neutral current I_{01} or I_{02}.

High-impedance type protection

Restricted earth-fault protection (REF protection) is often implemented by the high-impedance principle. When this principle is employed the relay operates exclusively on faults occurring within the protected area. At external faults relay operation is inhibited by a stabilizing resistor mounted in the differential current circuit in series with the matching transformer of the relay (see application examples 2 and 3).

The operation of high-impedance type protection, when a fault occurs in the protected area, is based on the fact that the impedance of the current transformer rapidly decreases when the current transformer is saturated. The reactance of the magnetizing circuit of a fully saturated transformer is zero and the impedance is formed of the winding resistance. Due to the resistor fitted in the differential current circuit the secondary current of an unsaturated transformer flows through the secondary circuit of the unsaturated transformer. The start value of the earth-fault protection is set high enough to prevent operation due to differential current circuit currents caused by faults outside the protected area. The basic settings P_1/I_n and P_2/I_n are used for setting the start values on the HV side and the LV side, when the high-impedance principle is used. The relay starts when the differential current flowing to the relay exceeds the setting. The operation is not stabilized in the relay.

At faults occurring within the protected area the current transformers try to feed current into the differential current circuit, in which case the relay operates. To keep the resistance of the secondary circuit as low as possible, the summing point of the currents should be located as close to the current transformers as possible.

Residual overcurrent principle and neutral overcurrent principle

The residual overcurrent method can be used for the earth-fault protection of delta-connected windings connected to the network which includes earthed neutral points. Three phase current transformers are used. The sum of the phase currents, i.e. the sum of the zero-sequence currents in the phases, is calculated in the relay module on the basis of the phase currents linked to the relay. The three phase currents will not sum to zero for internal earth faults. Special attention has to be paid to the operate time settings in order to avoid unwanted operations, when the phase CTs saturate at external faults or in inrush situations.

Earth-fault protection based on neutral current can be used as back-up protection for the earth-fault protection.

Earth-fault protection based on these principles starts when the residual current or neutral current exceeds the set start limit P_1/I_n or P_2/I_n. The operation has a definite-time characteristic.

A blocking function based on the second harmonic of the neutral current I_{01} or I_{02} can be used in combination with the neutral current principle. This blocking can also be used if the the residual current of the phase currents is formed via an external connection by connecting the neutral terminals of the windings of the relay's phase current matching transformers to the 5 A or 1 A terminal of the neutral current matching transformer I_{01} or I_{02}. Should the residual current be numerically formed inside the relay module, this blocking function cannot be used.

Operate time

The definite operate time $t_{01}>$ and $t_{02}>$ can be separately set for the the HV side and the LV side in the range 0.03...100 s.

Disturbance recorder

The earth-fault relay module SPCD 2D55 is provided with an integrated disturbance recorder capable of recording six phase currents, two neutral currents, the internal start and blocking signals of the module and the control input signals. Recording can be triggered by the rising or falling edge of these signals. The length of the recording is about 30 cycles and the capacity of the recording memory is one recording at a time. The sampling frequency of the disturbance recorder is 40 samples/cycle. A PC program can be used for downloading the recording from the memory. The recording memory has to be reset before a new recording is possible.

Combined overcurrent and earth-fault relay module SPCJ 4D28

The overcurrent unit of the combined overcurrent and earth-fault relay module SPCJ 4D28 is designed to be used for single-phase, two-phase and three-phase short-circuit protection of power transformers and generators. The overcurrent protection includes three overcurrent protection stages: stage I>, stage I>> and stage I>>>. An overcurrent stage starts once the current on one of the phases exceeds the setting value of the stage. If the overcurrent situation lasts long enough to exceed the operate time set for the module, the stage that started provides a trip signal to the circuit breaker.

The earth-fault unit of the combined overcurrent and earth-fault relay module SPCD 4D28 is intended to be used for non-directional earth-fault protection and it is well suited for earth-fault back-up protection for power transformers. The earth-fault unit is provided with two protection stages: a low-set stage I_0> and a high-set stage I_0>>. The starting of the stage provides a start signal which can be linked to the desired output signal. If the earth fault still persists, when the set operate time elapses, the concerned stage provides an operate signal.

The low-set stages (I> and I_0>) may have either a definite time or an inverse time operating characteristic, whereas the high-set stages only have a definite time mode of operation. The operation of the different stages can be totally inhibited by selecting the appropriate setting for the configuration switches.

In addition, the combined overcurrent and earth-fault relay module SPCJ 4D28 provides protection against phase discontinuity ΔI>. The phase discontinuity protection monitors the minimum and maximum phase current and calculates the differential current ΔI between the phases. The phase discontinuity protection unit can be used for monitoring the condition of the network. In the protection of Yy-connected power transformers the phase discontinuity protection can have a signalling function at least. In certain cases the phase discontinuity protection can be used for unbalance protection of small generators.

The combined overcurrent and earth-fault relay module SPCJ 4D28 measures currents applied to the HV side phase current inputs I_{L1}, I_{L2} and I_{L3} and the LV side neutral current input I_{02} of the relay.

Circuit-breaker failure protection

The relay modules SPCD 3D53, SPCD 2D55 and SPCJ 4D28 are provided with integrated circuit-breaker failure protection (CBFP), allowing a secured circuit breaker trip system to be implemented.

Connection diagram

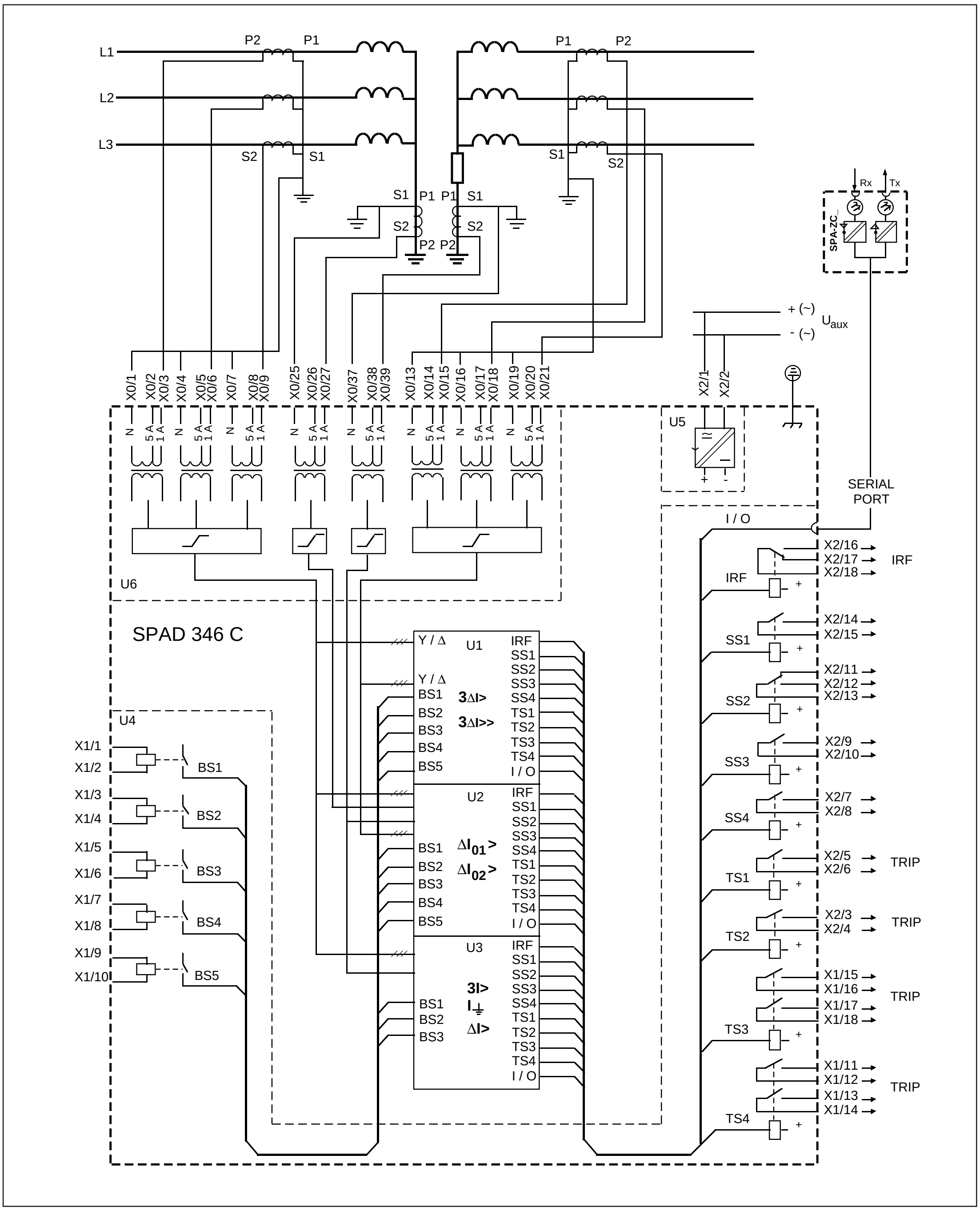


Fig. 1. Connection diagram for the stabilized differential relay SPAD 346 C.

U_{aux}	Auxiliary voltage
TS1...TS4	Output relay (heavy-duty types)
SS1...SS4	Output relay
IRF	Self-supervision output relay
BS1...BS5	External control inputs
U1	Three-phase stabilized differential relay module SPCD 3D53
U2	Earth-fault relay module SPCD 2D55
U3	Combined overcurrent and earth-fault relay module SPCJ 4D28
U4	I/O relay module SPTR 9B31
U5	Power supply module SPGU 240A1 or SPGU 48B2
U6	Energizing input module SPTE 8B18
TS1...TS4	Output signals (for heavy-duty output relays)
SS1...SS4	Output signals
SERIAL PORT	Serial communication port
SPA-ZC_	Bus connection module
Rx/Tx	Receiver (Rx) and transmitter (Tx) for the connection of optical fibres

Terminals

The terminals of the differential relay SPAD 346 C are as follows:

Terminal group	Contact interval	Function
X0	1-2	HV side or stator star-point side phase current I_{L1} (5 A)
X0	1-3	HV side or stator star-point side phase current I_{L1} (1 A)
X0	4-5	HV side or stator star-point side phase current I_{L2} (5 A)
X0	4-6	HV side or stator star-point side phase current I_{L2} (1 A)
X0	7-8	HV side or stator star-point side phase current I_{L3} (5 A)
X0	7-9	HV side or stator star-point side phase current I_{L3} (1 A)
X0	13-14	LV side or stator network side phase current I_{L1}' (5 A)
X0	13-15	LV side or stator network side phase current I_{L1}' (1 A)
X0	16-17	LV side or stator network side phase current I_{L2}' (5 A)
X0	16-18	LV side or stator network side phase current I_{L2}' (1 A)
X0	19-20	LV side or stator network side phase current I_{L3}' (5 A)
X0	19-21	LV side or stator network side phase current I_{L3}' (1 A)
X0	25-26	HV side neutral current I_{01} (5 A)
X0	25-27	HV side neutral current I_{01} (1 A)
X0	37-38	LV side neutral current I_{02} (5 A)
X0	37-39	LV side neutral current I_{02} (1 A)
X1	1-2	External control input BS1
X1	3-4	External control input BS2
X1	5-6	External control input BS3
X1	7-8	External control input BS4
X1	9-10	External control input BS5
X1	11-12-13-14	Output relay TS4 (heavy-duty two-pole relay, see "Circuit breaker control")
X1	15-16-17-18	Output relay TS3 (heavy-duty two-pole relay, see "Circuit breaker control")
X2	1-2	Auxiliary power supply. The positive pole of the dc supply is connected to terminal 1. Auxiliary power range is marked on the rating plate.
X2	3-4	Output relay TS2 (heavy-duty type)
X2	5-6	Output relay TS1 (heavy-duty type)
X2	7-8	Output relay SS4
X2	9-10	Output relay SS3
X2	11-12-13	Output relay SS2
X2	14-15	Output relay SS1
X2	16-17-18	Self-supervision (IRF) output relay

The protection relay is connected to the fibre-optic bus via a bus-connection module, type SPA-ZC 17 or SPA ZC 21, fitted to the D connector on the rear panel of the relay. The optical fibres are connected to the counter contacts Rx and Tx of the module through snap-on connectors. The selector switches are set in the position "SPA".

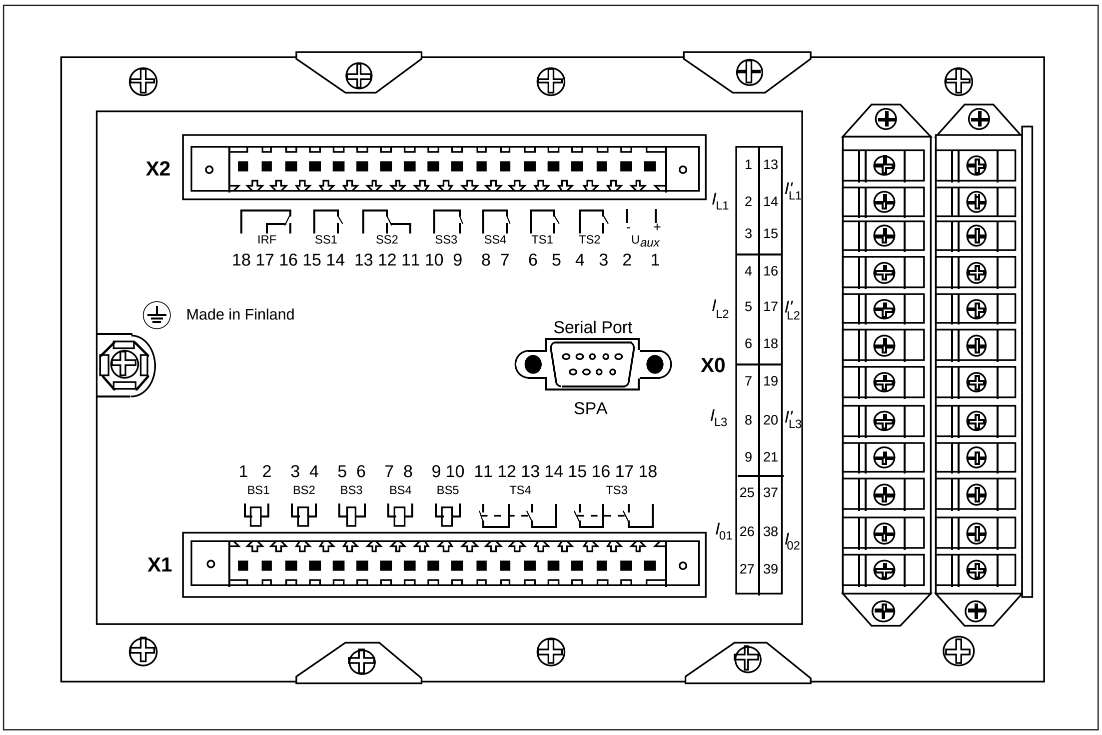


Fig. 2. Rear view of the stabilized differential relay SPAD 346 C

Control input and output relay module

The control input and output relay module of the differential relay SPAD 346 C is fitted to the rear panel of the relay in the same direction as the mother board. To remove the module, the fixing screws have to be undone and the protective earth cable of the module plus the flat cable connecting the mother board to the module have to be disconnected.

The control input and output relay module contains the output relays (8 pcs + IRF), the control circuits of the relays, the electronic circuits of the external control inputs (5 pcs) and the D connector required for serial communication. A flat cable links the output and input signals of the module to the mother board. The relay module locations U1, U2 and U3 are identical.

The output signals SS1...SS4 and TS1...TS4 of the mother board control an output relay with the same designation. The operation of the protection stages of the relay module is not fixed to any specific output relays, but the stages can be linked to the desired output signals. In contrast, the output relays TS1, TS2, TS3 and TS4 are the only output relays capable of circuit breaker control (see "Circuit-breaker control"). The configuration of the output relay matrix switchgroups of the relay modules is described in the manuals of the relay modules.

Five external inputs BS1, BS2, BS3, BS4 and BS5 are available to the differential relay SPAD 346 C. For example, the alarm and trip signals from the power transformer gas relay and the winding temperature sensor can be linked to the external control inputs. The external control inputs can be used for:

- blocking one or several protection stages of the relay modules
- direct output relay control
- the indication of the primary protection relay signals or operations
- resetting the operation indicators, latched output relays, registers and recording memory
- changing the actual setting values of the relay modules. i.e.switching from main setting values to second setting values and vice versa.

The switchgroups of the relay modules are used to specify the influence of the external control inputs BS1...BS5 on the operation of the relay and the active state of the control inputs.

The activation of a protection stage, a blocking function and an external control input is indicated on the display of the relay module by the red code representing the event. The codes are explained in the manuals of the relay modules. Event information is also received over the serial bus, when a protection stage, a blocking function, an external control input or an output signal is activated.

Intermodular signals
(modified 97-10)

The signals BS INT1, BS INT2 and BS INT3 are blocking signals for the relay modules SPCD 3D53 and SPCD 2D55. These blocking signals allow one relay module to prevent the operation of another relay module fitted in another relay module location. An intermodular blocking signal is activated when the corresponding blocking signal of one relay module is activated. The blocking signals BS INT1...3 are not capable of controlling output relays, nor can they be used for blocking the relay module SPCJ 4D28. The figure below shows how the the external control inputs, the start, operate and blocking signals of the relay modules can be configured to obtain the desired functions of the relay modules. The switches to be used for selecting the active state of the signals and for configuring the latching feature of the output relays and the operation of the circuit-breaker failure protection have been omitted.

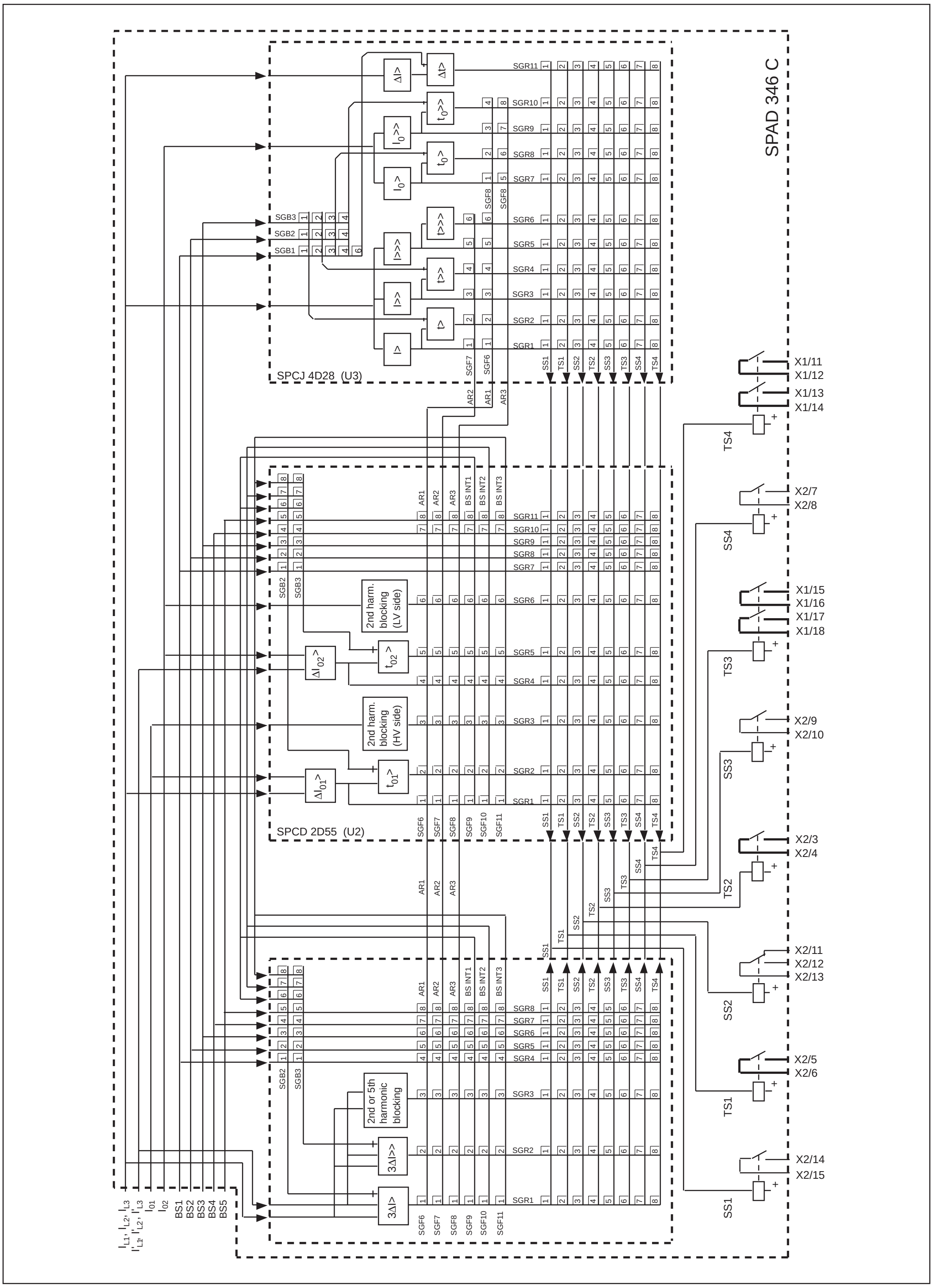


Fig. 3. The energizing inputs, external control inputs, intermodular signals, output signals and output relays of the differential relay SPAD 346 C.

Power supply module

The power supply module forms the voltages required by the relay modules. The power supply module, which is a separate unit, is located behind the system front panel. The module can be withdrawn after the system panel has been removed.

The power supply module is available in two versions, SPGU 240A1 and SPGU 48B2 , which have different input voltages:

SPGU 240A1
- rated voltage
  U_n = 110/120/230/240 V ac
  U_n = 110/125/220 V dc
- operation range
  U = 80...265 V ac/dc

SPGU 48B2
- rated voltage
  U_n = 24/48/60 V dc
- operation range
  U = 18...80 V dc

The power supply module type SPGU 240 A1 can be used for both ac voltage and dc voltage, whereas type SPGU 48 B2 is designed for dc voltage only. The voltage range of the power supply module of the relay is marked on the system panel of the relay.

The power supply module is a transformer connected, i.e. galvanically isolated primary and secondary side, flyback-type dc/dc converter. The primary side of the power supply module is protected with a fuse, F1, located on the PVC board of the module. The fuse size of SPGU 240A1 is 1 A (slow) and that of SPGU 48B2 is 4 A (slow).

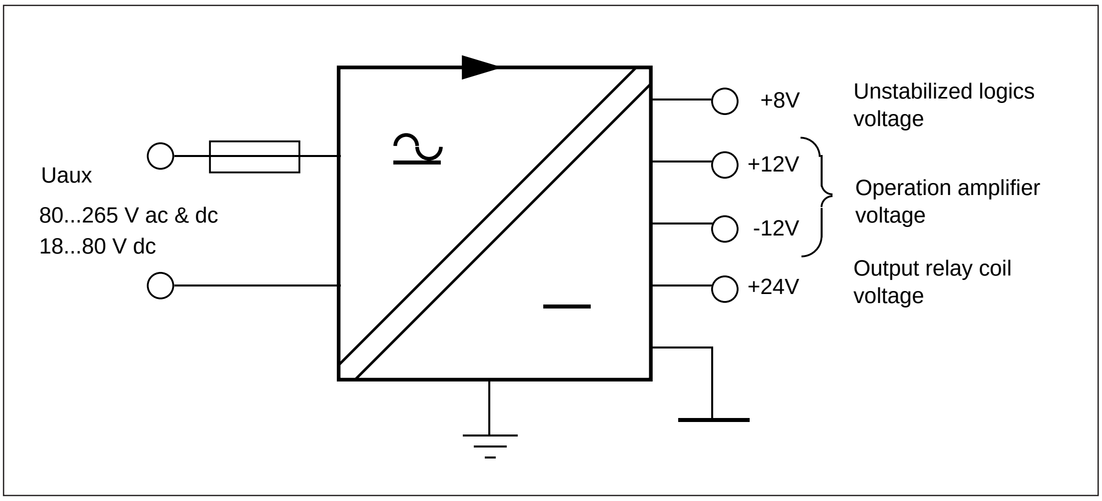


Fig. 4. Voltage levels of the power supply module

A green LED indicator U_{aux} is lit when the power supply module is operating. The supervision of the voltages supplying the electronics is integrated into the relay modules. Should a secondary voltage deviate from its rated value by more than 25% a self-supervision alarm will be obtained. An alarm signal will also be received if the power supply module has been removed or the power supply to the module is interrupted.

Operation indicators

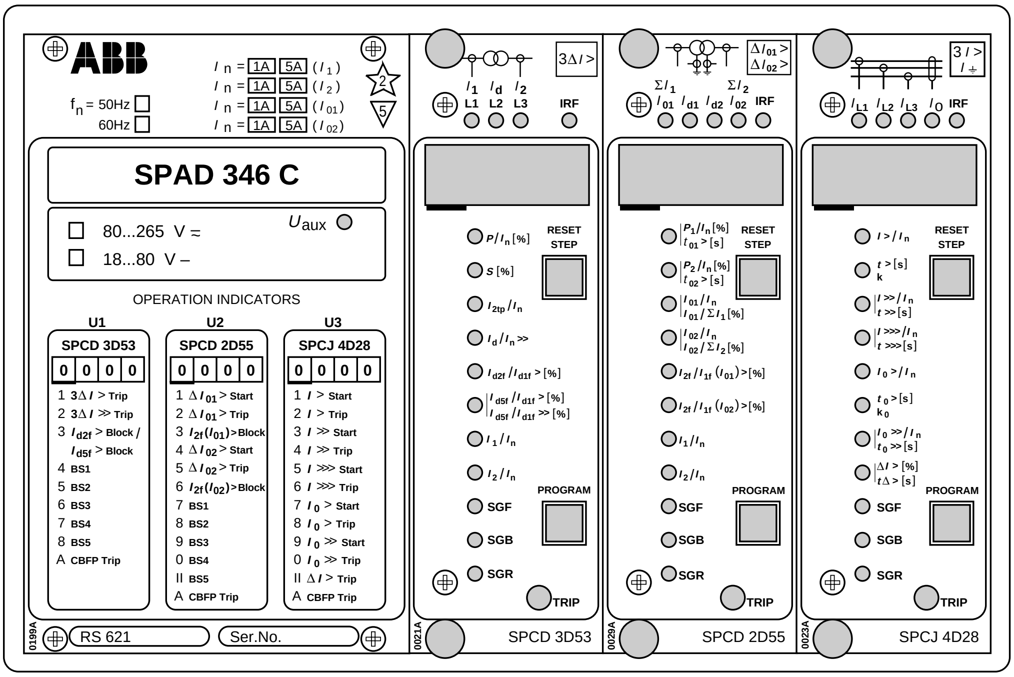


Fig. 5. Front panel of stabilized differential relay SPAD 346 C

1. The green LED U_{aux} on the system panel is lit when the power supply module is operating.

2. The displays of the relay modules indicate measured data, setting values and recorded information. The operation indicators of the relay modules consist of a red digit or code on the display and LED indicator "TRIP". The operation indicators, their internal priorities and means of resetting are explained in the manuals for the relay modules.

3. A measured value or setting value being presented on the display is recognized by yellow LED indicators on the front panel and red codes on the display. The measured values and setting values are explained in the manuals for the relay modules.

4. A permanent fault detected by the self-supervision system is indicated by the IRF indicators on the separate relay modules. The fault code appearing on the display of the module when a fault occurs should be stated when service is ordered. The fault codes are explained in the manuals of the relay modules.

Technical data

(modified 2002-04)

Measuring inputs

Rated current I_n	1 A	5 A
Terminal numbers	X0/1-3, 4-6, 7-9 X0/13-15, 16-18 X0/19-21, 25-27 X0/37-39	X0/1-2, 4-5, 7-8 X0/13-14, 16-17 X0/19-20, 25-26 X0/37-38
Thermal current withstand		
- continuously	4 A	20 A
- for 10 s	25 A	100 A
- for 1 s	100 A	500 A
Dynamic current withstand		
- half-vawe value	250 A	1250 A
Input impedance	<100 mΩ	<20 mΩ
Rated frequency f_n	50 Hz or 60 Hz	

Output relays

Heavy-duty output relays	
Terminal numbers	X1/11-12-13-14, 15-16-17-18 X2/3-4, 5-6
Rated voltage	250 V ac/dc
Continuous current carrying capacity	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 levels 48/110/220 V dc	5 A/3 A/1 A
Signal relays	
Terminal numbers	X2/7-8, 9-10, 11-12-13, 14-15 16-17-18
Rated voltage	250 V ac/dc
Continuous current carrying capacity	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 control circuit time constant L/R ≤40 ms at the control levels 48/110/220 V dc	1 A/0.25 A/0.15 A

Control inputs

Terminal numbers	X1/1-2, 3-4, 5-6, 7-8, 9-10
Control voltage	
- rated voltages	U_n = 24/48/60/110/220 V dc U_n = 110/220 V ac
- operation range	18...265 V dc and 80...265 V ac
Current drain	2...20 mA
Selectable mode of activation in the relay modules	
- input activated when	Energized
- input activated when	Non-energized
Time between activation of control input and relay operation (control input active when energized, to be programmed in the relay module)	<30 ms
Time between activation of control input and relay operation (control input active when non-energized, to be programmed in the relay module)	<50 ms

Power supply module

Terminal numbers	X2/1-2
Type SPGU 240A1	
- rated voltages	U_n = 110/120/230/240 V ac
	U_n = 110/125/220 V dc
- operation range	80...265 V ac/dc
Type SPGU 48B2	
- rated voltage	U_n = 24/48/60 V dc
- operation range	18...80 V dc
Current consumption under quiescent/operation conditions	about 10 W/15 W

Stabilized three-phase differential relay module SPCD 3D53

- see "Technical data" of the manual 1MRS 750097-MUM EN.

Earth-fault relay module SPCD 2D55

- see "Technical data" of the manual 1MRS 750098-MUM EN.

Combined overcurrent and earth-fault relay module SPCJ 4D28

- see "Technical data" of the manual 1MRS 750093-MUM EN.

Data communications

Transmission mode	Fibre-optic serial bus
Coding	ASCII
Data transfer rate	4800 or 9600 Bd
Optical bus connection module	
- for plastic core cables	SPA-ZC 21 BB
- for glass fibre cables	SPA-ZC 21 MM
Optical bus connection module power from an internal power source	
- for plastic core cables	SPA-ZC 17 BB
- for glass fibre cables	SPA-ZC 17 MM

Software support for SPAD 346 C

Substation monitoring program	SMS 010
Disturbance recorder PC program	DR-COM

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 service temperature range	-10...+55°C
Transport and storage temperature range	-40...+70°C
Temperature influence on the operating values of the relay over the specified service temperature range	<0.2%/°C
Damp heat test, cyclic IEC 60068-2-30	+25...55°C, r.h. > 93%, 6 cycles
Degree of protection by enclosure of the relay case when panel mounted	IP 54
Weight of fully equipped relay	6 kg

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

Recommendations for current transformers

The more important the object to be protected, the more attention should be paid to the current transformers. Normally, it is not possible to dimension the current transformers so that they repeat currents with high DC components without saturating, when the residual flux of the current transformer is high. The differential relay SPAD 346 C operates reliably, even though the current transformers are partially saturated. The purpose of the following current transformer recommendations is to secure the stability of the relay at high through-currents, and quick and sensitive operation of the relay at faults occurring in the protected area, where the fault currents may be high.

Differential protection

The accuracy class recommended for current transformers (IEC 60044-1) to be used with the differential relay SPAD 346 C is 5P, in which the limit of the current error at rated primary current is 1% and the limit of the phase displacement is 60 minutes. The limit of the composite error at rated accuracy limit primary current is 5%.

The approximate value of the accuracy limit factor F_a corresponding to the actual CT burden can be calculated on the basis of the rated accuracy limit factor F_n (ALF) at the rated burden, the rated burden S_n, the internal burden S_{in} and the actual burden S_a of the current transformer as follows:

$$F_a = F_n \times \frac{S_{in} + S_n}{S_{in} + S_a}$$

In the example the rated burden S_n of the LV side CTs 5P20 is 10 VA, the secondary rated current 5 A, the internal resistance $R_{in} = 0.07\ \Omega$ and the accuracy limit factor F_n (ALF) corresponding to the rated burden is 20 (5P20). Thus the internal burden of the current transformer is $S_{in} = (5\ A)^2 \times 0.07\ \Omega = 1.75$ VA. The input impedance of the relay at a rated current of 5 A is <20 mΩ. If the measurement conductors have a resistance of 0.113 Ω the actual burden of the current transformer is $S_a = (5\ A)^2 \times (0.113 + 0.020)\ \Omega = 3.33$ VA. Thus the accuracy limit factor F_a corresponding to the actual burden will be about 46.

The CT burden may grow considerably at rated current of 5 A. At 1 A rated current the actual burden of the current transformer decreases, at the same time as repeatability improves.

At faults occurring in the protected area on the HV side of the transformer, the fault currents may be very high compared to the rated currents of the current transformers. Thanks to the instantaneous stage of the differential relay module it is enough that the current transformers are capable of repeating, during the first cycle, the current required for instantaneous tripping.

Thus the current transformers should be able to reproduce the asymmetric fault current without saturating within the next 10 ms after the occurrence of the fault, to secure that the operate times of the relay comply with the times stated in the manuals of the modules

The accuracy limit factors corresponding to the actual burden of phase current transformer to be used in differential protection shall fulfil the following requirements:

$F_a > 40$ and
$F_a > 4 \times I_{max1}$

The setting $I_d/I_n>>$ of the instantaneous differential current stage is used as the factor I_{max1}.

The use of auto-reclosing to clarify a fault occurring outside the protected area may produce a substantial residual flux in the CT core. To guarantee that the differential protection remains stable in an auto-reclose situation also at large currents when the residual flux is great, the accuracy limit factors corresponding to the actual burden of the HV and LV side CTs should fulfill the requirements mentioned above and be of the same order, if possible.

In generator protection it is important that the repeatability of the phase current transformers on the neutral side and on the network side of the generator correspond, that means that the burdens of the current transformers on both sides are as equal as possible. Should, in connection situations following synchronization, high inrush or start currents containing high DC components pass through the protected generator, special attention should be paid to the performance and the burdens of the current transformers and to the settings of the relay.

The technical features of class X (BS 3938) current transformers are determined by the knee-point voltage and the resistance of the secondary winding. The knee-point voltage is the value of the CT secondary voltage at which a further 10% increase in the secondary voltage would cause a 50% increase in the excitation current. The knee-point voltages U_k of current transformers used in differential protection should fulfil the following requirement:

$$U_k > \frac{4 \times I_{max2} \times (R_{in} + R_L)}{n}$$

where

- n is the transformation ratio of the current transformer
- R_{in} is the secondary resistance of the current transformer
- R_L is the total resistance of the longest loop measured (outgoing and return lead)
- I_{max2} is the setting of the instantaneous differential current stage I_d/I_n>> multiplied by the rated current of the protected object.

Earth-fault protection

The recommendations for current transformers used in earth-fault protection based on the stabilized differential current principle are the same as for differential protection. The accuracy limit factor corresponding to the actual burden of the neutral current transformer should be as close as possible to the accuracy limit factor corresponding to the actual burden of the phase current transformers.

Earth-fault protection based on the high-impedance type protection

The sensitivity and reliability of differential current protection stabilized through a resistor are strongly related to the current transformers used. The number of turns of the current transformers that are part of the same differential current circuit should be the same. The current transformers should have the same transformation ratio.

To be able to feed the differential current circuit with the current required for starting, when a fault occurs in the protected area, the current transformers need a knee-point voltage that is about twice the stabilizing voltage required from the relay at faults outside the protected area. The stabilizing voltage U_s of the relay and the knee-point voltage U_k of the current transformer is calculated as follows:

$$U_s = \frac{I_{fmax} \times (R_{in} + R_L)}{n}$$

$$U_k = 2 \times U_s$$

where I_{fmax} is the maximum through-going fault current at which the protection is not allowed to operate. The factor two is used when no operation delay whatsoever is permitted for the protection. To prevent the knee-point voltage of the current transformers to grow too high, it is recommended to use current transformers whose secondary winding resistance is of the same level as the resistance of the measurement circuit.

The sensitivity requirements for the protection are jeopardized if the magnetizing current of the current transformers is allowed to rise too much compared to the knee-point voltage. The I_{prim} value of the primary current at which the relay operates at certain settings can be calculated as follows:

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

where

- n = the transformation ratio of the current transformer
- I_r = the current value representing the relay setting
- I_u = is the current flowing through the protection varistor
- m = the number of current transformers included in the protection
- I_m = the magnetizing current of one current transformer

A protection varistor connected in parallel with the differential current prevents the voltage generated in the differential circuit at faults occurring in the protected area from rising too high. The resistance of the varistor depends on the voltage applied to it: the higher the voltage the smaller the resistance.

Overcurrent protection

The recommendations for current transformers used in overcurrent protection are the same as those used in differential current protection, i.e. there are no special requirements.

Circuit-breaker control

The opening of the circuit-breaker can be implemented as double-pole control or single-pole control. The stabilized differential relay SPAD 346 C is provided with two heavy-duty one-pole relays (TS1 and TS2) and two heavy-duty double-pole relays (TS3 and TS4).

When double-pole circuit-breaker control is used, the control voltage is linked to both sides of the tripping coils of the transformer. If the heavy-duty output relay TS3 is used for double-pole control, for example, terminal X1/15 is connected to negative control voltage and terminal X1/18 is connected to positive control voltage. The terminals X1/16 and X1/17 are connected to the open coil of the circuit breaker. If the heavy-duty output relay TS4 is used for two-pole control, the terminal X1/11 can be connected to negative control voltage and terminal X1/14 can be connected to positive control voltage. Terminals X1/12 and X1/13 are connected to the open coil of the circuit breaker.

If the output relay TS3 is used for single-pole control, the terminals X1/16 and X1/17 should be connected together, that is, the relays should be connected in series. Terminal X1/15 is connected to the open coil of the circuit breaker and terminal X1/18 to the positive control voltage. Should output relay TS4 be used for single-pole control, terminals X1/12 and X1/13 should be connected together. Terminal X1/11 is connected to the open coil and terminal X1/14 to the positive control voltage.

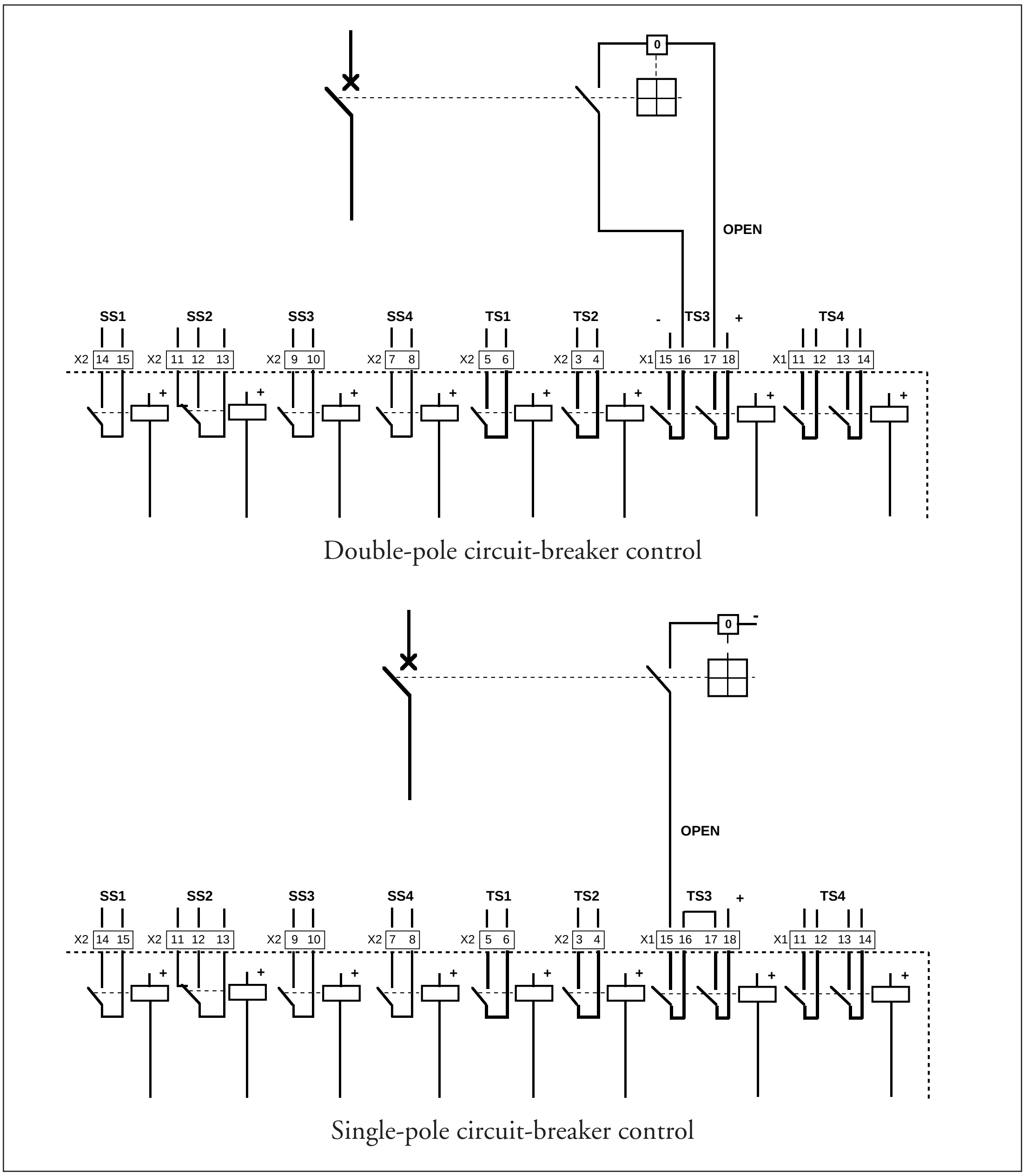


Fig. 6. Double-pole and single-pole circuit-breaker control

Application examples

The following application examples show the differential relay SPAD 346 C used for the protection of power transformers.

All the three relay modules have been used in solutions presented.

Example 1.

Differential relay SPAD 346 C used for the protection of a YNyn0-connected power transformer.

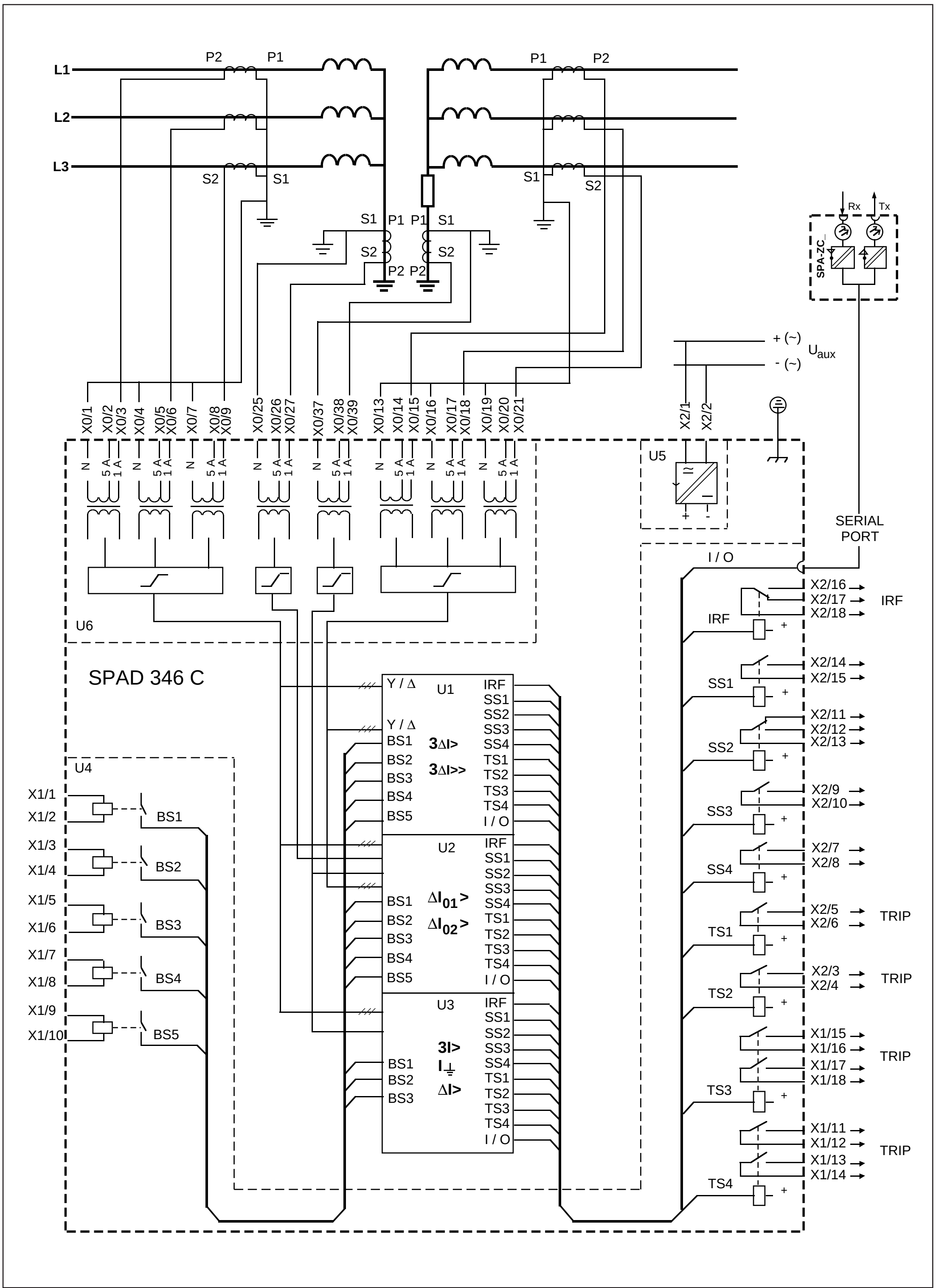


Fig. 7. Application of example 1.

The stabilized stage and the instantaneous stage of the three-phase differential relay module SPCD 3D53 are used to protect the power transformer against winding short circuit and interturn faults. In an inrush situation the tripping of the stabilized stage is inhibited by a blocking function based on the second harmonic of the differential current. In cases where the transformer is not allowed to be disconnected from the network in a situation of overexcitation, a blocking arrangement based on the fifth harmonic of the differential current is used.

The stabilized differential current principle or the high-impedance principle of the relay module SPCD 2D55 is employed for protecting the HV and LV side winding against earth fault. When the stabilized differential current principle is used, the inverse time stage I_0> of the relay module SPCJ 4D28 can be used as back-up protection on the LV side. The blocking based on the ratio between the second harmonic and the fundamental frequency component of the neutral current is permitted both on the HV side and on the LV side. If the high-impedance principle is used on the LV side, no back-up protection can be arranged for the earth-fault protection.

The relay module SPCJ 4D28 provides three-phase, three-stage overcurrent protection and earth-fault back-up protection. The module measures the phase currents on the HV side and neutral current on the LV side. The definite time overcurrent stage I>>> is set to operate on short circuits occurring on the HV side of the transformer. The overcurrent stage I>> is configured to operate on short circuits in the poles of the LV side and serves as back-up at short circuits in the LV side busbar system. A facility of automatic doubling of the setting value of the I>> stage at magnetizing inrush currents is available. The overcurrent stage I> of the module can be employed as inverse time earth-fault back-up protection for the LV side feeders.

Blocking based on the second harmonic of the differential current of the relay module SPCD 3D53 can be used for blocking the overcurrent stages I> and I>> of the relay module SPCJ 4D28 at transformer magnetizing inrush currents. The blocking is programmed in the relay module SPCD 3D53 for the desired output relay, from which it is linked to the external control input BS1, BS2 or BS3. The concerned control input is programmed to block the operation of the overcurrent stage I> and/or I>> of the relay module SPCJ 4D28. The operation of the overcurrent stage I>>> will not be blocked.

In combination with protection of YNyn-connected power transformers the phase discontinuity protection ΔI> of the relay module SPCJ 4D28 can be used for network supervision, at least as alarming protection. Then it should be noticed that the phase discontinuity protection can provide an alarm signal at earth fault as well.

The operate signals of the integrated circuit-breaker failure protection of the relay modules are linked to a heavy-duty output relay that is capable of operating the circuit breaker preceding the HV side circuit breaker in the supply direction.

Example 2. Differential relay SPAD 346 C used for the protection of a YNd11-connected power transformer.

The principle of the winding and the interturn fault protection and the overcurrent protection is the same as in example 1. The high-impedance protection principle of the module SPCD 2D55 is used for protecting the HV side windings against earth fault.

The stage I_0>, operating with inverse time characteristic, of the relay module SPCJ 4D28 serves as back-up for the earth-fault protection. Then the neutral current from the second neutral connection transformer on the HV side is connected to the terminals XO/37-38 or X0/37-39, as illustrated in the figure. When the HV side star point is directly earthed the definite time stage I_0>> can also be used as earth-fault back-up protection.

The neutral current principle is programmed to be used on the LV side in the relay module SPCD 2D55. Then the blocking function based on the second harmonic of the neutral current can be used. The blocking function can be used for blocking the stages I_0> and I_0>> of the relay module SPCJ 4D28 in transformer inrush situations. In the relay module SPCD 2D55 the blocking is programmed to the desired output relay, from which it is externally linked to the control input BS1, BS2 or BS3. The concerned control input is programmed to block the operation of the desired earth-fault stage of the module SPCJ 4D28.

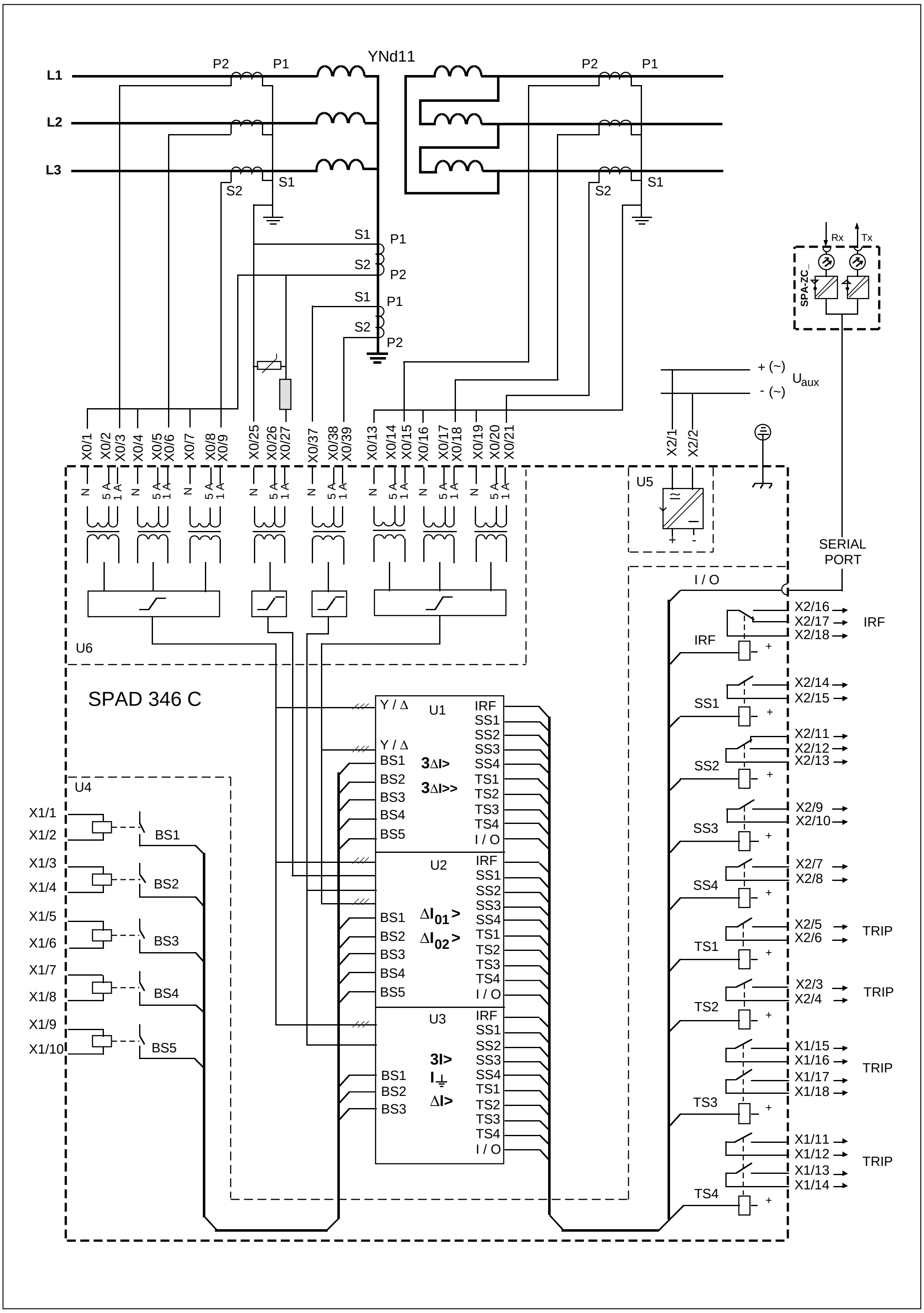


Fig. 8. Application of example 2

Example 3. Differential relay SPAD 346 C used for the protection of a YNd11-connected power transformer and a zigzag-connected earthing transformer.

The winding and interturn fault protection and the overcurrent protection are arranged in the same manner as in example 1. The high-impedance principle or the stabilized differential current principle can be used for the earth-fault protection. The figure below shows the connection when the high-impedance principle is used.

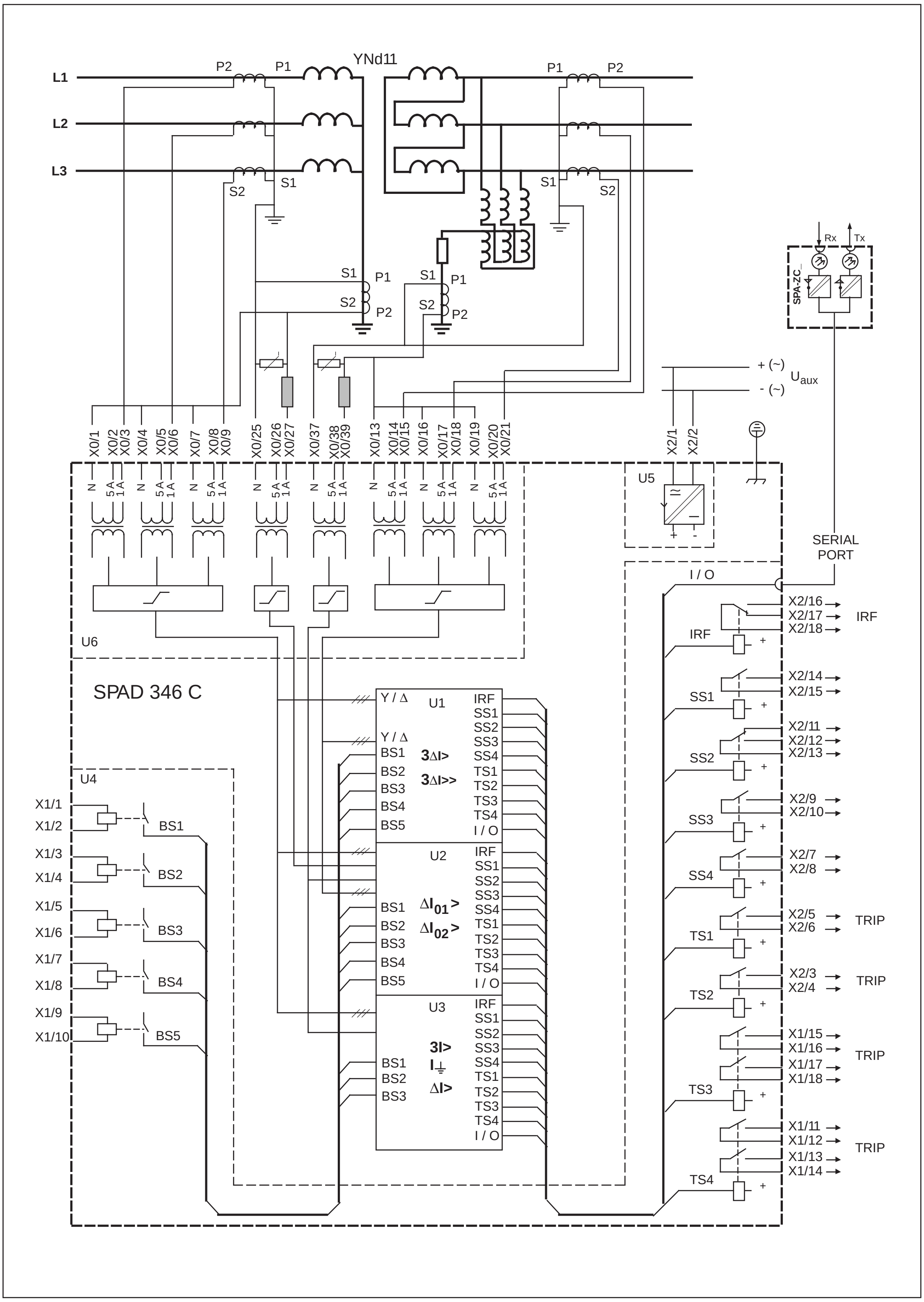


Fig. 9. Application of example 3.

Setting instructions

Three-phase differential relay module SPCD 3D53

A table in the manual of the differential relay module presents the vector group matching settings corresponding to the most general power transformer vector groups. The vector group matching shown in the table is programmed into the relay module via the switches of switchgroup SGF1. To be able to use the table you must know the vector group of the power transformer to be protected and the connection type of the current transformers, which also has to be considered in the protection of generators.

In the application example 1 (Fig. 7) the phase current transformers are connected according to connection type I, in which case the phase difference of HV and LV side phase currents applied to the relay is 180°. The phase difference is matched in the differential relay module on the LV side (SGF1/3=1, SGF 1/4=1 and SGF1/5...8=0). The star points of the transformer HV side and LV side windings are earthed, so the zero-sequence component occurring in earth faults outside the protection area is set to be eliminated from the HV and LV side phase currents (SGF1/1=1, SGF 1/2=1). The checksum of swichgroup SGF1 will be 15.

In the application example 2 (Fig. 8) the connection of the current transformers is in accordance with connection type II, so the connection of the current transformers does not cause phase difference between the currents linked to the relay. On the HV side the zero-sequence component of the phase currents is eliminated in the matching of the phase difference in the numerically implemented delta connection (SGF1/6=1, SGF1/7=0 and SGF1/8=1). The checksum of switchgroup SGF1 will be 160.

Should the required vector group matching not appear from the table, the vector group matching is set by means of the additional tables. All the vector groups of two-winding transformers can be matched in the relay module irrespective of the earthing method of the transformer and the network.

The setting of the vector group matching shown in the application example 3 (Fig. 9) takes into account not only the vector group of the main transformer but also the earthing transformer in the protected area on the LV side. The connection of the phase current transformers is in accordance with connection type I. In the protected area there is an earthed neutral point both on the HV side and on the LV side and thus the zero-sequence component of the phase currents has to be considered in the vector group matching. On the HV side the zero-sequence component is eliminated in the phase difference matching (SGF1/6=0, SGF1/7=1 and SGF1/8=0). On the LV side the zero-sequence component has to be set to be calculated and eliminated from the phase currents separately (SGF1/1=1). The checksum of switchgroup SGF1 will be 65.

If the rated primary current of the HV and LV side current transformers is not equal to the rated current of the power transformer on the concerned side, the settings I_1/I_n and I_2/I_n are used for correcting the transformation ratios. In the example the rated power of the power transformer is 40 MVA and the rated voltage is 110 kV/ 10.5 kV. The transformation ratio of the HV side current transformers is 300 A/1 A and that of the LV side current transformers is 2500 A/5A.

The rated HV side current I_{1n} of the power transformer is

$$I_{1n} = \frac{Sn}{\sqrt{3}\,U_{1n}} = \frac{40\ \text{MVA}}{\sqrt{3} \times 110\ \text{kV}} = 210\ \text{A}$$

Correspondingly, the rated LV side current I_{2n} is

$$I_{2n} = \frac{Sn}{\sqrt{3}\,U_{2n}} = \frac{40\ \text{MVA}}{\sqrt{3} \times 10.5\ \text{kV}} = 2199\ \text{A}$$

The settings for the transformation ratio correction are calculated on the basis of these rated currents and the rated primary currents of the HV and LV side current transformers:

I_1/I_n = 210 A / 300 A = 0.70 and
I_2/I_n = 2199 A / 2500 A = 0.88

The basic setting P/I_n is used to set the maximum sensitivity of the differential relay. This setting takes into account the differential currents caused by a no-load situation and a small overexcitation of the transformer. The basic setting can also be used to influence the level of the whole operation characteristic. The basic setting P/I_n for transformer protection is typically 20...40%. In generator protection the basic setting is typically 5...20%.

When setting the starting ratio S the accuracy class of the current transformers to be used, the accuracy limit factors corresponding to the actual burden of the current transformers, the regulation range of the tap changer of the power transformer and the location of the second turning point I_{2tp}/I_n of the operation characteristic have to be considered. The bigger the errors of the current transformers used, the greater the value of S. Should, for instance, the accuracy class of the HV and LV side current transformers be 5P, the composite error at rated accuracy limit primary current would be maximum 5% on both sides.

The transformation ratios of the current transformers on the HV and LV side of the power transformer are normally matched to correspond to the middle position of the tap changer. The maximum error will be caused by the tap changer position, when the tap changer is in the extreme position. One setting factor for the starting ratio is the regulation range of the tap changer, which may be for example ±9 x 1.67% = 15%. Another factor to be considered in the starting ratio setting is the error caused by the matching transformers of the relay and the inaccuracy of the A/D converters. This error is about 2% at a maximum.

The starting ratio is set by means of above setting factors. In the case of the example the appropriate setting of the starting ratio is 25... 35%. Should the accuracy limit factors corresponding to the actual burden of the current transformers to be used on the HV side and LV side clearly deviate from each other, the starting ratio S must be given a greater value than in the case where the concerned accuracy limit factors are nearly the same.

The setting I_{2tp}/I_n of the second turning point of the operation characteristic influences on the tripping sensitivity at values above the rated current. If the short circuit power is mainly fed from one direction at a fault occurring in the protected area, the appropriate setting of I_{2tp}/I_n is 2.0...2.5. Should the short-circuit power be fed both from the HV side and the LV side when a fault accurs in the protected area, the second turning point can be given a smaller value without the sensitivity being reduced. In the protection of the block transformer of the generator the short circuit power is normally fed from two directions and then, when a fault occurs in the protection area, the phase difference of the currents increases and the stabilizing current decreases. In the case of the block transformer the recommended setting of I_{2tp}/I_n is 1.5...2.0.

The instantaneous tripping limit I_d/I_n>> is set so that the differential relay module does not trip when the transformer is energized. The instantaneous stage trips, when the fundamental frequency component of the differential current exceeds the set tripping limit I_d/I_n>> or when the instantaneous value of the differential current exceeds the limit 2.5 x I_d/I_n>>. When the differential current is below 2.5 x I_d/I_n>> the DC component and the harmonics of the current do not affect the operation of the relay. Normally, the peak value of the asymmetric inrush current of the power transformer is considerably greater than the peak value of the symmetric inrush. At asymmetric inrush current the DC component is great. The amplitude of the fundamental frequency component is typically only half of the peak value of the inrush current. Thus the instantaneous tripping value I_d/I_n>> of the relay can be set below the peak value of the asymmetric inrush. In power transformer protection the setting value of the instantaneous differential current stage is typically 6...10. In generator protection the appropriate setting value for instantaneous tripping is 5...8.

Blocking of the stabilized stage based on the ratio between the second harmonic and the fundamental frequency component of the differential current is enabled when the switch SGF2/1 = 1. In power transformer protection the blocking should always be enabled. The appropriate setting of the blocking ratio I_{d2f}/I_{d1f}> in power transformer protection is usually 15%. When SGF2/2 = 1, the operate time of the relay is not getting longer in a situation when the transformer is connected against a fault in the protected area.

Blocking based on the second harmonic of the differential current should be allowed in the differential relay of a generator in such situations where a relatively large block transformer or power transformer is energized through the generator after synchronization. The inrush current passing through the generator may saturate the current transformers, thus causing differential current that typically contains a high amount of second harmonic. In this situation the main and second settings of the relay can be used. In a connection situation the actual settings of the differential relay module are replaced by the second settings, in which the blocking is enabled. After damping of the inrush current the main settings, which do not allow the blocking function, are used.

When setting the blocking of the fifth harmonic it has to be specified whether blocking is to be allowed at all (SGF2/3=0 and SGF2/4=0), whether only the blocking ratio I_{d5f}/I_{d1f}> (SGF2/3=1 and SGF2/4=0) is to be set for the differential relay module or whether both the blocking ratio I_{d5f}/I_{d1f}> and the deblocking ratio I_{d5f}/I_{d1f}>> (SGF2/3=1 and SGF2/4=1) are to be set. In the last case mentioned the operation of the stabilized stage will be blocked, if the ratio between the fifth harmonic and the fundamental frequency component of the differential current is between the setting values I_{d5f}/I_{d1f}> and I_{d5f}/I_{d1f}>>. Should only the blocking facility be used the blocking ratio is set high enough to prevent the module from blocking its operation at high overvoltages, which might cause damage to the transformer.

Earth-fault relay module SPCD 2D55

The type of earth-fault protection to be used on the HV and LV side of the transformer is selected with the configuration switches SGF1/1...8. The switch positions corresponding to the different protection principles are presented in the manual of the module.

The basic settings P_1/I_n and P_2/I_n are used for selecting the start value of the earth-fault protection. When the numerical stabilized differential current principle is used the basic setting influences the level of the whole operation characteristic.

When the stabilized differential current principle is used the setting of the operate time t_{01}> or t_{02}> should be longer than the DC time constant of the network. The smaller the basic setting, the longer the operate time setting should be. If the high-impedance type protection is used, the operate time of the earth-fault relay module should be set at the minimum value, i.e. 0.03 s.

When the protection principle is based on the residual current of the phase currents the operate time has to be long enough (up to several seconds) to prevent unwanted tripping due to the very asymmetric inrush or start-up current passing through the protected object.

The connection of the phase CTs and neutral connection CT can cause a 180° phase displacement between the residual current of the phase currents and the neutral current at external earth faults (see Fig. 6 in the manual of the module SPCD 2D55). When the stabilized differential current principle is used the phase difference has to be matched in the relay module (switches SGF2/1 and SGF2/2).

When the differential current principle is used the transformation ratio corrections I_{01}/I_n, I_{02}/I_n, I_1/I_n and I_2/I_n are set in the same way as the transformation ratio correction of the differential relay module. The settings can also be used for scaling the start values when other protection principles are used.

The settings $I_{01}/\Sigma I_1$ and $I_{02}/\Sigma I_2$ are determined on the basis of the zero-sequence impedances of the transformer and the supplying network. If the star point of the transformer is directly earthed, the earth-fault current and the ratio between the neutral current and the residual current of the phase currents are typically greater than in a situation where the concerned star point is earthed through a resistor or a choke. When the star point of the power transformer is directly earthed the recommended setting is 5...15%. The position of the earth fault in the winding and also the number and position of the other star points of the network, too, affect the distribution of the earth-fault current.

Blocking based on the ratio between the second harmonic and the fundamental frequency component of the neutral current should be used in combination with the stabilized differential current principle and the neutral current principle. The blocking is enabled by the switch settings SGF2/3=1 and SGF2/4=1. The blocking limits are typically 20...30%.

Combined overcurrent and earth-fault relay module SPCJ 4D28

The settings of the combined overcurrent and earth-fault relay module are dependent on the object to be protected and the use of the protection stages. The low-set stages (I> and I_0>) can have a definite time or an inverse time operation characteristic. Four international standardized time/current characteristics and two special-type time/current characteristics are available for the inverse time operation (IDMT). The switch SGF1 is used for selecting the operation mode and the time/current characteristic. The operation of the high-set stages I>>, I>>> and I_0>> is based on the definite time characteristic only. The operation of the individual stages can be blocked by means of the concerned configuration switches.

In transformer protection the setting of the overcurrent stages should be at least 1.5 x I_n, to be able to utilize the overload capacity of the transformer. The setting value of the high-set stage I>> can be set to automatically double when the transformer is energized. The operation of the overcurrent stages I> and I>> and the earth-fault stages I_0> and I_0>> can be blocked by the control signals BS1, BS2 and BS3. The switches SGB1/1...4, SGB2/1...4 and SGB3/1...4 are used for configuring the blocking signals.

When required, the blocking signal BS1 can be used to block the operation of the phase discontinuity protection ΔI> of the relay module SPCJ 4D28. The switch SGB1/6 is used for configuring the blocking. The phase discontinuity protection supervision can be set out of operation (SGF3/1).

Commissioning

The differential relay module SPCD 3D53 is capable of reliably measuring the amplitudes of the phase currents and the differential currents, the phase angles between the phase currents and the phase differences of the HV and LV side phase currents when the current supplied to the relay is above 1% of the rated current. Even at lower currents it is possible to measure the phase differences. The amplitudes and phase angles measured are presented on the display of the module. The amplitudes are expressed as relative values (x I_n and % I_n). The values displayed take into account the vector group matching and the transformation ratio correction set for the relay.

After mounting the following low-voltage test can be made on the relay to verify the connection, phase sequence, vector group matching and transformation ratio correction of the differential relay: Connect three-phase low-voltage to the primary poles of the current transformers on the HV side of the power transformer so that the HV side current transformers are included in the circuit. By making a three-phase short-circuit on the LV side of the transformer so that the LV side current transformers are included in the circuit a three-phase current of some mAs is injected into the relay.

During the test the HV and LV side current amplitudes and phase angles measured by the relay module are shown for the individual phases on the display of the differential relay module (or over the serial bus). If the connection, vector group matching and the transformation ratio corrections of the relay are correct the following applies to each phase:

- the phase currents are equally high
- the differential currents are 0%
- the phase differences of the HV and LV side phase currents are 0°
- the phase differences between the phase currents on the same side are 120°.

Testing

The relay should be subject to regular tests in accordance with national regulations and instructions. The manufacturer recommends an interval of five years between the tests.

The test is recommended to be carried out as a secondary test. Then the relay has to be disconnected during the test procedure. However, it is recommended to check the condition of the signal and trip circuits as well.

WARNING!
Do not open the secondary circuits of the current transformers when disconnecting and testing the relay, because the high voltage produced may be lethal and could damage insulation.

The test should be carried out using the normal setting values of the relay and the energizing inputs used. When required, the test can be extended to include more setting values.

As the settings of the relay modules vary in different applications, these instructions present the test procedure in general. Ordinary current supply units and instruments for measuring current and time can be used for the tests.

During the test procedure the relay records currents and relay operations. The registers should be read before the test is started and during the test.

The relay settings may have to be changed during testing. A PC program is recommended to be used to read the relay settings before starting the test, to make sure that the original settings are being restored when the test has been completed.

Testing of differential relay module SPCD 3D53

The following values and functions of the stabilized differential current stage 3ΔI> and the instantaneous differential current stage 3ΔI>> should be tested:

- operate value (to be measured on all three phases)
- operate time (to be measured on one phase at least)
- operation indication and operation of output relays

Note!
When testing the three-phase differential relay module the effect of the vector group matching, elimination of the zero-sequence component and transformation ratio corrections on the operation of the stabilized differential current stage and the instantaneous differential current stage have to be taken into account.

If Yd vector group matching has been selected for the HV or LV side, the current measured by the relay module for the concerned side will, after matching of the vector group, be $1/\sqrt{3}$ of the current applied to the relay at single-phase testing.

Example 1. Vector group matching of a YNd11-connected power transformer on the HV side. CT connection according type II.

$$\bar{I}_{L1m} = \frac{\bar{I}_{L1} - \bar{I}_{L2}}{\sqrt{3}}$$

$$\bar{I}_{L2m} = \frac{\bar{I}_{L2} - \bar{I}_{L3}}{\sqrt{3}}$$

$$\bar{I}_{L3m} = \frac{\bar{I}_{L3} - \bar{I}_{L1}}{\sqrt{3}}$$

At single-phase testing the HV side currents injected are I_{L1} = 1 A, I_{L2} = 0 A and I_{L3} = 0 A. After vector group matching the amplitudes of the currents are I_{L1m} = 0.58 A, I_{L2m} = 0 A and I_{L3m} = 0.58 A.

If the zero-sequence component has been selected to be numerically reduced from the phase currents on the HV side or the LV side, i.e. SGF1/1 = 1 or SGF1/2 = 1, the current measured by the relay module on that side will be 2/3 of the current applied to the relay at single-phase testing.

Example 2. On the HV side of the YNyn-connected transformer zero-sequence current is set to be eliminated as follows (SGF1/2 = 1):

$$\bar{I}_{L1m} = \bar{I}_{L1} - \frac{1}{3} \times (\bar{I}_{L1} + \bar{I}_{L2} + \bar{I}_{L3})$$

$$\bar{I}_{L2m} = \bar{I}_{L2} - \frac{1}{3} \times (\bar{I}_{L1} + \bar{I}_{L2} + \bar{I}_{L3})$$

$$\bar{I}_{L3m} = \bar{I}_{L3} - \frac{1}{3} \times (\bar{I}_{L1} + \bar{I}_{L2} + \bar{I}_{L3})$$

At single-phase testing the HV side currents injected are I_{L1} = 1 A, I_{L2} = 0 A and I_{L3} = 0 A. After the zero-sequence current elimination the currents are I_{L1m} = 0.67 A, I_{L2m} = 0.33 A and I_{L3m} = 0.33 A.

The table below shows how the HV side settings of the relay module affect the values measured at single-phase testing. I is the one-phase current (A) applied to the relay, I_n is the rated current (1 A or 5 A) of the matching transformer and I_1/I_n is the setting of the HV side transformation ratio correction (the corresponding HV side setting is I_2/I_n).

HV side vector group matching	Separate zero-sequence elimination	Current displayed by the relay module
Yy	No	$\frac{I}{I_n} \times \frac{1}{I_1/I_n}$
Yy	Yes	$\frac{I}{I_n} \times \frac{1}{I_1/I_n} \times \frac{2}{3}$
Yd	No	$\frac{I}{I_n} \times \frac{1}{I_1/I_n} \times \frac{1}{\sqrt{3}}$

Instantaneous differential current stage 3ΔI>>

The testing of the module should be started with the differential current stage 3ΔI>>. To prevent operation of the stabilized differential stage during the testing of the differential current stage its operate signal should be disconnected at the output relays, that is, the switches of switchgroup SGR1 should be set in the position 0. Alternatively, the operation of the stage can be inhibited by applying an external blocking signal to the stage.

The operation of the instantaneous differential current stage is not stabilized. The instantaneous stage can be tested by applying one or two currents to the relay. When two currents are used, it should be noted that the setting value required for the operation of the instantaneous stage will be reduced by 50%, if the stabilizing current (average of the HV and LV side currents) calculated by the relay module falls below 30% of the differential current (the difference between the HV and LV side currents).

When the instantaneous differential current stage has been tested the original settings should be restored.

Stabilized differential current stage 3ΔI>

The stabilized differential current stage can be tested by applying one or two currents to the relay. If one current is used the phase current inputs of the HV and LV side are tested one by one until all of six inputs have been tested.

Two currents have to be used to verify the operation characteristic of the stabilized differential current stage of the module. At least one stabilizing current value has to be selected from each of the three parts of the operation characteristic. Apply the current to the HV side and the LV side on one phase so that the currents calculated by the relay module initially are the same. First the differential current is zero, and the stabilizing current is the average of the currents applied. Then increase the differential current by raising one current and decreasing the other current so that the stabilizing current remains constant. Increase the differential current until the module operates when the differential current exceeds the value of the operation characteristic. Repeat the test on all three phases. The test can also be made by raising one current and keeping the other at a constant value.

The table below shows the differential current required for operation in the different parts of the operation characteristic.

Part of operating characteristic	Stabilizing current I_b/I_n	Differential current I_d/I_n required for operation
1	0...0.5	P/I_n
2	0.5...I_{2tp}/I_n	$P/I_n + S \times (I_b/I_n - 0.5)$
3	> I_{2tp}/I_n	$P/I_n + S \times (I_{2tp}/I_n - 0.5) + (I_b/I_n - I_{2tp}/I_n)$

Note! The effect of the transformation ratio correction, vector group matching and zero-sequence component elimination on the currents to be applied to the relay should be considered when using the table.

Special equipment is required for testing the blockings based on the ratio between the second harmonic and the fundamental frequency component or the fifth harmonic and the fundamental frequency component of the differential current. The weighting factors, 4, 1 and 1, to be used between the different phases have to be taken into account when testing the second harmonic blocking. During the testing of the blocking based on the second harmonic of the differential current the blocking inhibit algorithm based on the waveform of the differential current should be set out of use, that is, the switch SGF2/2 is set to 0.

Operate times

Apply current to the relay by closing the current switch so that the differential current is about 2 times the differential current required for operation. Then measure the operate time, i.e. the time from closing the switch until the relay operates. The operate times of the instantaneous differential current stage and the stabilized differential current stage plus the selected operate time of the circuit breaker failure protection can be separately tested. The operate time of the instantaneous differential current stage can be tested at various differential current levels, say, 1.5 x I_d/I_n>> and 4 x I_d/I_n>>.

Operation indicators, alarm and trip signals

Check that the operation indicators and the output relays (alarm and heavy-duty) operate properly during the testing of the relay module.

Testing of the earth-fault relay module SPCD 2D55

Test the following values and functions of the protection stages ΔI_{01} and ΔI_{02}:

- start value
- operate time
- operation indication and operation of output relays

Note!
The earth-fault protection for the HV side and the LV side is identical and, therefore, tested in the same way. The test procedure depends on the protection principle employed. The switches SGF1/1...8 are used to select the protection principle for the HV and LV side. The effect of the transformation ratio correction settings on the currents calculated by the relay module have to be considered when the module is tested.

Testing of the stabilized differential current principle

The stabilized differential current principle is tested by applying one or two currents to the relay. When one current is used, inject the current into the neutral current input I_{01} or I_{02}. The neutral current does not affect the stabilizing current. Increase the current until the module starts. The start value of the module is the same as the basic setting of the concerned side.

When testing the differential current principle using two currents, inject one current into the phase current input and the other into the neutral current input of the same side. Then the residual current calculated by the relay module will be the same as the current injected into the phase current input. At single-phase testing the stabilizing current calculated by the relay module (average of the amplitudes of the three phase currents) will be 1/3 of the phase current applied to the relay. Repeat the test on each phase current input.

The phase difference of the currents applied to the relay should be considered in the test (see the functions of switches SGF2/1 and SGF2/2 in the manual for the earth-fault relay module and the specification of the sign of the cosφ term).

The module starts, if the following conditions are fulfilled at the same time:
- the ratio of the neutral current and the residual current of the phase currents is above the setting $I_{01}/\Sigma I_1$ on the HV side or the setting $I_{02}/\Sigma I_2$ on the LV side
- the directional differential current exceeds the value of the operation characteristic
- the blocking based on the second harmonic and external blocking do not prevent starting

Note!
When the setting $I_{01}/\Sigma I_1$ or the setting $I_{02}/\Sigma I_2$ is greater than 0%, the minimum value of the neutral current required for tripping on that side is 2% of the rated current.

The directional criterion $\cos\varphi = 1$, if the residual current or the neutral current of that side is less than 4% of the rated current.

Verify the operation characteristic of the stabilized differential current principle by selecting a point on either part of the characteristic. Keep the stabilizing current at a constant value and increase the differential current until the module starts.

Special equipment is required for testing the blockings based on the ratio of the second harmonic and the fundamental frequency component of the neutral current.

Testing of high-impedance principle

Test the high-impedance principle by injecting current into the neutral current input of the relay. The start value of the module is equal to the basic setting of the concerned side.

Testing of residual overcurrent principle

Test the residual overcurrent principle by injecting current into the phase current inputs one by one. Increase the current until the module starts. The start value of the module is equal to the basic setting of the concerned side.

Testing of neutral current principle

Test the neutral current principle by injecting current into the neutral current input of the concerned side. Raise the current until the module starts. The start value of the module is equal to the basic setting of the concerned side.

Operate times

Apply a current of 1.5...2 times the current required for starting to the module by closing the current switch. Measure the operate time, i.e. the time from closing the switch until the relay module operates. The operate times must be within the specified tolerances. The operate time of the circuit breaker failure protection is to be separately tested.

Operation indicators, alarm and operate signals

Check that the operation indicators and the output relays operate properly during the testing of the relay module.

Testing of the combined overcurrent and earth-fault relay module SPCJ 4D28

When the relay module SPCJ 4D28 is tested, it should be noted that the module measures the transformer HV side or the generator star point side phase currents, i.e. the phase currents connected to the terminals X0/1...9, and the transformer LV side neutral current, i.e. neutral current connected to the terminals X0/37...39.

The tests should include the following values and functions of the protection stages (I>, I>>, I>>>, I_0>, I_0>>, ΔI>) used:

- start value (for the high-set stages to be measured for all three phases)
- resetting value (when desired/required)
- start time (for one phase)
- operate time (for one phase)
- resetting times (when desired/required)
- operation indication, circuit breaker opening and signalling

Start value:
Check the start value by raising the current, starting from zero, until the relay starts. The start value should be within the permitted tolerances.

To measure the resetting value, raise the current enough to make the relay start. Then decrease the current until the relay resets.

When multi-stage protection relays are tested, the operation of the low-set stages may disturb the testing of the high-set stages. In consequence, the operation of the lower current level stages, generally, has to be inhibited or delayed by changing their setting values, to enable testing of the high-set stages. In such a case it is recommended to start the testing from the stage with the highest current setting and then move on to the lower current stages. Thus the original settings of the stages are restored during the test.

Start and operate times

Apply a current of about 1.5...2 times the setting of the protection stage by closing the current switch. Measure the operate time, i.e. the time from closing the switch until the relay operates. The operate times should be within the permitted tolerances. When inverse times are measured the measurements can be made with several current values (for example 2 x and 10 x the setting value).

The reset time is the time from opening the current switch until the relay resets.

Operation indicators, alarm and operate signals

Check that the operation indicators and the output relays (signalling and tripping) operate properly during the testing of the relay module.

Maintenance and repairs

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

Should the temperature and humidity at the site differ from the values specified, or the atmosphere contain chemically active gases or dust, the relay should be visually inspected during the secondary testing of the relay. This visual inspection should focus on:

- Signs of mechanical damage to relay case and terminals
- Collection of dust inside the relay case; to be removed with compressed air
- Signs of corrosion on terminals, case or inside the relay

If the relay malfunctions or the operating values differ from those specified, the relay should be overhauled. Minor measures can be taken by the customer but any major repair involving the electronics has to be carried out by the manufacturer. Please contact the manufacturer or his nearest representative for further information about checking, overhaul and recalibration of the relay.

The protection relay contains circuits that are sensitive to electrostatic discharge. If you have to withdraw a relay module, ensure that you are at the same potential as the module, for instance, by touching the case. Detached modules should always be transported and stored in antistatic plastic bags.

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

Spare parts

Three-phase stabilized differential relay module	SPCD 3D53
Earth-fault relay module	SPCD 2D55
Combined overcurrent and earth-fault relay module	SPCJ 4D28
Power supply modules	
- U = 80...265 V ac/dc (operative range)	SPGU 240A1
- U = 18...80 V dc (operative range)	SPGU 48B2
I/O module	SPTR 9B31
Connection module	SPTE 8B18
Case (including connection module)	SPTK 8B18
Bus connection module	SPA-ZC 17_
	SPA-ZC 21_

Delivery alternatives

Equipment	Type designation
Basic version, including all modules	SPAD 346 C
Version excluding the combined overcurrent and earth-fault relay module SPCJ 4D28	SPAD 346 C1
Version excluding earth-fault relay module SPCD 2D55	SPAD 346 C2
Version including the stabilized differential relay module SPCD 3D53 only	SPAD 346 C3

Ordering numbers

SPAD 346 C without test adapter	RS 621 002-AA RS 621 002-CA RS 621 002-DA RS 621 002-FA
SPAD 346 C provided with test adapter RTXP 18:	RS 621 202-AA RS 621 202-CA RS 621 202-DA RS 621 202-FA

The letter combinations of the order number denote the rated frequency f_n and auxiliary voltage U_{aux} of the protection relay:

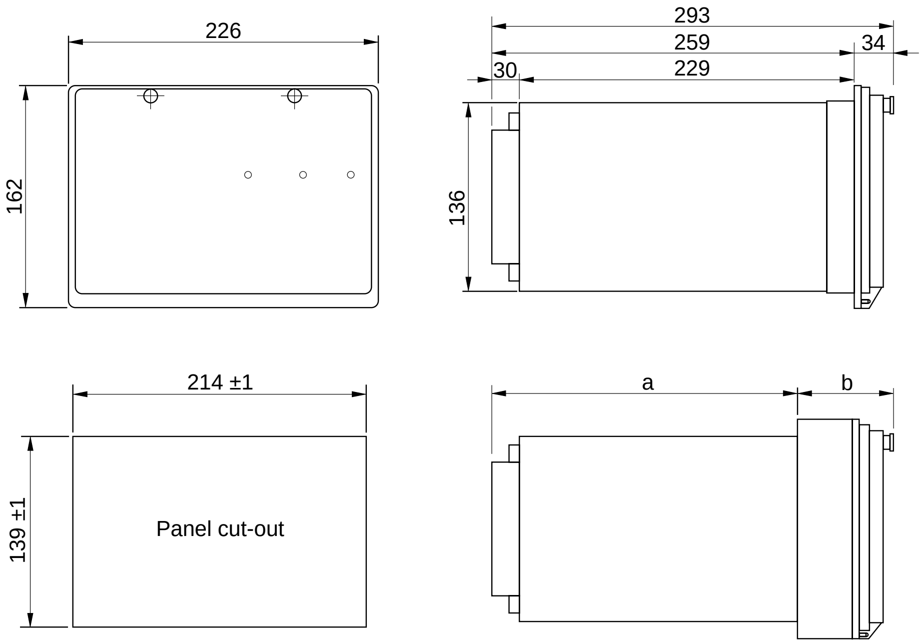
Designation	Rated frequency f_n	Operative range of power module of the relay
AA	50 Hz	80...265 V ac/dc
CA	50 Hz	18...80 V dc
DA	60 Hz	80...265 V ac/dc
FA	60 Hz	18...80 V dc

Order data

	Example
1. Quantity and type designation	2 relays SPAD 346 C
2. Ordering number	RS 621 002-AA
3. Rated frequency	f_n = 50 Hz
4. Auxiliary voltage	U_{aux} = 110 V dc
5. Accessories	2 bus connection modules SPA-ZC 17 MM2A
6. Special requirement	-

Dimension drawings and mounting

The basic model of the protection relay case is designed for flush-mounting. When required, the mounting depth of the case can be reduced. Three types of raising frames are available: type SPA-ZX 301 reduces the depth by 40 mm, type SPA-ZX 302 by 80 mm and type SPA-ZX 303 by 120 mm.



Raising frame	a	b
SPA-ZX 301	219	74
SPA-ZX 302	179	114
SPA-ZX 303	139	154

Fig. 10. Dimension and mounting drawings for differential relay SPAD 346 C.

The relay case is made of grey anodized profile aluminium.

The rubber gasket fitted to the mounting collar provides an IP 54 degree of protection by enclosure between the relay case and the mounting base.

The hinged cover of the case is made of transparent, UV-stabilized polycarbonate polymer and provided with two sealable locking screws. The rubber gasket of the cover provides an IP 54 degree of protection between the case and the cover.

The required input and output connections are made to the screw terminals on the rear panel. The energizing currents are linked to the terminal block X0 which consists of fixed screw terminals. Each terminal screw is dimensioned for one wire of maximum 6 mm^2 or two wires of maximum 2.5 mm^2.

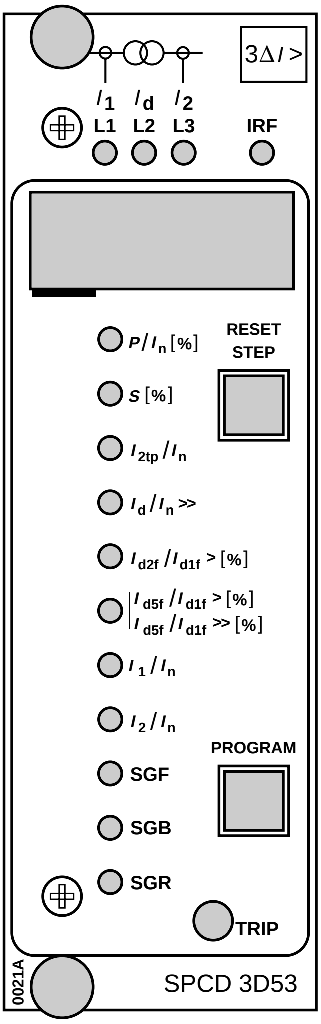
The terminal blocks X1 and X2 contain disconnectable multi-pole screw terminals. The male part of the disconnectable terminal blocks is attached to the I/O module. The female parts, which are included in the delivery, can be locked to the male part with fixing accessories and screws.

The external control inputs of the modules are connected to the terminal block X1. The trip signals are obtained from the the terminal blocks X1 and X2. The alarm signals are obtained from X2. Each terminal of X1 and X2 is dimensioned for one wire of max 1.5 mm^2 or two wires of max. 0.75 mm^2.

The 9-pole D-type connector is intended for serial communication.

SPCD 3D53
Differential Relay Module

User´s manual and Technical description



1MRS 750097-MUM EN

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Version F (replaces 34 SPCD 2 EN1)
Checked PS
Approved MÖ

SPCD 3D53 Differential Relay Module

Contents

Features

Stabilized three-phase differential relay module providing winding short circuit, interturn fault and short circuit protection for two-winding transformers and for generator-transformer units and winding short circuit and short circuit protection for generators

Can also be used for the protection of three-winding transformers, provided over 75% of the short circuit power is fed from the same direction

The relay module is completely numerical; the differential current and the stabilizing current are calculated on the basis of the currents' fundamental frequency component. The DC component and the harmonics of the phase currents are digitally filtered.

No interposing current transformers are needed for the protection of two-winding transformers; the vector group of the transformer is numerically matched on the HV and LV side. When required, the zero-sequence component of the phase currents can be reduced without vector group matching.

Digital front panel settings for the correction of CT transforming ratios

Adjustable operating characteristic of the relay module

Separate adjustable instantaneous differential current stage

Short operate time for faults occurring in the zone to be protected, also at partially saturated current transformers.

Stabilized against connection inrush currents and faults outside the protected area

Blocking based on the ratio between the second harmonic and the fundamental frequency component of the differential current prevents operation at transformer connection inrush currents

Blocking based on the ratio between the fifth harmonic and the fundamental frequency component of the differential current prevents unnecessary operation in harmless situations of transformer overexcitation. This blocking function can be prevented if the ratio between the fifth harmonic and the fundamental frequency component increases at high overvoltages

Measured, set and recorded values are indicated on the display of the relay module.

Sensitive phase current and phase angle displays facilitate the checking of connection and vector group matching

Writing and reading of setting values through local display and front panel push-buttons, a PC with configuration software, or from higher system levels over the serial port and optical fibres.

Five programmable external control inputs

Output relay matrix allowing the operate and control signals to be linked to the desired output relay

Integrated circuit breaker failure protection

Integrated disturbance recorder capable of recording six phase currents, the internal operate and blocking signals, and the control signals linked to the relay

High immunity to electrical and electromagnetic interference allows the relay to be used in severe environments

Dynamic measuring functions

High availability - the integrated self-supervision system monitors the operation of the electronics and the software and gives an alarm signal in the event of a fault.

Description of function

The differential relay module SPCD 3D53 provides differential current protection for three phases. The settings are the same for each phase. The differential relay module measures the phase currents on the HV and LV side of the transformer to be protected or the phase currents on the stator star-point side and the network side of the generator to be protected. The operation of the stabilized differential stage and the instantaneous differential stage is based on the fundamental frequency components I_1 and I_2 of the phase currents. The fundamental frequency component I_{d1f} (i.e. I_d) of the differential current , the fundamental frequency component I_{b1f} (i.e. I_b) of the stabilizing current, the second harmonic I_{d2f} of the differential current, and the fifth harmonic I_{df5} are digitally filtered.

Rated frequency

The differential relay module can be used at frequencies between 16 $^2/_3$ and 60 Hz. The rated frequency setting is accurate to within 1 mHz. The rated frequency has two settings, i.e. Hz and mHz, which are separately set from 16.667 Hz up to 60 Hz. The setting is made either via the push-buttons on the front panel, the subregisters 5 and 6 of register A, or the serial bus, in which case the control parameters V180 and V181 are used.

Transformer vector group matching

The phase difference of the HV side and LV side currents that is caused by the vector group of the power transformer to be protected is numerically compensated. The matching of the phase difference is based on phase shifting and numerical delta connection inside the relay. The switches SGF1/3...8 are used to select the desired vector group. The matching of the phase difference in vector group matching can be set for the HV and LV side at intervals of 30°. The switches SGF1/3...5 are used for the LV side vector group matching, whereas SGF1/6...8 are used for the vector group matching on the HV side.

Elimination of the zero-sequence component of the phase currents

In vector group matching the zero-sequence component of the phase currents is eliminated before the differential and stabilizing current are calculated. Unless the vector group matching is made on the side of the earthed winding, the zero-sequence component of the phase currents can, when required, be separately calculated and reduced for each phase current. Elimination of the zero-sequence component on the HV and/ or the LV side is selected with the switches SGF1/1 and SGF1/2.

Transforming ratio correction of phase current transformers

Should the CT secondary currents deviate from the rated current at the rated load of the transformer or generator to be protected, the CT transforming ratios can be corrected on both sides of the protected object by adjusting the setting of the ratios I_1/I_n and I_2/I_n on the front panel of the relay module in the range of 0.40...1.50 x I_n.

Stabilized differential current stage 3ΔI>

The operating characteristic of the stabilized stage 3ΔI> is determined by the basic setting P/I_n, the setting of the starting ratio S, and the setting I_{2tp}/I_n of the second turning point of the characteristic. When the differential current exceeds the setting value of the operating characteristic, the relay provides an operate signal unless the relay module internally blocks the trip function and it is not blocked by an external blocking signal BS1, BS2, BS3, BS4 or BS5, or an intermodular blocking signal BS INT1, BS INT2 or BS INT3. The switches SGB2/1...8 are used for configuring the blocking signals

Designate the phasors $\bar{I}_1$ and $\bar{I}_2$ of the fundamental frequency currents of the CT secondary currents on the input and output side of the protected object. The amplitude of the differential current I_d is obtained as follows:

$$I_d = |\bar{I}_1 - \bar{I}_2| \qquad (1)$$

In a normal situation there is no fault in the area protected by the differential relay. Then the currents $\bar{I}_1$ and $\bar{I}_2$ are equal and the differential current $I_d = 0$. In practice, however, the differential current deviates from zero in normal situations. In power transformer protection differential current is caused by CT inaccuracies, variations in tap changer position, transformer no-load current and instantaneous transformer inrush currents. Increases in the load current cause the differential current caused by the CT inaccuracies and the tap changer position to grow at the same percentage rate.

In a stabilized differential relay the differential current required for tripping is higher the higher the load current is. The stabilizing current I_b of the relay is obtained as follows:

$$I_b = \frac{|\bar{I}_1 + \bar{I}_2|}{2} \qquad (2)$$

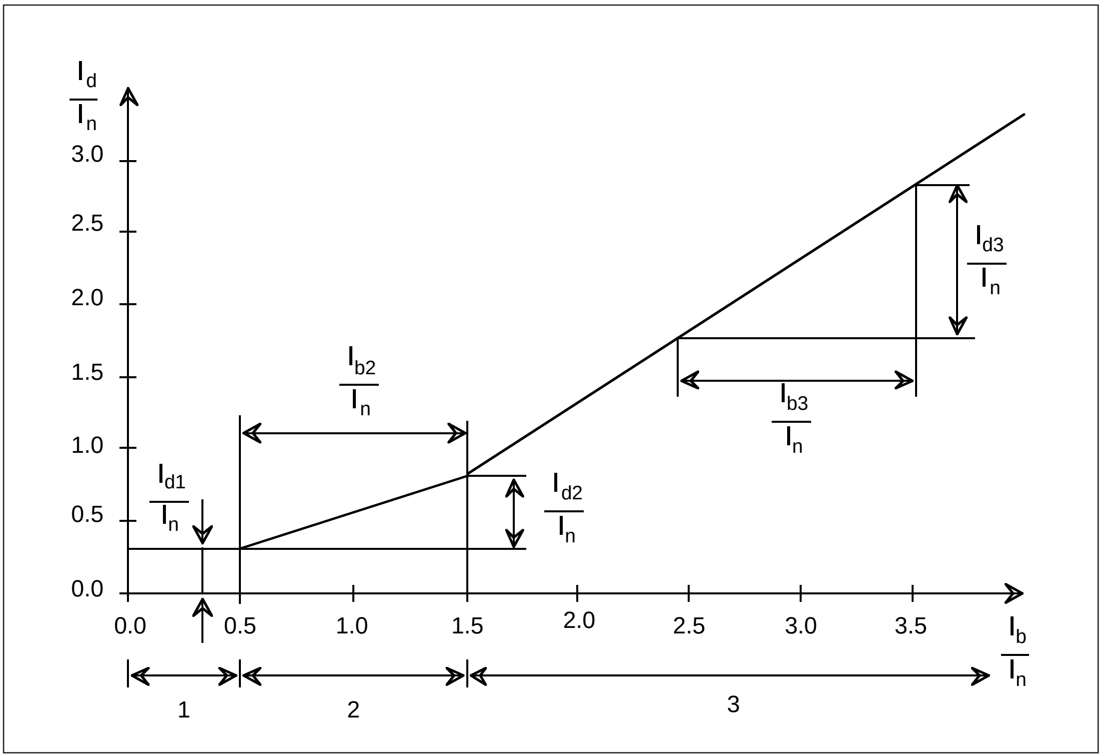


Fig. 1. Operating characteristic of the stabilized differential current stage of the differential relay module SPCD 3D53

The operation of the relay is affected by the stabilization as shown graphically by the operating characteristic illustrated in Fig. 1.

The basic setting P/I_n of the stabilized stage of the differential relay module is determined according to Fig. 1:

$$P/I_n = I_{d1}/I_n \qquad (3)$$

The starting ratio S is determined correspondingly

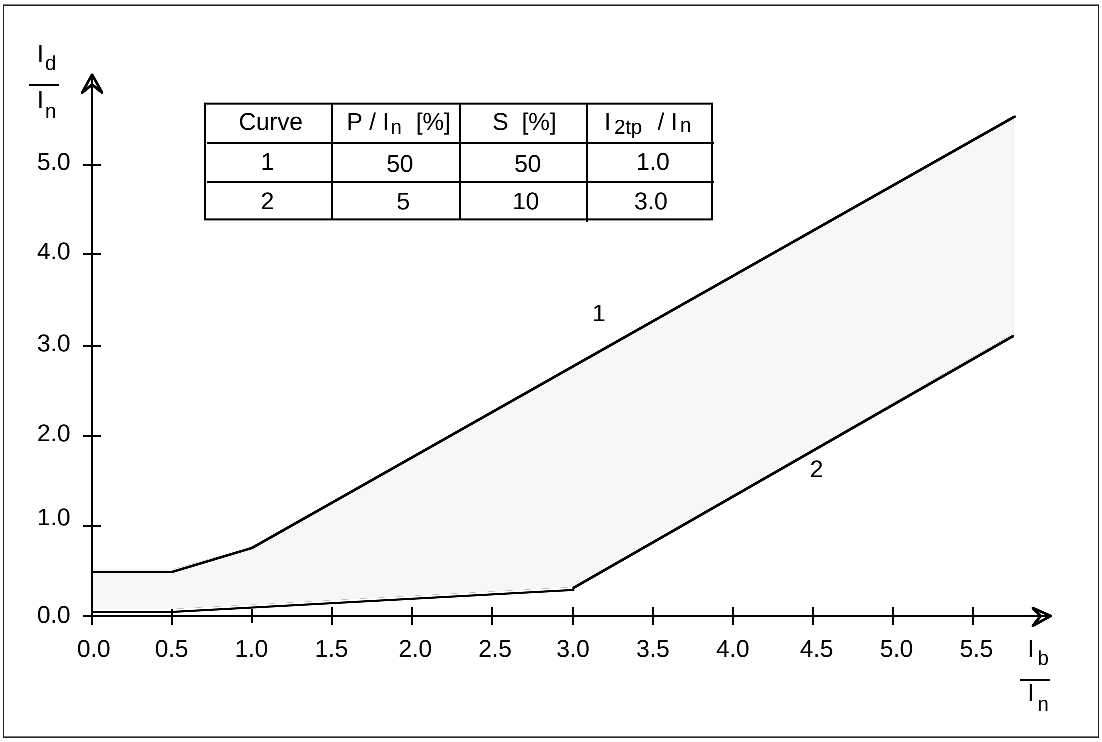
$$S = I_{d2}/I_{b2} \qquad (4)$$

The second turning point I_{2tp}/I_n can be set at the desired point in the range 1.0...3.0. The first turning point is always fixed at $I_b/I_n = 0.5$.

The slope of operating characteristic of the differential relay module varies in the different parts of the range. In part 1 ($0.0 \le I_b/I_n < 0.5$) the differential current required for tripping is constant. The value of the differential current is the same as the basic setting P/I_n selected for the relay module. The basic setting basically allows for the no-load current of the power transformer, but it can also be used to influence the overall level of the the operation characteristic. At rated current the no-load losses of the power transformer are about 0.2 per cent at rated voltage. Should the supply voltage of the transformer suddenly increase due to operational disturbances the magnetizing current of the transformer increases as well. In general the magnetic flux density of the transformer is rather high at rated voltage and the rise in voltage by a few per cent will cause the magnetizing current to increase by tens per cent. This should be considered in the basic setting.

Part 2, i.e. $0.5 \le I_b/I_n < I_{2tp}/I_n$, is called the influence area of starting ratio S. In this part variations in the starting ratio affect the slope of the characteristic, that is, how big the change in the differential current, in comparison with the change in the load current, is required for tripping. The starting ratio should consider CT errors and variations in the power transformer tap changer position. Too high a starting ratio should be avoided, because the sensitivity of the differential relay for detecting transformer interturn faults depends basically on the starting ratio.

At high stabilizing currents $I_b/I_n \ge I_{2tp}/I_n$ the slope of the characteristic is constant (part 3). The slope is 100%, which means that the increase in the differential current is equal to the corresponding increase in the stabilizing current.



Curve	P/I_n [%]	S [%]	I_{2tp}/I_n
1	50	50	1.0
2	5	10	3.0

Fig. 2. Setting range for the stabilized differential current stage of the differential relay module SPCD 3D53.

Blocking based on the second harmonic of the differential current I_{d2f}/I_{d1f}

The blocking of relay operation at transformer inrush currents is based on the ratio I_{d2f}/I_{d1f} of the amplitudes of the second harmonic and the fundamental frequency component of the differential current. The ratio to be used for blocking is calculated as a weighted average on the basis of the ratios between the second harmonic and the fundamental frequency component calculated from the differential currents of the three phases. The ratio between the second harmonic and the fundamental frequency component of the differential current of the concerned phase is of most weight compared with the ratios of the other two phases. Using separate blocking for the individual phases and weighted averages calculated for the separate phases provides a blocking scheme that is stable at connection inrush currents.

The operation of the stabilized stage on the concerned phase is blocked if the weighted ratio of the second harmonic and the fundamental frequency component of the differential current of the concerned phase is above the set blocking limit I_{d2f}/I_{d1f} > and if blocking is enabled through switch SGF2/1. The switchgroup SGR3 is used to route the blocking signals to the required output relays, if the differential current of the phase concerned is above the value of the trip curve and if the operate signal of the other phases is not active at the same time. The blocking remains active until the ratio I_{d2f}/I_{d1f} falls below the blocking limit.

If the power transformer is connected against a fault in the protected area, the blocking based on the second harmonic of the differential current is inhibited by a special algorithm. The operation of the relay will not be delayed even if the differential current contains a great amount of second harmonics due to the connection inrush current. The operation of the blocking inhibiting algorithm is based on the different waveform and the different rate of change of normal connection inrush current and connection inrush current containing fault current. The algorithm does not eliminate the blocking at connection inrush currents, unless there is a fault in the protected area. When required, the operation of the algorithm can be disabled (switch SGF2/2).

Blocking based on the fifth harmonic of the differential current I_{d5f}/I_{d1f}

Blocking of relay operation in situations of overexcitation is based on the ratio I_{d5f}/I_{d1f} of the amplitudes of the fifth harmonic and the fundamental frequency component of the differential current. The ratio is calculated separately for each phase without weighting factors. Should the ratio exceed the setting value of I_{d5f}/I_{d1f} and blocking is enabled through switch SGF2/3, the operation of the stabilized stage of the relay in the concerned phase will be blocked. The blocking signal is routed to the output relays determined by SGR3, provided the differential current of the phase concerned exceeds the value of the trip curve and no operate signal of the other phases is active at the same time.

The setting value I_{d5f}/I_{d1f}>> is used to eliminate the blocking immediately if the ratio between the fifth harmonic and the fundamental frequency component of the differential current approaches a dangerous level because of a high overvoltage. The blocking is eliminated, if enabled by switch SGF2/4 (SGF2/4 = 1) and the ratio of the fifth harmonic and the fundamental frequency component is greater than the setting value of I_{d5f}/I_{d1f}>>.

Differential current stage 3ΔI>>

In addition to the stabilized stage the relay includes an instantaneous differential current stage 3ΔI>> which does not allow for stabilization. This stage provides an operate signal to the output relays selected with the switchgroup SGR2, when the amplitude of the fundamental frequency component of the differential current exceeds the set operate value I_d/I_n>> or the instantaneous value of the differential current exceeds 2.5 x I_d/I_n>>. The value can be set in the range 5...30 x I_n. The internal blocking signals of the relay module do not prevent the operate signal of the differential current stage 3ΔI>>. When required the operate signal of the stage can be blocked by the external control signals BS1...BS5 or the intermodular blocking signals BS INT1...BS INT3. Blocking is enabled via switches SGB3/1...8.

Should the fundamental frequency component of the stabilizing current fall below 30% of the fundamental frequency component of the differential current, a fault has most certainly occurred in the area protected by the differential relay module. Then the operate value set for the stage 3ΔI>> will be automatically halved and the internal blocking signals of the stabilized stage will be inhibited.

Output signals

The switchgroups SGR1...SGR8 can be used to link the operate signals of the stabilized differential stage and the instantaneous differential stage, the internal blocking signals and the external control signals BS1...BS5 to the desired signal outputs SS1...SS4 or TS...TS4.

The switchgroup SGF4 allows a self-holding feature to be selected for the output signals SS1...SS4 and TS1...TS4. When this function has been selected, the output signal remains active though the signal that caused operation resets. The means of resetting the output relays are shown in the table in paragraph "Resetting".

The operation of the TRIP operation indicator on the front panel can be configured to be initiated by the activation of any TS signal. The operation indicator remains lit when the signal resets. The switchgroup SGF5 is used for programming. The means of resetting are shown in the table in paragraph "Resetting".

Circuit-breaker failure protection

The differential relay module SPCD 3D53 is provided with circuit-breaker failure protection (CBFP), which provides an operate signal TS1 0.1...1 s after the operate signal TS2, TS3 or TS4, unless the fault has disappeared during this time. In the range 100...440 ms the operate time can be adjusted in steps of 20 ms and in the range 440....1000 ms in steps of 40 ms. The heavy-duty output relay TS1 of the circuit-breaker failure protection can be used to operate the circuit breaker in front of the circuit breaker of the feeder of the object to be protected. The switches SGF3/1...3 are used to enable the circuit-breaker failure protection and the switches SGF3/4...8 are used for setting the operate time of the CBFP.

Signals between the relay modules

The signals BS INT1, BS INT2 and BS INT3 are intermodular blocking signals which can be used to block the operation of a relay module located in another card location of the same protection relay. An intermodular signal is activated when the corresponding blocking signal of one relay module is activated. The blocking signals BS INT1, BS INT2 and BS INT3 are not capable of controlling the output relays. The switches SGB1/1...8 are used for the selection of the logic active state of the external control signals and the intermodular blocking signals. So, the input can be activated when energized or when non-energized.

The signals AR1, AR2 and AR3 can be used to trigger the disturbance recorder SPCR 8C27 fitted in one of the card locations of the relay. These signals cannot be used to control the output relays.

Second settings

Two different setting values are available for the relay: main setting values and second setting values. Switching between these two types of setting value can be done in three ways as follows:

1) Over the serial bus, using command V150
2) By means of an external control signal: BS1, BS2 or BS3
3) Via the push-buttons on the front panel of the relay module and subregister 4 of register A. Selecting the value 0 for the subregister brings the main settings into effect, whereas the value 1 activates the second settings.

The S parameters allow the main setting values and second setting values to be read and set over the serial bus. The push-buttons on the front panel can be used for reading and setting actual setting values only.

N.B. If external control signals have been used for selecting main or second setting values, it is not possible to switch between main settings and second settings via the serial bus or the push-buttons on the front panel.

Resetting

The operation indicators on the front panel of the relay module, the operation codes on the display, latched output relays, and the registers of the relay module can be reset in three ways: with the push-buttons on the front panel, via an external control signal or a serial communication parameter as shown in the table below.

Means of resetting recording	Operation indicators	Output relays	Registers & recording memory
RESET	x		
PROGRAM	x	x	
RESET & PROGRAM	x	x	x
External control signal BS1, BS2 or BS3, when			
SGB5/1...3 = 1	x		
SGB6/1...3 = 1	x	x	
SGB7/1...3 = 1	x	x	x
Parameter V101	x	x	
Parameter V102	x	x	x

Integrated disturbance recorder

The integrated disturbance recorder records the waveforms of the currents to be measured, the digital control inputs of the module and the internal signals. The module has six analog and 11 digital channels. The memory has a capacity of one record the length of which is 38 cycles. The record has to be downloaded before a new recording sequence can be started. The memory is also emptied by resetting the values recorded by the module. The sampling frequency of the disturbance recorder is 40 times the rated frequency of the module, that means that the sampling frequency at 50 Hz is 2000 Hz.

The recording can be triggered by the internal signals of the relay module or the control signals linked to the module. Internal signals are the operate signals of the stabilized stage (3ΔI>) and the instantaneous stage (3ΔI>>), plus the blocking signal . The control signals linked to the module are the signals BS1...5 and BS INT1...3. Recording can be triggered by the rising or falling edge of any (one or several) of these signals. Triggering at rising edge means that the recording sequence starts when the signal is activated. Correspondingly, triggering by falling edge means that the recording sequence starts when the active signal resets.

The serial communication parameters V241... V245 are used for configuring the disturbance recorder. Parameter V241 specifies the internal signals to be used for triggering and parameter V242 specifies whether the recording is to be started by the rising or falling edge of the signal specified by parameter V241. Parameter V243 defines the control signals to be used for triggering, and parameter V244 specifies whether the rising or falling edge of the control signal is to start the recording sequence.

Parameter V245 is used for setting the length of the recording that follows triggering. The number of the recording cycles following triggering is equal to the value of parameter V245. The total recording length is fixed and always about 38 cycles.

When the serial communication parameter V246 = 0, the disturbance recorder has not been triggered, i.e. the recording memory is empty. When V246 = 1, the disturbance recorder has been triggered and the memory is full. The recording memory is emptied by giving the parameter V246 the value 0. The memory has to be empty before the disturbance recorder is able to start a new recording sequence. A memorized recording is indicated by the letter "d" to the right of the display, when no measured, set or recorded value is displayed.

The recorded data of the built-in disturbance recorder are downloaded, for instance, with the help of a PC program and the serial communication parameter V247.

Block schematic diagram

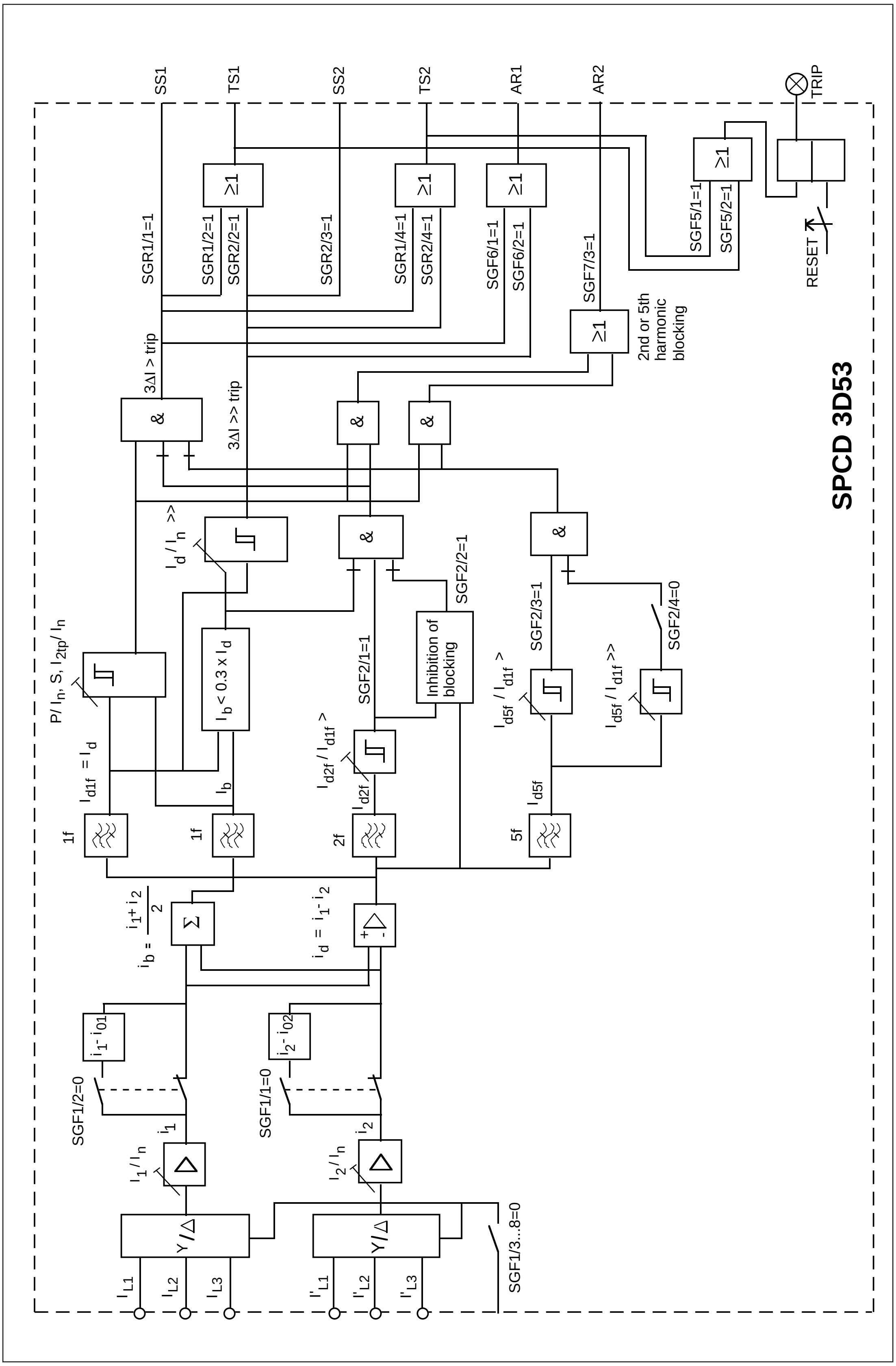


Fig. 3. Block schematic diagram with switchgroup default settings

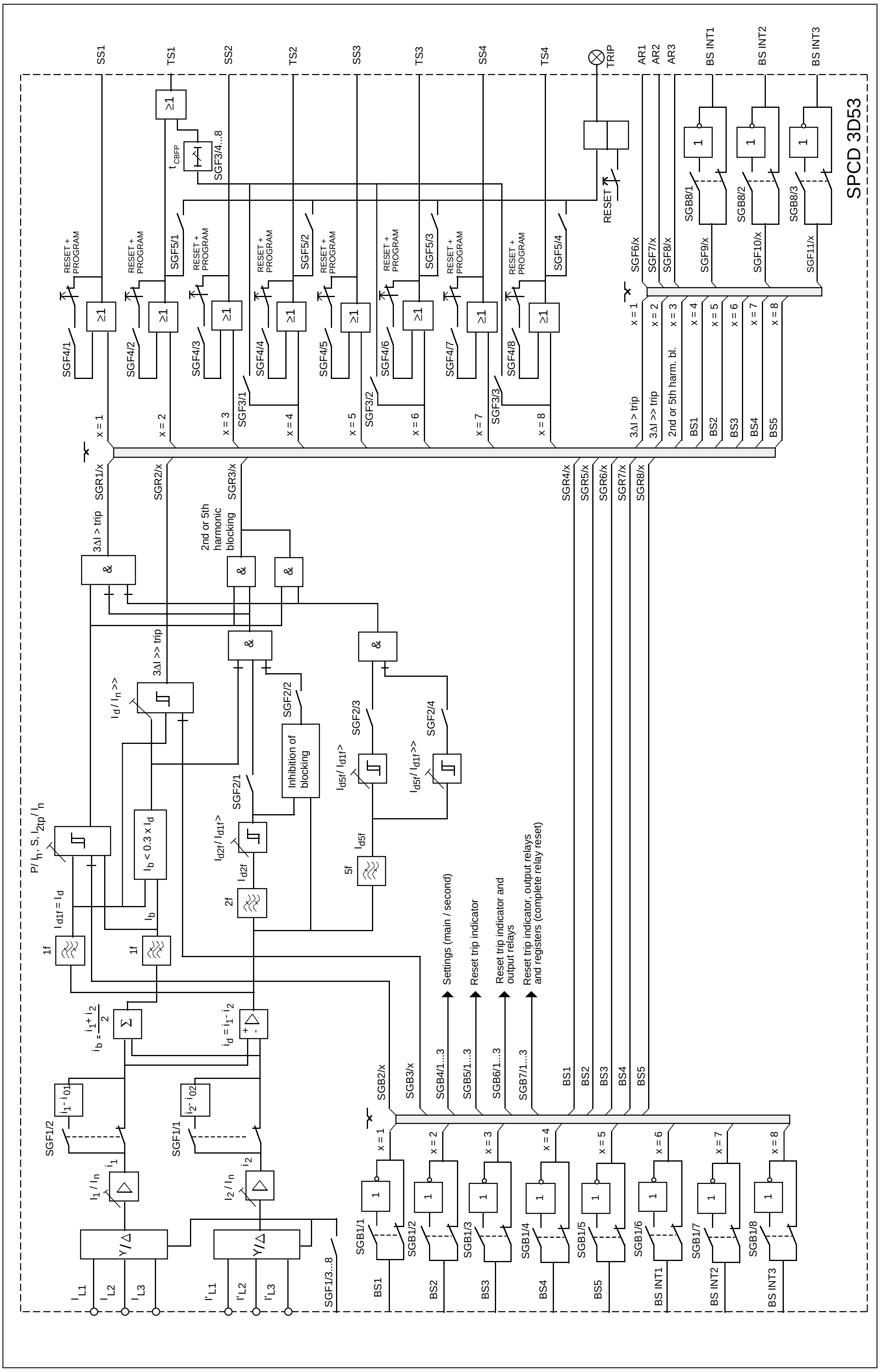


Fig. 4. Block schematic diagram for differential relay module SPCD 3D53

Symbols and signal abbreviations used

I_{L1}, I_{L2}, I_{L3}	Phase currents measured on the HV side
I'_{L1}, I'_{L2}, I'_{L3}	Phase currents measured on the LV side
I_1	HV side phase current
I_2	LV side phase current
I_n	Rated current
i_1	Instantaneous value of HV side phase current
i_2	Instantaneous value of LV side phase current
i_{01}	Instantaneous value of the zero-sequence component calculated on the basis of the HV side phase currents
i_{02}	Instantaneous value of the zero-sequence component calculated on the basis of the LV side phase currents
i_d	Instantaneous value of differential current
i_b	Instantaneous value of stabilizing current
I_{d1f}, I_d	Amplitude of the fundamental frequency component of the differential current
I_b	Amplitude of the fundamental frequency component of the stabilizing current
I_{d2f}	Amplitude of the second harmonic of the differential current
I_{d5f}	Amplitude of the fifth harmonic of the differential current
3ΔI>	Stabilized stage
3ΔI>>	Instantaneous stage
SGF1...SGF11	Switchgroups for configuring the functions
SGB1...SGB8	Switchgroups for configuring external control and blocking signals
SGR1...SGR8	Output relay matrix switchgroups
BS1...BS5	External control inputs
SS1...SS4	Output signals
TS1...TS4	Output signals
BS INT1...BS INT3	Intermodular blocking and control signals
AR1...AR3	Intermodular control signals
t_{CBFP}	Adjustable operate time for circuit-breaker failure protection

Note!
All input and output signals of the module are not necessarily wired to the terminals of every relay assembly using this module. The signals wired to the terminals are shown in the diagram illustrating the flow of signals between the plug-in modules of the relay assembly.

Front panel

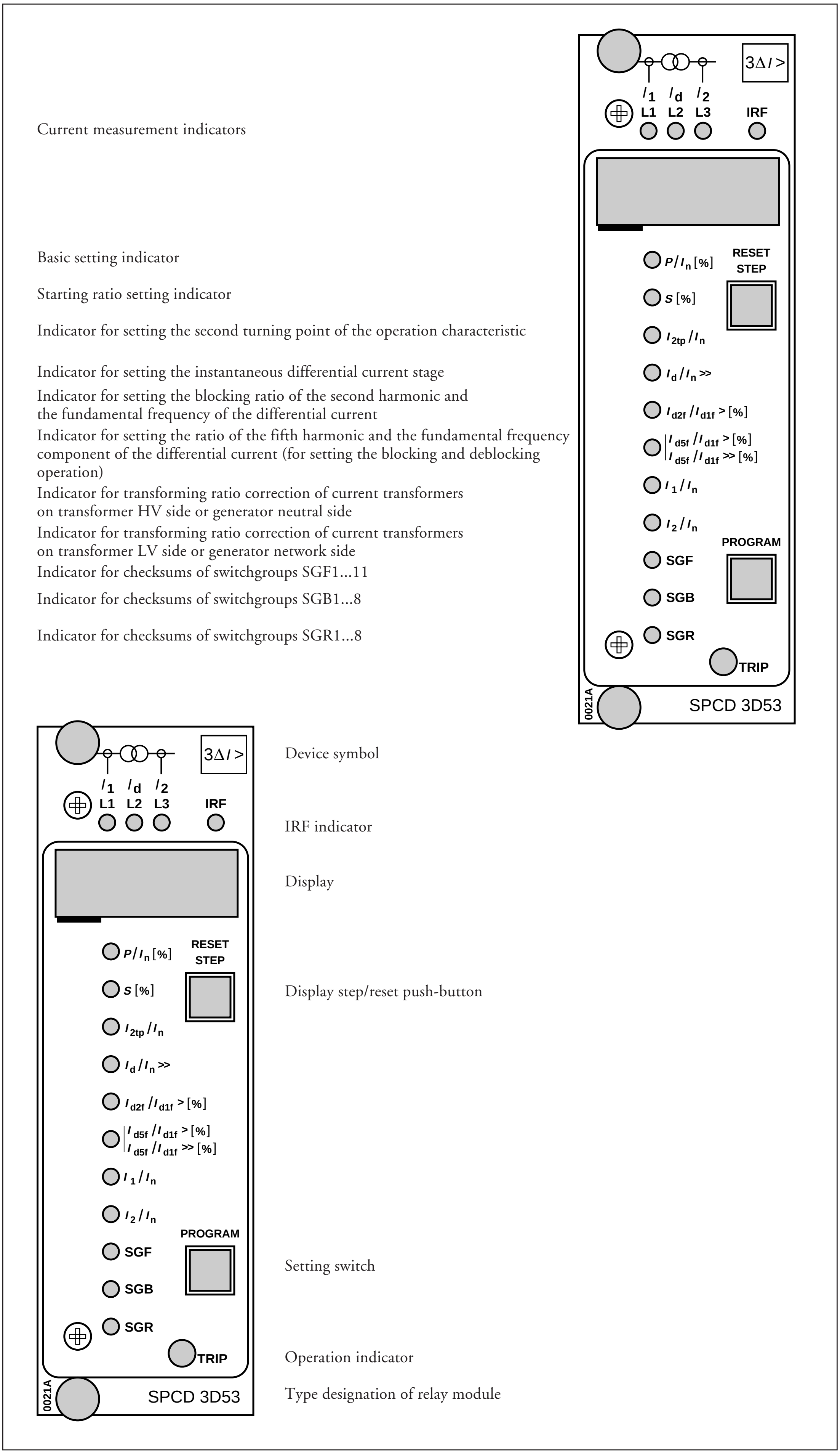


Fig. 5. Front panel for differential relay module SPCD 3D53

Operation indicators

The operation indicators of the differential relay module are the red operation code of the display and the red TRIP indicator that indicates operation.

An operate signal issued by the stabilizing stage of the differential relay module is indicated by a red operation code 1 on the display, whereas an operate signal by the instantaneous stage is indicated by the operation code 2. When an operate signal is issued by the stabilizing stage or the instantaneous stage the TRIP indicator is lit, provided the operate signal of the concerned stage is linked to a heavy-duty output relay TS1, TS2, TS3 or TS4 via a switch of switchgroup SGR1 or SGR2. The phase that initiated relay operation is indicated by the yellow LED indicators above the display. Should the operation code 1 or 2 be indicated on the display the TRIP indicator still being dark, the operate signal was not linked to a heavy-duty output relay. Indicators indicating operation remain lit until reset.

Activation of the external control signals BS1...BS5 is indicated on the display by the respective red operation code 4, 5, 6, 7 and 8. The operation code remains lit as long as the control signal is active. If the control signal was programmed (switchgroups SGB4...7) to be used to switch the main settings to second settings or vice versa, or to reset the operation indicators, latched output relays, registers or recording memory, the activation of the control signal is not indicated on the display.

The external control signals can be used as operate or alarm signals by routing the concerned signal to the desired output relay via the switchgroups SGR4...SGR8. Operation inititated by an external control signal is indicated on the display by the respective operation code. The operation codes remain lit until reset.

When relay operation is initiated by an external control signal, the TRIP indicator is automatically lit, if the output relay selected is one of the heavy-duty output relays TS1...TS4 configured to be controlled by stage 3ΔI> or stage 3ΔI>>. Otherwise the TRIP indicator is lit only if the output signal of the control signal has been set to light the indicator (switchgroup SGF5). If latching feature is selected for the output signal, the operation indicators remain lit until reset.

Blocking based on the ratio between the second harmonic and the fundamental frequency component of the differential current and on the ratio between the fifth harmonic and the fundamental frequency component of the differential current is indicated by the red operation code 3 on the display. The code is displayed as long as the blocking signal is active. If the output relays controlled by the blocking has a latching feature, the operation code is displayed until the relays are reset. If the circuit-breaker failure protection has operated, the operation code A is indicated on the display until the operation indicators are reset.

The table below describes the red operation codes shown on the display to indicate operate signals, blocking, an activated control input or operation of the circuit-breaker failure protection.

Code	Description
1	Stabilized 3ΔI> stage operated
2	Instantaneous 3ΔI>> stage operated
3	Blocking based on the second or the fifth harmonic of the differential current is active
4	External control signal BS1 active
5	External control signal BS2 active
6	External control signal BS3 active
7	External control signal BS4 active
8	External control signal BS5 active
A	Circuit-breaker failure protection operated
Yellow d	Disturbance recorder triggered, recording memorized

When the protection stage or the control signal resets, the TRIP indicator and the red operation code remain lit. The operation indicators can be reset via the push-buttons on the front panel of the relay, an external control signal or over the serial bus, see the table in paragraph "Description of operation". Unreset operation indicators do not affect the operation of the relay module.

The self-supervision alarm indicator IRF indicates internal relay faults. Once the self-supervision system of the relay module has detected a permanent fault, the red indicator is lit. At the same time the relay module delivers a signal to the self-supervision system output relay of the relay assembly. In addition, a fault code is lit on the display to show the type of the fault that has occurred. This fault code that consists of a red figure one and a green code number cannot be removed by resetting. It should be recorded and stated when service is ordered.

The table below shows the priority of the operation codes representing certain events. If the priorities of the events to be indicated are the same, the operation indicator of the latest event is indicated on the display.

Priority	Event to be indicated
1.	Self-supervision fault code
2.	Circuit-breaker failure operation
3.	Instantaneous stage $3\Delta I>>$ operated
4.	Stabilized stage $3\Delta I>$ operated, or operation initiated by an external control signal
5.	Activation of external control signal when the output signal controlled by the external control signal has a latching feature
6.	External control signal activated
7.	Internal blocking $I_{d2f}/I_{d1}>$ or $I_{d5f}/I_{d1}>$ activated

Settings

The setting values are indicated by the three right-most digits on the display. When a LED in front of a setting value symbol is lit it shows that the particular setting value is indicated on the display. The setting value given in parentheses under the setting range is the default setting.

The second settings of the differential relay module can be activated via subregister 4 of register A. The setting ranges are the same as those of the main settings. When the second settings are active the LED representing the particular setting value indicated on the display is flashing.

Setting	Description	Setting range (Default)
P/I_n(%)	Basic setting of start, step 1%	5...50% (5%)
S (%)	Starting ratio, step 1%	10...50% (10%)
I_{2tp}/I_n	Second turning point of the operation characteristic, step 0.1	1.0...3.0 (1.5)
$I_d/I_n>>$	Instantaneous differential current stage, step 1 x I_n	5...30 (10)
$I_{d2f}/I_{d1f}>$(%)	Ratio of the second harmonic and the fundamental frequency component of the differential current, step 1%	7...20% (15%)
$I_{d5f}/I_{d1f}>$(%)	Ratio of the fifth harmonic and the fundamental frequency component of the differential current, step 1%	10...50% (35%)
$I_{d5f}/I_{d1f}>>$(%)	Fifth harmonics deblocking ratio, step 1%	10...50% (35%)
I_1/I_n	Transforming ratio correction of HV side CTs, step 0.01	0.40...1.50 (1.00)
I_2/I_n	Transforming ratio correction of LV side CTs, step 0.01	0.40...1.50 (1.00)

The setting of the switchgroups SGF1...11, SGB1...8 and SGR1...8 are described in the following paragraph "Configuration switches".

Configuration switches

(modified 2004-04)

The switches of switchgroups SGF1...11, SGB1...8 and SGR1…8 can be used to select additional functions required for different applications. The switch number, 1...8, and position, 0 or 1, are displayed during the setting procedure. In normal service conditions the checksums of the switchgroups are displayed. These are found in the main menu of the relay module, see chapter "Main menus and submenus of settings and registers". The default settings and their checksums are also mentioned in the tables. The calculation of the checksum is described in the end of this paragraph. Further, the module contains an extra switchgroup SGX, which is located in submenu 7 of register A on the frontpanel (*effective from software version 187 A onwards).*

Switchgroup SGF1

Vector group matching and elimination of the zero-sequence component

The Table 1. below includes the switch positions representing the most general power transformer vector groups. In the vector groups given in column "I" the connection of the main current transformers are of type I. Then the normal directions of the HV and LV side relay currents are opposite, i.e. when there is no fault in the protected zone, see Fig. 6.

The connection of the main current transformers in the vector groups of column "II" is of type II. In this case the normal directions of the HV and LV side relay currents are equal, see Fig. 7.

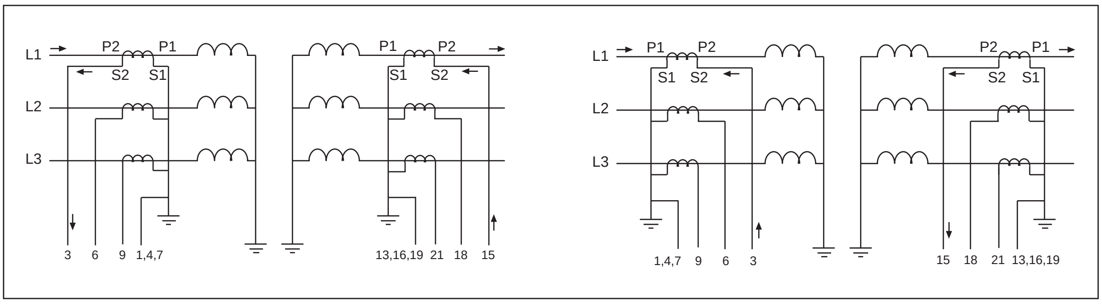


Fig. 6. Connections of current transformers of type I. The relay currents on HV and LV side have opposite directions. The CT wires are numbered according to the 1 A nominal current input terminals of the relay.

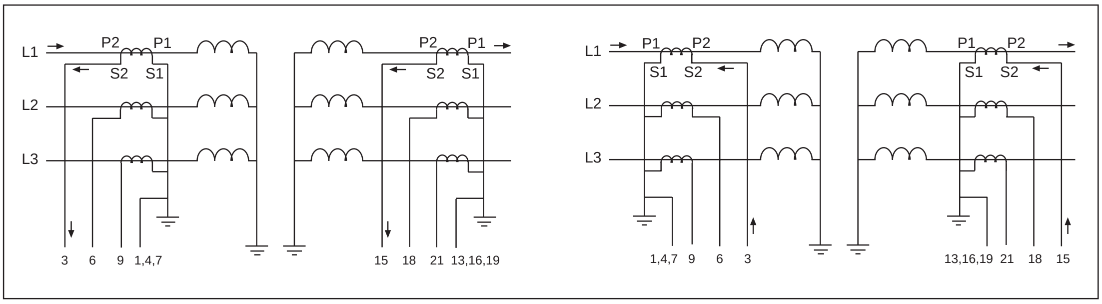


Fig. 7. Connections of current transformers of type II. The relay currents on HV and LV side have equal directions. The CT wires are numbered according to the 1 A nominal current input terminals of the relay.

Table 1. Matching of the most general power transformer vector groups

Power transformer vector group I	II	Switches SGF1/1...8 1	2	3	4	5	6	7	8	Checksum
Yy6	Yy0	0	0	0	0	0	0	0	0	0
YNyn8	YNyn2	0	0	1	0	1	1	0	0	52
YNyn10	YNyn4	0	0	1	0	0	0	1	0	68
YNyn6	YNyn0	1	1	0	0	0	0	0	0	3
Yy0	Yy6	0	0	1	1	0	0	0	0	12
YNyn2	YNyn8	0	0	1	0	1	0	0	1	148
YNyn4	YNyn10	0	0	1	0	0	1	0	1	164
YNyn0	YNyn6	1	1	1	1	0	0	0	0	15
Yd1	Yd7	0	0	0	1	0	0	0	0	8
YNd1	YNd7	0	0	0	0	0	0	0	1	128
Yd5	Yd11	0	0	1	0	0	0	0	0	4
YNd5	YNd11	0	0	0	0	0	1	0	1	160
Yd7	Yd1	0	0	1	0	1	0	0	0	20
YNd7	YNd1	0	0	0	0	0	1	0	0	32
Yd11	Yd5	0	0	0	0	1	0	0	0	16
YNd11	YNd5	0	0	0	0	0	0	1	0	64
Dd6	Dd0	0	0	0	0	0	0	0	0	0
Dd0	Dd6	0	0	1	1	0	0	0	0	12
Dy1	Dy7	0	0	0	0	0	0	0	1	128
Dyn1	Dyn7	0	0	0	1	0	0	0	0	8
Dy5	Dy11	0	0	0	0	0	1	0	1	160
Dyn5	Dyn11	0	0	1	0	0	0	0	0	4
Dy7	Dy1	0	0	0	0	0	1	0	0	32
Dyn7	Dyn1	0	0	1	0	1	0	0	0	20
Dy11	Dy5	0	0	0	0	0	0	1	0	64
Dyn11	Dyn5	0	0	0	0	1	0	0	0	16
YNzn1	YNzn7	1	0	0	0	0	0	0	1	129
YNzn5	YNzn11	1	0	0	0	0	1	0	1	161
YNzn7	YNzn1	1	0	0	0	0	1	0	0	33
YNzn11	YNzn5	1	0	0	0	0	0	1	0	65
Dzn0	Dzn6	1	0	1	1	0	0	0	0	13
Dzn2	Dzn8	0	0	0	1	0	1	0	0	40
Dzn4	Dzn10	0	0	1	0	0	1	0	1	164
Dzn6	Dzn0	1	0	0	0	0	0	0	0	1
Dzn8	Dzn2	0	0	1	0	1	1	0	0	52
Dzn10	Dzn4	0	0	1	0	0	0	1	0	68

The switches SGF1/3...8 are used for compensating the phase difference of the HV and LV side phase currents that is caused by the vector group of the power transformer.

Vector group matching can be implemented both on the HV side and the LV side or only on the HV or the LV side. Vector group matching is almost always made on the star connected side of YNd and Dyn connected transformers. Then the zero-sequence component of the phase currents at earth faults occurring out of the protection area is eliminated in the vector group matching on the star connected side before the differential current and the stabilizing current are calculated.

Vector group matching is not required if there is no phase difference between the HV and LV side phase currents of the transformer to be protected. However, the zero-sequence component of the phase currents on the star-connected side that is earthed at its start point has to be eliminated before the differential and stabilizing current are calculated. The switches SGF1/1...2 are used for eliminating the zero-sequence component from the HV and/or LV side phase currents.

If, for instance, there is an earthing transformer on the delta-connected side of the YNd power transformer in the area to be protected, the vector group matching is normally made on the side of the star connection. On the side of the delta connection elimination of the zero-sequence component of the phase currents has to be separately selected with switch SGF1/1. No interposing transformers are required for the elimination of the zero-sequence component. The table below shows the function of the switches SGF1/1 and SGF1/2.

Table 2. Calculated zero-sequence component elimination

Switch	Function
SGF1/1 = 1	The zero-sequence component is calculated and eliminated from the phase currents on the LV side before the differential and stabilizing current are calculated.
SGF1/1 = 0	The zero-sequence component is not calculated on the LV side.
SGF1/2 = 1	The zero-sequence component is calculated and eliminated from the phase currents on the HV side before the differential and stabilizing current are calculated.
SGF1/2 = 0	The zero-sequence component is not calculated on the HV side.

The tables below show how the switches SGF1/3...8 can be used to set the vector groups for phase currents linked to the relay. The first column "internal matching" shows the vector group matching implemented numerically inside the relay module.

Table 3. Vector group matching on LV side.

Internal matching	SGF1/3	SGF1/4	SGF1/5	Checksum Σ
Yy0	0	0	0	0
Yd1	1	0	0	4
Yd5	0	1	0	8
Yy6	1	1	0	12
Yd7	0	0	1	16
Yd11	1	0	1	20

Table 4. Switchgroup matching on HV side

Internal matching	SGF1/6	SGF1/7	SGF1/8	Checksum Σ
Yy0	0	0	0	0
Yd1	1	0	0	32
Yd5	0	1	0	64
Yy6	1	1	0	96
Yd7	0	0	1	128
Yd11	1	0	1	160

When the internal matching is Yy0 the phase angle of the phase currents connected to the relay does not change. When the internal matching is Yy6, the phase currents will be turned 180° in the relay. If the internal matching is Yd1, Yd5, Yd7 or Yd11, a possible zero-sequence component in the phase currents will be eliminated in the numerically implemented delta connection before the differential current and the stabilizing current are calculated. With the internal matching Yy0 and Yy6 the zero-sequence component of the phase currents is not eliminated. Then the switches SGF1/1 and SGF1/2 have to be used to eliminate the zero-sequence component of the phase currents, when required.

By using the tables 2, 3 and 4 it is possible to program vector groups for the differential relay module other than those presented in table 1 "Matching of the most general power transformer vector groups".

Switchgroup SGF2 Internal blockings

Switch	Function	Factory setting
SGF2/1	The switch is used to select whether the operate signal of stage 3ΔI> is to be blocked when the ratio of the second harmonic and the fundamental frequency component of the differential current exceeds the setting value I_{d2f}/I_{d1f}> When SGF2/1 = 1, blocking is enabled. When SGF2/1 = 0, blocking is disabled.	1
SGF2/2	The switch is used to select whether it is possible to use a blocking inhibit algorithm to immediately eliminate a blocking based on the second harmonic of the differential current if the inrush current of the power transformer contains fault current. When SGF2/2 = 1, the blocking can be eliminated. When SGF2/2 = 0, the blocking cannot be eliminated.	1
SGF2/3	The switch is used to select whether the operate signal of stage 3ΔI> is to be blocked when the ratio of the fifth harmonic and the fundamental frequency component of the differential current exceeds the setting value I_{d5f}/I_{d1f}> When SGF2/3 = 1, blocking is enabled. When SGF2/3 = 0, blocking is disabled.	1
SGF2/4	The switch is used to select whether the blocking of stage 3ΔI>, based on the fifth harmonic of the differential current, is to be eliminated when the ratio of the fifth harmonic and the fundamental frequency component of the differential current exceeds the setting value I_{d5f}/I_{d1f}>> When SGF2/4 = 1, blocking can be eliminated. When SGF2/4 = 0, blocking cannot be eliminated.	0
SGF2/5	Not in use. Has to be in position 0.	0
SGF2/6	Not in use. Has to be in position 0.	0
SGF2/7	Not in use. Has to be in position 0.	0
SGF2/8	Not in use. Has to be in position 0.	0
∑SGF2		7

Switchgroup SGF3 Circuit-breaker failure protection (CBFP)

Switch	Function	Factory setting
SGF3/1	Circuit-breaker failure protection (CBFP) start initiated by signal TS2	0
SGF3/2	Circuit-breaker failure protection (CBFP) start initiated by signal TS3	0
SGF3/3	Circuit-breaker failure protection (CBFP) start initiated by signal TS4 When the switch is in position 1, the output signal TS_ starts the CBFP operate time. Should the operate time expire the output signal still being active, the relay provides an operate signal TS1. When the switch is in position 0, the circuit-breaker failure protection is disabled.	0
SGF3/4...8	Circuit-breaker failure protection operate time t_{CBFP}, see table 5.	0
∑SGF3		0

Table 5. Circuit-breaker failure protection operate times to be selected with switches SGF3/4...8.

t_{CBFP} / ms	SGF3/4	SGF3/5	SGF3/6	SGF3/7	SGF3/8	∑SGF3/4…8
100	0	0	0	0	0	0
120	1	0	0	0	0	8
140	0	1	0	0	0	16
160	1	1	0	0	0	24
180	0	0	1	0	0	32
200	1	0	1	0	0	40
220	0	1	1	0	0	48
240	1	1	1	0	0	56
260	0	0	0	1	0	64
280	1	0	0	1	0	72
300	0	1	0	1	0	80
320	1	1	0	1	0	88
340	0	0	1	1	0	96
360	1	0	1	1	0	104
380	0	1	1	1	0	112
400	1	1	1	1	0	120
420	0	0	0	0	1	128
440	1	0	0	0	1	136
480	0	1	0	0	1	144
520	1	1	0	0	1	152
560	0	0	1	0	1	160
600	1	0	1	0	1	168
640	0	1	1	0	1	176
680	1	1	1	0	1	184
720	0	0	0	1	1	192
760	1	0	0	1	1	200
800	0	1	0	1	1	208
840	1	1	0	1	1	216
880	0	0	1	1	1	224
920	1	0	1	1	1	232
960	0	1	1	1	1	240
1000	1	1	1	1	1	248

Switchgroup SGF4 Self-holding of output signals

Switch	Function	Factory setting
SGF4/1	Selection of self-holding for output signal SS1	0
SGF4/2	Selection of self-holding for output signal TS1	0
SGF4/3	Selection of self-holding for output signal SS2	0
SGF4/4	Selection of self-holding for output signal TS2	0
SGF4/5	Selection of self-holding for output signal SS3	0
SGF4/6	Selection of self-holding for output signal TS3	0
SGF4/7	Selection of self-holding for output signal SS4	0
SGF4/8	Selection of self-holding for output signal TS4	0
∑SGF4		0
	When a switch is in position 0, the output signal resets when the measured signal that caused operation falls below the setting value. When a switch is in position 1, the output signal remains active even though the signal that caused operation falls below the setting value. When the self-holding feature has been selected the output signal has to be reset with the push-buttons on the front panel, via an external control input or the serial bus, see paragraph "Description of operation".	

Switchgroup SGF5 Activation of TRIP operation indicator

Selection of the output signal to control the TRIP operation indicator on the front panel. When the switch linked to a certain signal output is in position 1, the TRIP operation indicator is lit by the activation of the signal. The switches SGF5/5...8 are not in use.

Switch SGF5/	Controlling signal	Switch position TRIP dark	TRIP is lit	Factory setting
1	TS1	0	1	1
2	TS2	0	1	1
3	TS3	0	1	0
4	TS4	0	1	0
∑ SGF5				3

Note!
The operate signal of the stabilizing and the instantaneous stage of the differential relay module lights the TRIP indicator irrespective of the setting of switchgroup SGF5, provided the operate signal is linked to a heavy-duty output relay via an output signal TS1, TS2, TS3 or TS4.

Special attention should be paid to the setting of switchgroup SGF5 when the operate signal can be initiated by an external control signal BS1, BS2, BS3, BS4 or BS5.

Switchgroups SGF6...11

Selection of the signals of the protection stages and the external control signals BS1...5 to be used as intermodular signals AR1...3 and BS INT1...3. The signal configuration is presented in Fig 8 below.

The signals of the protection stages and the control signals are linked with the desired intermodular signal lines, for example, by encircling the intersections of the signal lines. The switch number is marked at each intersection point and the weighting value of the switch is given on the right side of the matrix. By adding the weighting values of the switches selected from each switchgroup the checksums of the switchgroups are obtained at the bottom of the matrix. The checksums of the factory settings are given under the calculated checksums.

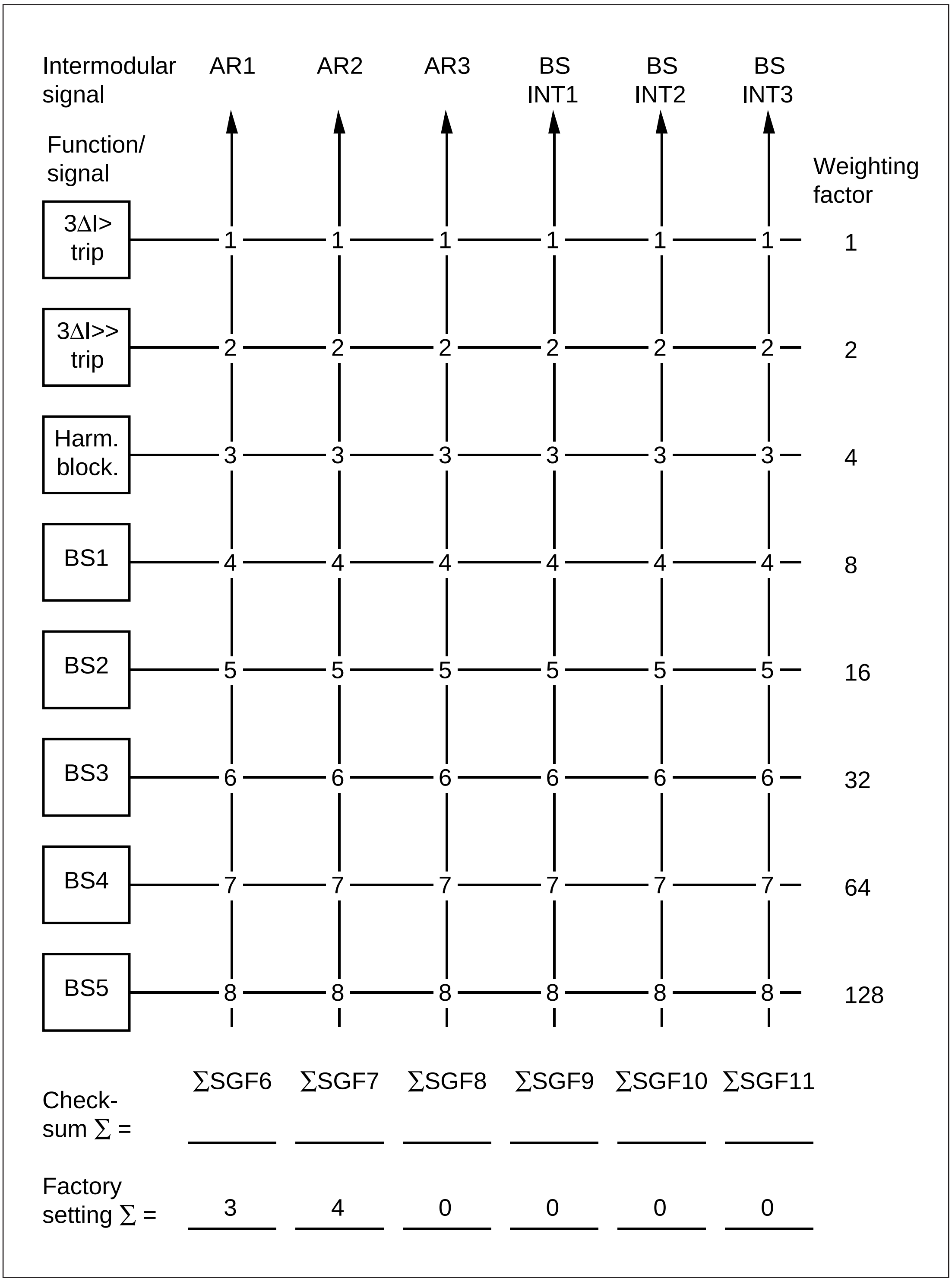


Fig. 8. Programming matrix for intermodular signals

Switchgroup SGB1

Selection of the logic active state of the external control signals BS1...5 and the intermodular blocking signals BS INT1...3.

When the switch is in position 0, the signal is active (state 1), when voltage, either DC voltage 18...265 V or AC voltage 80...265 V, is applied to the control input. When the switch is in position 1, the signal is active when no voltage is applied to the control input.

Switch	Function	Factory setting
SGB1/1	Selection of active state, signal BS1	0
SGB1/2	Selection of active state, signal BS2	0
SGB1/3	Selection of active state, signal BS3	0
SGB1/4	Selection of active state, signal BS4	0
SGB1/5	Selection of active state, signal BS5	0
SGB1/6	Selection of active state, signal BS INT1	0
SGB1/7	Selection of active state, signal BS INT2	0
SGB1/8	Selection of active state, signal BS INT3	0
∑SGB1		0

Switchgroup SGB2...7

The switchgroups SGB2...7 are used to configure the functions of the control signals BS1...5 and BS INT1...3. The matrix below can be used for configuring the signals. The control signals are linked with the desired function by marking the intersections of the lines. The switch number is marked at each intersection point and the corresponding weighting factor to the right of the matrix. Adding the weighting factors of the selected switches for each switchgroup gives the switchgroup checksums at the bottom of the matrix. Switches not mentioned are not in use and should be in position 0.

Note!
Before programming it should be checked whether all control signals of the relay module SPCD 3D53 are used in the relay.

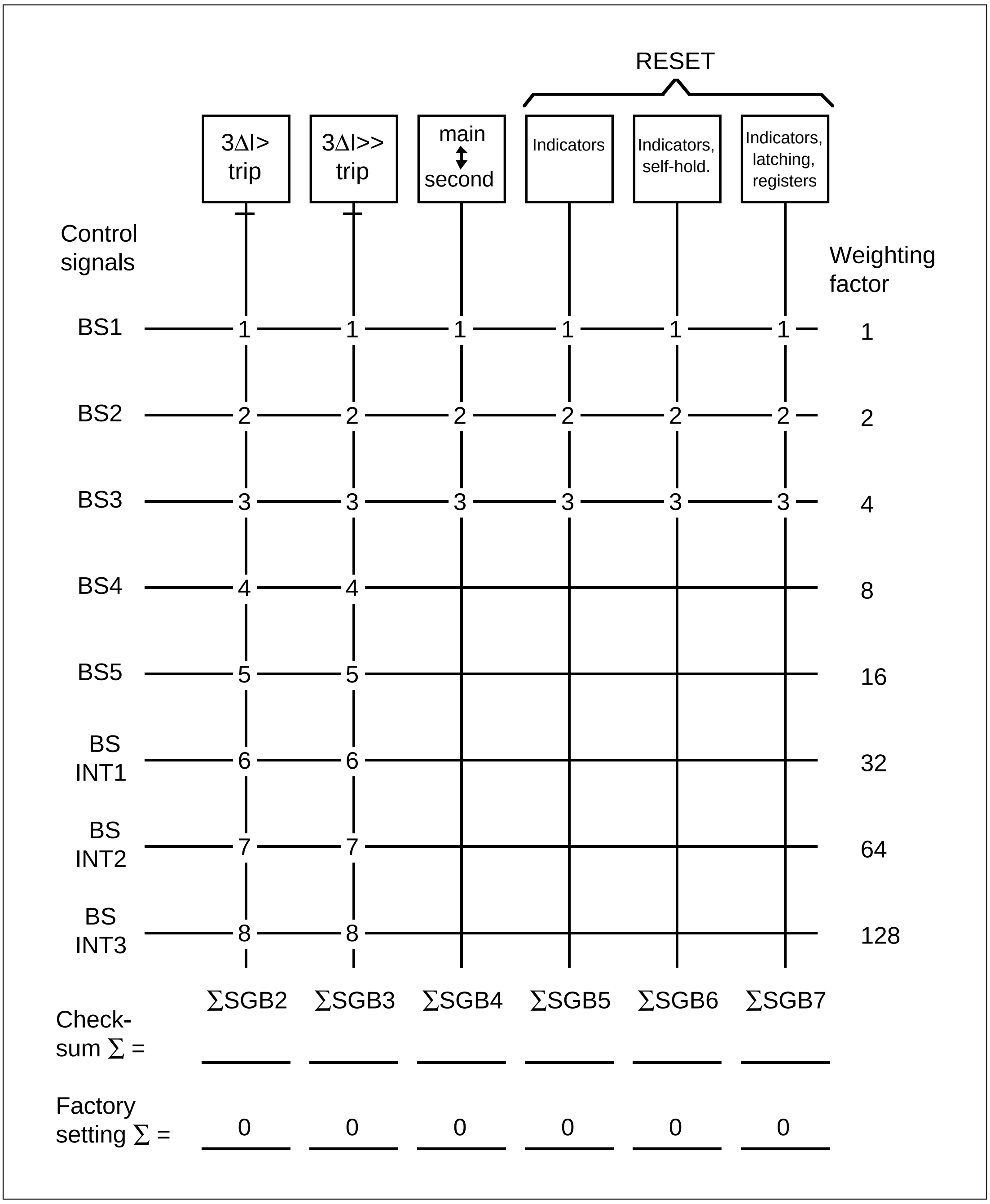


Fig. 9. Matrix for programming external control signals

Switches	Function
SGB2	Selection of the blocking signals for the operation of the stabilized stage 3ΔI>. When the switch is in position 1, and the blocking signal linked with the concerned switch is activated, the operation of the stage is blocked.
SGB3	Selection of the blocking signals for the operation of the instantaneous differential current stage 3ΔI>>. When the switch is in position 1, and the blocking signal linked with the concerned switch is activated, the operation of the stage is blocked.
SGB4/1...3	Switching between main and second setting values. When an external control signal is used, the main setting values are effective when the signal is active. When the signal is not active the second settings are effective. When SGB4/1...3 = 0, an external control signal cannot be used to switch between the setting values. Then the push-buttons on the front panel or a command over the serial bus have to be used. When SGB4/1...3 = 1, the actual setting values (main settings or second settings) depend entirely on the status of the control signal. Note! When SGB4/1...3 = 1, the relay module does not respond to switch-over commands given over the serial bus or with the push-buttons on the front panel. When both the main setting values and the second setting values are used, it is important that the switches SGB4/1...3 are in the same positions in the main setting and the second setting. Otherwise there may be a conflict situation when settings are changed.
SGB5/1...3	Resetting of front panel operation indicators
SGB6/1...3	Resetting of latched output relays and front panel operation indicators
SGB7/1...3	Resetting of front panel operation indicators, latched output relays, and registers

Switchgroup SGB8

The active logic state of the blocking signals BS INT1, BS INT2 or BS INT3 of the relay module in relation to the logic state of the signal linked to the blocking signal.

Switch	Function	Factory setting
SGB8/1	When SGB8/1 = 0, the active state of BS INT1 is not changed. When SGB8/1 = 1, the active state of BS INT1 is changed.	0
SGB8/2	When SGB8/2 = 0, the active state of BS INT2 is not changed. When SGB8/2 = 1, the active state of BS INT2 is changed.	0
SGB8/3	When SGB8/3 = 0, the active state of BS INT3 is not changed. When SGB8/3 = 1, the active state of BS INT3 is changed.	0
SGB8/4	Not in used. Has to be in position 0.	0
SGB8/5	Not in used. Has to be in position 0.	0
SGB8/6	Not in used. Has to be in position 0.	0
SGB8/7	Not in used. Has to be in position 0.	0
SGB8/8	Not in used. Has to be in position 0.	0
∑SGB8		0

Switchgroups SGR1...SGR8

The switches SGR1...8 are used to configure the operate signals of the protection stages and the control signals to operate as desired output signals SS1...SS4 or TS1...TS4.

The matrix below can be used for programming. The signals are connected with the desired output signal SS1...SS4 or TS1...TS4 by encircling the intersections of the signal lines. The switch number is marked at each intersection point and the weighting value of the switch is given at the bottom of the matrix. By adding the weighting factors of the switches selected from each switchgroup the checksums of the switchgroups are obtained to the right of the matrix. (The checksums of the factory setting are given in paranthesis).

Note!
Check that all output signals of the relay module SPCD 3D53 are in use in the concerned protection relay before programming.

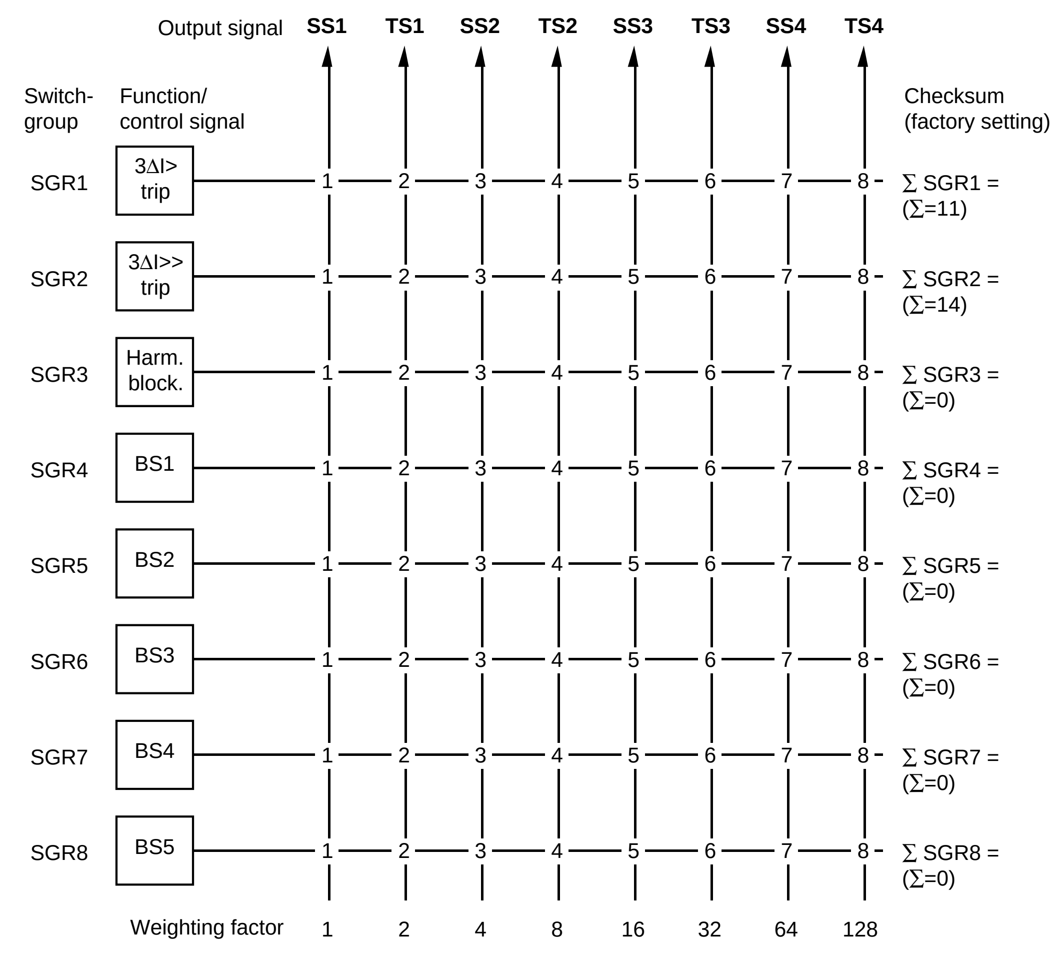


Fig. 10. Output relay matrix for differential relay module SPCD 3D53.

Switchgroup SGX

Switch	Function	Factory setting
SGX/1	The switch is used to select if the recorded values remain at loss of power supply or ara cleared at loss of power supply. When SGX/1 = 1, the recorded values are stored to non-volatile memory When SGX/1 = 0, recorded values are cleared at loss of power supply	1
SGX/2..8	Not in use, has to be in position 0	0

Measured data

Measured values are indicated by the three green right-most digits on the display. Data that is currently being measured is indicated by a LED above the display and by a red digit or letter to the left on the display.

Note! The measured data displayed consider the effect of the transforming ratio corrections I_1/I_n and I_2/I_n. The phase difference displayed is the phase difference of the currents after vector group matching.

Measured data of main menu

LED indicator	Red symbol	Measured data
L1	1	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a multiple of the rated current on phase L1.
L2	1	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a multiple of the rated current onphase L2.
L3	1	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a multiple of the rated current onphase L3.
L1	d	Differential current I_d measured by the module as a multiple of the rated current on phase L1.
L2	d	Differential current I_d measured by the module as a multiple of the rated current on phase L2.
L3	d	Differential current I_d measured by the module as a multiple of the rated current on phase L3.
L1	2	Phase current I_2 on the transformer LV side or the network of the generator stator as a multiple of the rated current on phase L1.
L2	2	Phase current I_2 on the transformer LV side or the network of the generator stator as a multiple of the rated current on phase L2.
L3	2	Phase current I_2 on the transformer LV side or the network of the generator stator as a multiple of the rated current on phase L3.

Measured data of submenu

The measured data of the submenu are described in the table below. The red symbol displayed on main menu level shows the main register in the subregister of which the concerned measured data is available.

LED indicator	Main menu red symbol	Submenu red digit	Data measured
L1	1	0	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a percentage of the rated current on phase L1.
L2	1	0	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a percentage of the rated current on phase L2.
L3	1	0	Phase current I_1 on the transformer HV side or the star-point side of the generator stator as a percentage of the rated current on phase L3.
L1	d	0	Differential current I_d measured by the module, expressed as a percentage of the rated current on phase L1.
L1, L2	d	1	Phase difference, expressed in degrees, of the phase currents on phases L1 and L2 on the transformer HV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.
L2, L3	d	2	Phase difference, expressed in degrees, of the phase currents on phases L2 and L3 on the transformer HV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.

LED indicator	Main menu red symbol	Submenu red digit	Data measured
L1, L3	d	3	Phase difference, expressed in degrees, of the phase currents on phases L3 and L1 on the transformer HV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.
L2	d	0	Differential current I_d measured by the module, expressed as a percentage of the rated current on phase L2.
L1	d	1	Phase difference, expressed in degrees, of the transformer HV and LV side currents I_1 and I_2 on phase L1 after vector group matching. A zero "0" will be indicated on the display if the vector group matching was carried out correctly.
L2	d	2	Phase difference, expressed in degrees, of the transformer HV and LV side currents I_1 and I_2 on phase L2 after vector group matching. A zero "0" will be indicated on the display if the vector group matching was carried out correctly.
L3	d	3	Phase difference, expressed in degrees, of the transformer HV and LV side currents I_1 and I_2 on phase L3 after vector group matching. A zero "0" will be indicated on the display if the vector group matching was carried out correctly.
L3	d	0	Differential current I_d measured by the module, expressed as a percentage of the rated current on phase L3.
L1, L2	d	1	Phase difference, expressed in degrees, of the phase currents on phases L1 and L2 on the transformer LV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.
L2, L3	d	2	Phase difference, expressed in degrees, of the phase currents on phases L2 and L3 on the transformer LV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.
L1, L3	d	3	Phase difference, expressed in degrees, of the phase currents on phases L3 and L1 on the transformer LV side or the star-point side of the generator stator. Under normal conditions the phase difference is 120°.
L1	2	0	Phase current I_2 on the transformer LV side or the network side of the generator stator, expressed as a percentage of the rated current on phase L1.
L2	2	0	Phase current I_2 on the transformer LV side or the network side of the generator stator, expressed as a percentage of the rated current on phase L2.
L3	2	0	Phase current I_2 on the transformer LV side or the network side of the generator stator, expressed as a percentage of the rated current on phase L3.

Recorded information

(modified 2004-04)

The information recorded is stored in a pushdown storage either at the moment of the relay operation, registers 1…6, or during transformer connection inrush, registers 7…9. The pushdown storage contains the five latest values recorded (n)...(n-4). Each new value is stored in the first location (n) in the storage and pushes all the previous items one step forward (n-1). When a sixth item is stored the oldest item (n-4) of the memory is lost.

The most recently stored values (n) are available in the main registers. Maximum four of the previous values are in the subregisters. The left-most digit indicates the address of the storage location and the other three digits the numerical value of the parameter recorded.

Note!
Minimum value of the ratio of the second harmonic and the fundamental frequency component of the differential current is recorded in each phase without using any weighting coefficients.

Note!
Recorded information can be stored to non-volatile memory by setting SGX/1 in position 1. By factory settings, SGX/1 is in position 0, recorded information is cleared after a loss of auxiliary power supply.

Register number	Recorded value
1	Differential current on phase L1 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
2	Differential current on phase L2 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
3	Differential current on phase L3 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
4	Stabilizing current on phase L1 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
5	Stabilizing current on phase L2 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
6	Stabilizing current on phase L3 as a multiple of the rated current at the moment of operation. The subregisters 1...4 contain the values of the differential current at the moment of operation (n-1)...(n-4).
7	Minimum value of the ratio of the second harmonic and the fundamental frequency component of the differential current on phase L1 at connection inrush. The subregisters 1...4 contain the minimum values at connection inrush (n-1)...(n-4).
8	Minimum value of the ratio of the second harmonic and the fundamental frequency component of the differential current on phase L2 at connection inrush. The subregisters 1...4 contain the minimum values at connection inrush (n-1)...(n-4).
9	Minimum value of the ratio of the second harmonic and the fundamental frequency component of the differential current on phase L3 at connection inrush. The subregisters 1...4 contain the minimum values at connection inrush (n-1)...(n-4).

<table>
<tr><th>Register number</th><th>Recorded value</th></tr>
<tr><td>0</td><td>Status of external blocking and control signals. The number indicated on the display shows the status of the external blocking and control signals BS1...5 and BS INT1...3. The numbers representing active signal status are given below. The value of the register is equal to the sum of the numbers representing the active signals. The register has a value in the range 0...255.

<table>
<tr><th>Control signal</th><th>Number representing active status of the control signal</th></tr>
<tr><td>BS1</td><td>1</td></tr>
<tr><td>BS2</td><td>2</td></tr>
<tr><td>BS3</td><td>4</td></tr>
<tr><td>BS4</td><td>8</td></tr>
<tr><td>BS5</td><td>16</td></tr>
<tr><td>BS INT1</td><td>32</td></tr>
<tr><td>BS INT2</td><td>64</td></tr>
<tr><td>BS INT3</td><td>128</td></tr>
</table>

From this register it is possible to enter the test mode of the output relays. In this mode the output signals and the settings of the SGR switchgroups of the output relay matrix can be tested. The output signals to be activated are indicated by a flashing LED next to the settings, one LED flashing at a time.

A detailed description of the test mode is given in the following paragraph "Testing of output relays".</td></tr>
<tr><td>A</td><td>The address code of the relay module, required for serial communication. Register A contains the additional subregisters:

1. Setting of the data transfer rate for the relay module: 4.8 or 9.6 kBd. Default setting 9.6 kBd.
2. Bus traffic monitor. If the relay module is connected to a data communication system and the communication operates properly, the value of the monitor is 0. Otherwise the numbers 0...255 are rolling.
3. Password required for remote setting. The password (parameter V160) must always be entered before a setting can be changed over the serial bus.
4. Selection of main and second settings (0 = main settings, 1 = second settings). Default setting 0.
5. Hz setting of rated frequency f_n. Default setting 50 Hz.
6. mHz setting of rated frequency f_n. Default setting 0 mHz.
So, the default setting of the rated frequency is 50.000 Hz.
7. Checksum of the switchgroup SGX.</td></tr>
</table>

When the display is dark, access to the beginning of the main menu is gained by pressing the STEP push-button on the front panel for more than 0.5 s. Pressing the push-button for less than 0.5 s gives direct access to the end of the main menu of the relay module (Serial communication address).

The information recorded in registers 1...9 can be reset using the push-buttons on the front panel, an external control signal, or a serial communication parameter, see section "Resetting" in paragraph "Description of function". In case storing of the recorded value into non-volatile memory function is not use (SGX/1 = 0), the registers are also cleared by an auxiliary power supply failure. The setting values, the address code, the data transfer rate and the password of the relay module are not affected by voltage failures. Instructions for setting the address code and data transfer rate are given in the document "General characteristics of D-type relay modules".

Main menus and submenus of settings and registers

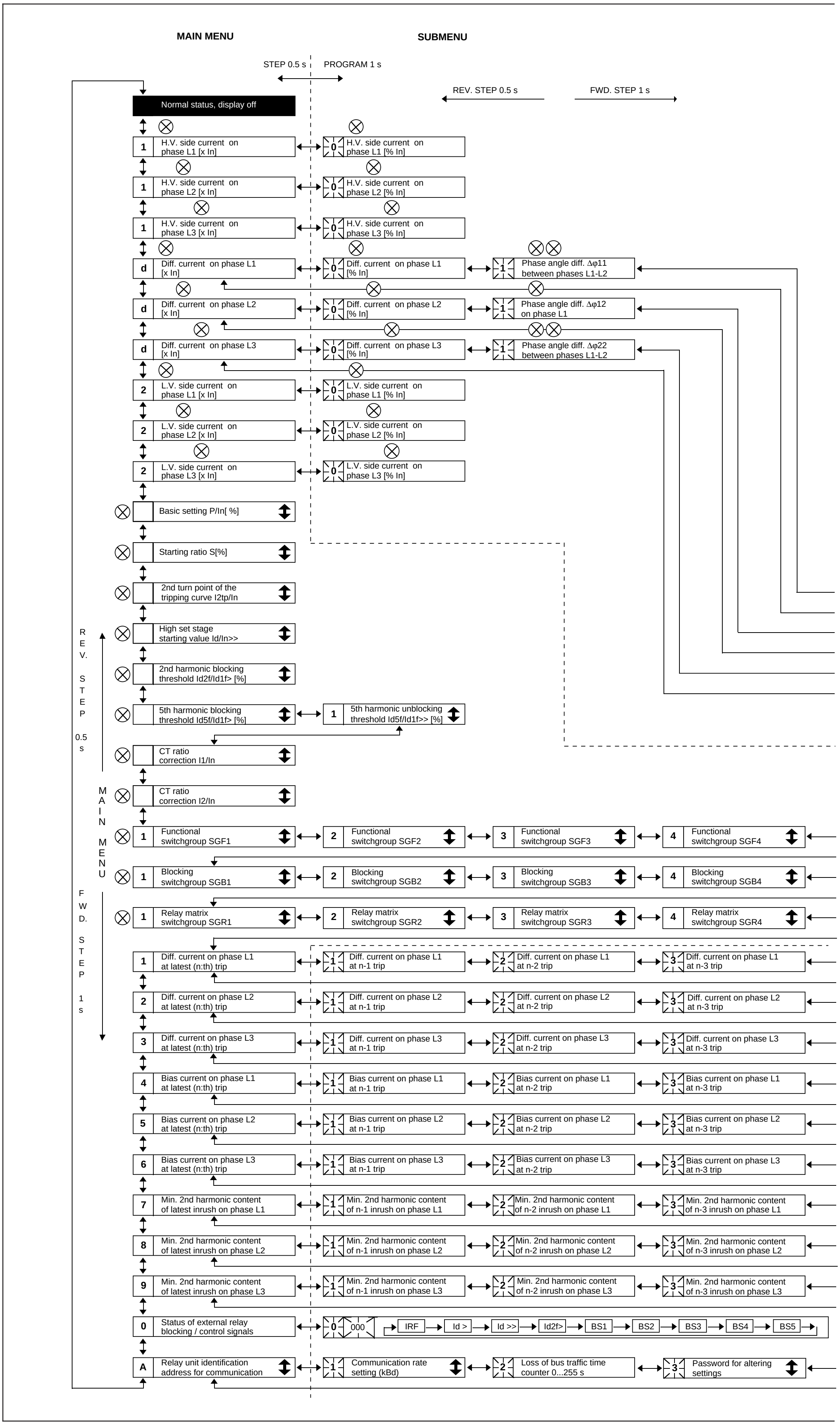
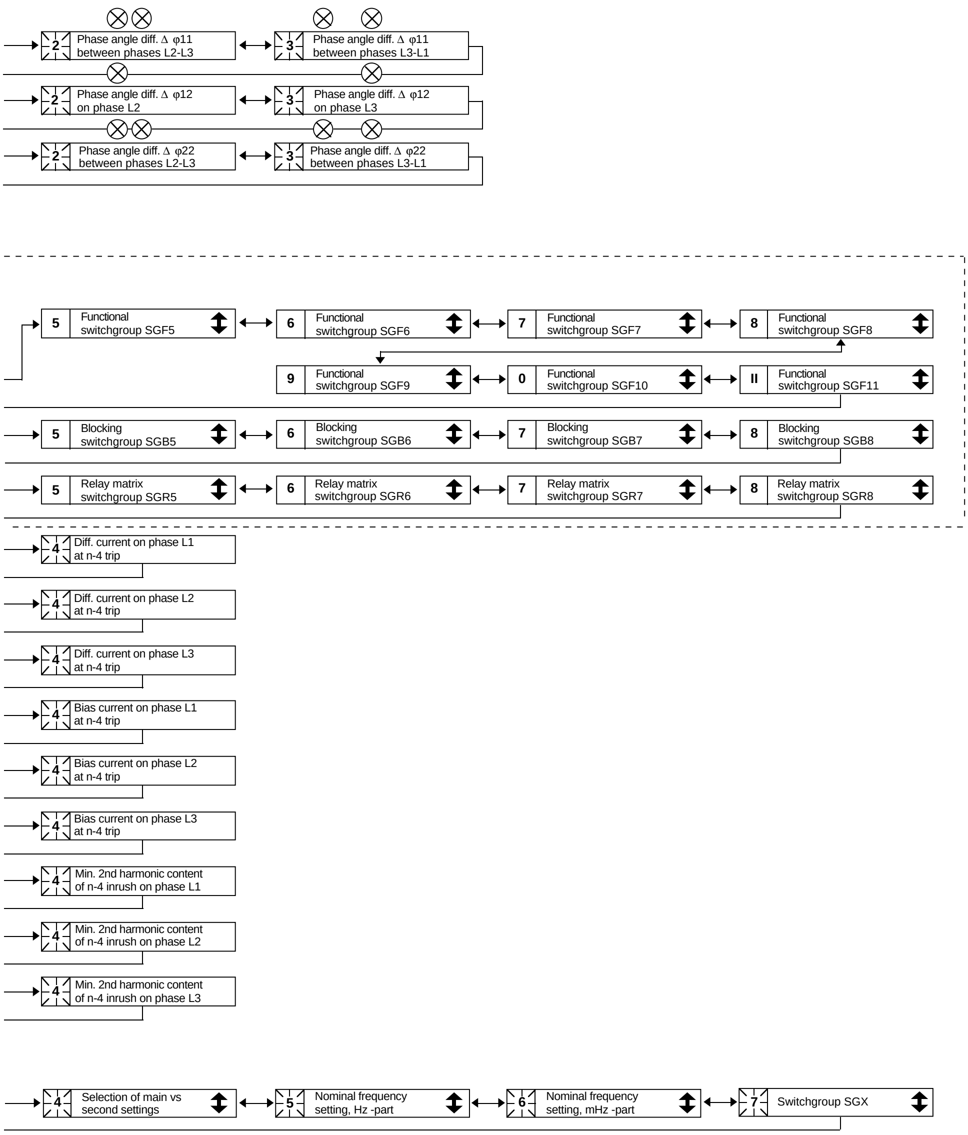


Fig. 11. Main menus and submenus for settings and registers of differential relay module SPCD 3D53.

The procedure for entering a submenu or a setting mode and for configuring the module is described in detail in the manual 34 SPC 3 ENG "General characteristics of D-type SPC relay modules. Below a simplified instruction.

Desirde step or function	Push-button	Action
One step forward in main or submenu	STEP	Press for more than 0.5 s
Rapid browse forward in main menu	STEP	Keep depressed
One step backwards in main or submenu	STEP	Press for less than 0.5 s
Entering a submenu from the main menu	PROGRAM	Press for 1 s (activated when push-button is released)
Entering or quitting a setting mode	PROGRAM	Press for 5 s
Increasing a value in the setting mode	STEP	
Moving the cursor in the setting mode	PROGRAM	Press for about 1 s
Storing a setting value in the setting mode	STEP & PROGRAM	Press simultaneously
Resetting of memorized values	STEP & PROGRAM	
Resetting of latched output relays	PROGRAM	Note! Display must be dark



Testing of output relays

In the test mode, entered from the submenu of register 0, it is possible to activate the output signals of the relay one by one.

When the PROGRAM push-button is pressed for about five seconds the three digits to the right start flashing as an indication of the relay module being in the test mode. Initially, the self-supervision output is tested. The LEDs in front of the settings show the output signals to be activated at the moment. The desired output signal is selected by pressing PROGRAM for about one second.

The setting LEDs on the front panel and their respective output signals are as follows:

No LED	Self-supervision IRF
Setting P/I_n (%)	Operation of stabilized stage 3ΔI>
Setting S (%)	Operation of instantaneous stage 3ΔI>>
Setting I_{2tp}/I_n	Internal blocking I_{df2}/I_{d1f}> or I_{d5f}/I_{d1f}>
Setting I_d/I_n>>	External control signal BS1
Setting I_{d2f}/I_{d1f}> (%)	External control signal BS2
Setting I_{d5f}/I_{d1f}> (%)	External control signal BS3
Setting I_1/I_n	External control signal BS4
Setting I_2/I_n	External control signal BS5

Pressing the push-buttons STEP and PROGRAM simultaneously activates the selected output signal, which remains active as long as the push-buttons are being pressed. The effect on the functions of the output relays depends on the settings of the switchgroups SGR1...SGR8.

When the push-button STEP is being pressed in the test mode, the self-supervision output relay operates in about 1 second and remains operated until the push-button is reset. Return to the main menu is possible at any stage of the test sequence by pressing the PROGRAM push-button for about five seconds.

The signals are selected in the sequence illustrated in the Fig. 12.

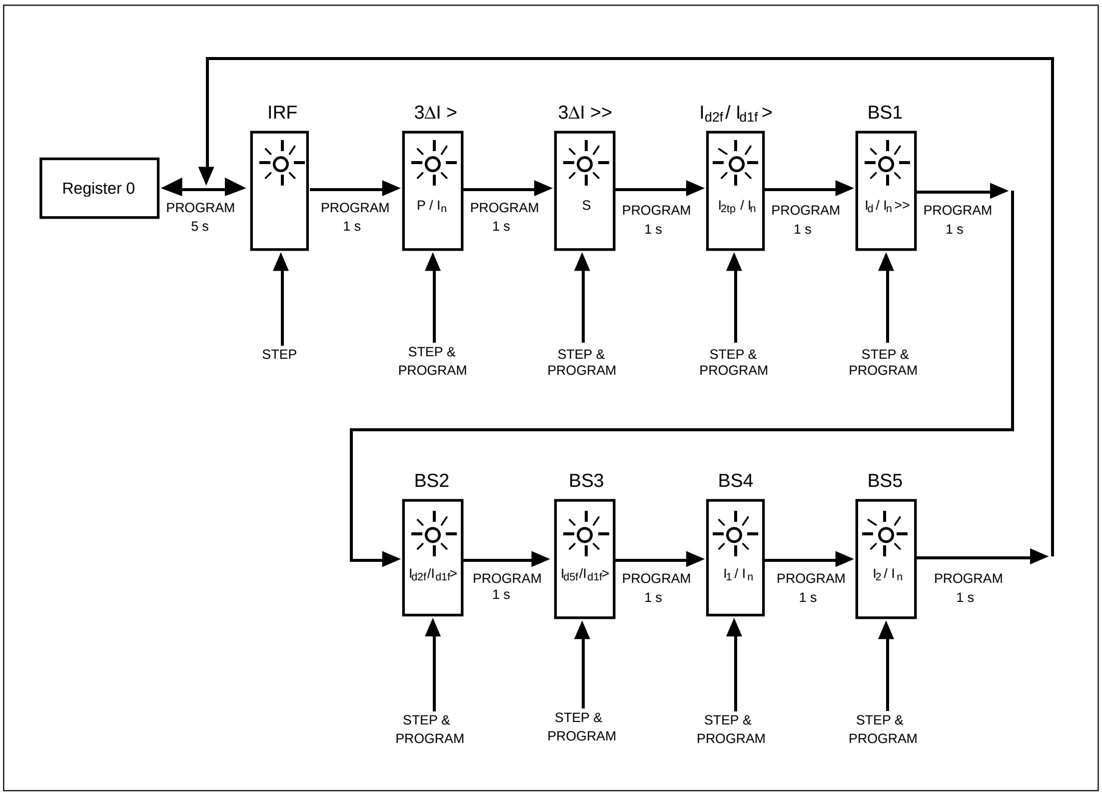


Fig. 12. Sequence for selecting output signals during testing of the output relay control functions.

Technical data

Selectable rated frequency f_n	$16^2/_3$...60 Hz
CT ratio correction range on power transformer HV side I_1/I_n	0.40...1.50
CT ratio correction range on power transformer LV side I_2/I_n	0.40...1.50

Stabilized differential current stage 3ΔI>

Basic setting P/I_n	5...50%
Starting ratio setting S	10...50%
Second turning point I_{2tp}/I_n of characteristic curve	1.0...3.0
Harmonics blocking ratio I_{d2f}/I_{d1f}>	7...20%
Harmonics blocking ratio I_{d5f}/I_{d1f}>	10...50%
Harmonics deblocking ratio I_{d5f}/I_{d1f}>>	10...50%
Operate time (including heavy-duty output relays)	
- at currents 1.5…4 x operate value	< 50 ms
- at currents above 4 x operate value	< 45 ms
Operation accuracy	±4% of set value or ±2% x I_n

Instantaneous differential current stage 3ΔI>>

Setting range I_d/I_n>>	5...30
Operate time (including heavy-duty output relays)	
- at currents in the range 1.1...2.6 x I_d/I_n>>	< 35 ms
- at currents above 2.6 x I_d/I_n>>	< 30 ms
Operation accuracy	±4% of set value or ±2% x I_n
Circuit breaker failure protection	
Operate time	0.1...1.0 s

Integrated disturbance recorder

Recording length	38 cycles
Recording memory capacity	1 recording = 38 cycles
Sampling frequency	40 samples/cycle
Signals to be recorded	6 analog signals
	11 digital signals
Triggering	
- when the selected digital signal	is activated
- when the selected digital signal	resets
Length of recording preceding triggering	0...38 cycles

Note!
Operate times are valid at rated frequency 50 Hz and 60 Hz.

Serial communication parameters

Event codes

Special codes have been specified to represent different events such as operation and blocking of protection stages, activation of control and output signals, etc. These event codes can be transferred to higher-level systems over the serial bus.

The event mask V155 is available on the channels 0, 1, 2 and 3 so that the event mask 0V155 is shared by all phases and the event masks 1V155, 2V155 and 3V155 represent events on the respective phases L1, L2 and L3.

In channel 0 operation or signal activation of one phase alone is enough to cause an event. A condition for resetting, on the other hand, is that the operations or signal activations of all phases have reset.

An event to be included in event reporting is marked with 1. The event mask is obtained by adding the weighting factors of the events included, see the tables below.

Event mask	Codes	Setting range	Default
0V155	E1...E10	0...1023	5
1V155	E1...E8	0...255	5
2V155	E1...E8	0...255	5
3V155	E1...E8	0...255	5
V156	E11...E20	0...1023	0
V157	E21...E28	0...255	12
V158	E29...E36	0...255	0

Channel	Code	Event	Number of event	Default
0	E1	Operation of stage 3ΔI>	1	1
0	E2	Operation of stage 3ΔI> reset	2	0
0	E3	Operation of stage 3ΔI>>	4	1
0	E4	Operation of stage 3ΔI>> reset	8	0
0	E5	$I_{d2f}/I_{d1f}>$ blocking activated	16	0
0	E6	$I_{d2f}/I_{d1f}>$ blocking reset	32	0
0	E7	$I_{d5f}/I_{d1f}>$ blocking activated	64	0
0	E8	$I_{d5f}/I_{d1f}>$ blocking reset	128	0
0	E9	Circuit breaker failure protection operated	256	0
0	E10	Circuit breaker failure protection reset	512	0
		Default of event mask V155		5
1...3	E1	Stage 3ΔI> operated on phase L1...L3	1	1
1...3	E2	Operation of stage 3ΔI> reset on phase L1...L3	2	0
1...3	E3	Stage 3ΔI>> operated on phase L1...L3	4	1
1...3	E4	Operation of stage 3ΔI>> reset on phase L1...L3	8	0
1...3	E5	$I_{d2f}/I_{d1f}>$ blocking activated on phase L1...L3	16	0
1...3	E6	$I_{d2f}/I_{d1f}>$ blocking reset on phase L1...L3	32	0
1...3	E7	$I_{d5f}/I_{d1f}>$ blocking activated on phase L1...L3	64	0
1...3	E8	$I_{d5f}/I_{d1f}>$ blocking reset on phase L1...L3	128	0
		Default of event masks 1...3 V155		5

Channel	Code	Event	Number of event	Default
0	E11	Control signal BS1 activated	1	0
0	E12	Control signal BS1 reset	2	0
0	E13	Control signal BS2 activated	4	0
0	E14	Control signal BS2 reset	8	0
0	E15	Control signal BS3 activated	16	0
0	E16	Control signal BS3 reset	32	0
0	E17	Control signal BS4 activated	64	0
0	E18	Control signal BS4 reset	128	0
0	E19	Control signal BS5 activated	256	0
0	E20	Control signal BS5 reset	512	0
		Default of event mask V156		0
0	E21	Output signal SS1 activated	1	0
0	E22	Output signal SS1 reset	2	0
0	E23	Output signal TS1 activated	4	1
0	E24	Output signal TS1 reset	8	1
0	E25	Output signal SS2 activated	16	0
0	E26	Output signal SS2 reset	32	0
0	E27	Output signal TS2 activated	64	0
0	E28	Output signal TS2 reset	128	0
		Default of event mask V157		12
0	E29	Output signal SS3 activated	1	0
0	E30	Output signal SS3 reset	2	0
0	E31	Output signal TS3 activated	4	0
0	E32	Output signal TS3 reset	8	0
0	E33	Output signal SS4 activated	16	0
0	E34	Output signal SS4 reset	32	0
0	E35	Output signal TS4 activated	64	0
0	E36	Output signal TS4 reset	128	0
		Default of event mask V158		0
	E50	Restarting of microprocessor		
	E51	Overflow of event register		
	E52	Temporary interference in data communication		
	E53	The relay module does not respond over the data bus.		
	E54	The module responds again over the data bus		

The event codes E50...E54 and the events represented by these cannot be excluded from reporting. The capacity of the event register is 60 events.

The event codes E52...E54 are generated by the control data communicator (e.g. SRIO 1000M).

Data to be transferred over the serial bus

In addition to event codes input data (I data), output data O data), setting values (S data) memorized data (V data), and some other data can be read from the module over the serial bus. The setting of parameters marked with the letter W can be changed over the SPA bus.

When a setting value is to be changed, either via the push-buttons on the front panel or over the serial bus, the relay module checks whether the given parameter value is legal. Values outside the permitted setting range are not memorized by the relay module, but the previous setting remains in memory.

Changing a setting parameter over the serial bus requires a password in the range 1...999. The default setting of the password is 1.

The password is opened by giving the serial communication parameter V160 the desired numerical value. Parameter V161 is used for closing the password. The password is also closed by failures in the voltage supply.

The push-buttons of the relay module or a command over the serial bus can be used to change the password. To be able to change the password over the serial bus, it first has to be opened. The new password is entered by means of parameter V161. When the push-buttons are used, the new password is written in the place of the old one in subregister 3 of register A.

Should the wrong password be given 7 successive times, it turns into a zero, and after that it is no longer possible to open it over the serial bus. Then the password can be given a new numerical value via the push-buttons.

R = data to be read from the module
W = data to be written to the module
(P) = writing allowed through a password

Input data

The parameters I1...I28 are readable parameters (R).

Measured data	Parameter	Values
Current on HV side phase L1	I1	0.00...65.5 (x I_n)
Current on HV side phase L2	I2	0.00...65.5 (x I_n)
Current on HV side phase L3	I3	0.00...65.5 (x I_n)
Differential current of phase L1	I4	0.00...65.5 (x I_n)
Differential current of phase L2	I5	0.00...65.5 (x I_n)
Differential current of phase L3	I6	0.00...65.5 (x I_n)
Current on LV side phase L1	I7	0.00...65.5 (x I_n)
Current on LV side phase L2	I8	0.00...65.5 (x I_n)
Current on LV side phase L3	I9	0.00...65.5 (x I_n)
Current on HV side phase L1 as a percentage of the rated current	I10	0.0...6554 (% I_n)
Current on HV side phase L2 as a percentage of the rated current	I11	0.0...6554 (% I_n)
Current on HV side phase L3 as a percentage of the rated current	I12	0.0...6554 (% I_n)
Differential current of phase L1 as a percentage of the rated current	I13	0.0...6554 (% I_n)
Differential current of phase L2 as a percentage of the rated current	I14	0.0...6554 (% I_n)
Differential current of phase L3 as a percentage of the rated current	I15	0.0...6554 (% I_n)
Current on LV side phase L1 as a percentage of the rated current	I16	0.0...6554 (% I_n)
Current on LV side phase L2 as a percentage of the rated current	I17	0.0...6554 (% I_n)
Current on LV side phase L3 as a percentage of the rated current	I18	0.0...6554 (% I_n)
Status data of control signals BS1...5 and BS INT1...3	I19	0...255, see table in "Recorded inform.."
Phase difference of the currents on HV side phases L1 and L2	I20	0...359 degrees
Phase difference of the currents on HV side phases L2 and L3	I21	0...359 degrees
Phase difference of the currents on HV side phases L3 and L1	I22	0...359 degrees
Phase difference of HV and LV side phase currents on phase L1	I23	0...359 degrees
Phase difference of HV and LV side phase currents on phase L2	I24	0...359 degrees
Phase difference of HV and LV side phase currents on phase L3	I25	0...359 degrees
Phase difference of the currents on LV side phases L1 and L2	I26	0...359 degrees
Phase difference of the currents on LV side phases L2 and L3	I27	0...359 degrees
Phase difference of the currents on LV side phases L3 and L1	I28	0...359 degrees

Output data

The actual status data provide information about the current status of the signals at the moment. The operations stored in the memory indicate those signal activations which has taken place after the latest reset of the registers. When the value is 0, the signal is not activated and when the value is 1, the signal is activated.

Status data of protection stages and control signals

Protection stage/ signal	Actual status data (R)	Memorized events (R)	Values
3ΔI>, operate signal	O1	O21	0 or 1
3ΔI>>, operate signal	O2	O22	0 or 1
Internal blocking signal $I_{d2f}/I_{d1f}>$ or $I_{d5f}/I_{d1f}>$	O3	O23	0 or 1
Output relay controlled			
by control signal BS1	O4	O24	0 or 1
by control signal BS2	O5	O25	0 or 1
by control signal BS3	O6	O26	0 or 1
by control signal BS4	O7	O27	0 or 1
by control signal BS5	O8	O28	0 or 1
Trip signal of CBFP	O9	O29	0 or 1

Signal activations

Output signal	Actual status data (R,W,P)	Memorized events (R)	Values
Output signal SS1	O10	O30	0 or 1
Output signal TS1	O11	O31	0 or 1
Output signal SS2	O12	O32	0 or 1
Output signal TS2	O13	O33	0 or 1
Output signal SS3	O14	O34	0 or 1
Output signal TS3	O15	O35	0 or 1
Output signal SS4	O16	O36	0 or 1
Output signal TS4	O17	O37	0 or 1
Enable signal for remote control of output signals	O41		0 or 1

The parameters V11...V59 can be used to read (R) the latest five values stored in the registers. Event n = the most recent value recorded, event n-1 = the value before that, and so on. The registers are described in detail in the paragraph "Recorded information".

Value measured	Event					Measuring range
	n	n-1	n-2	n-3	n-4	
Differential current on phase L1	V11	V21	V31	V41	V51	0...65.5 x I_n
Differential current on phase L2	V12	V22	V32	V42	V52	0...65.5 x I_n
Differential current on phase L3	V13	V23	V33	V43	V53	0...65.5 x I_n
Stabilizing current on phase L1	V14	V24	V34	V44	V54	0...65.5 x I_n
Stabilizing current on phase L2	V15	V25	V35	V45	V55	0...65.5 x I_n
Stabilizing current on phase L3	V16	V26	V36	V46	V56	0...65.5 x I_n
Smallest ratio I_{d2f}/I_{d1f} during the latest connection inrush current on phase L1	V17	V27	V37	V47	V57	0...127%
Smallest ratio I_{d2f}/I_{d1f} during the latest connection inrush current on phase L2	V18	V28	V38	V48	V58	0...127%
Smallest ratio I_{d2f}/I_{d1f} during the latest connection inrush current on phase L3	V19	V29	V39	V49	V59	0...127%
Stage/phase that initiated tripping	V1					1: 3ΔI>/L1 2: 3ΔI>/L2 4: 3ΔI>/L3 8:3ΔI>>/L1 16:3ΔI>>/L2 32:3ΔI>>/L3

Setting values

Setting	Actual values (R)	Main setting values (R,W,P)	Second setting values (R,W,P)	Setting range
Basic setting P/I_n	S1	S51	S101	5...50 (%)
Starting ratio S	S2	S52	S102	10...50 (%)
Second turning point of characteristic curve I_{2tp}/I_n	S3	S53	S103	1.0...3.0
Operate range I_d/I_n>> of instantaneous differential current stage 3ΔI>>	S4	S54	S104	5...30
Harmonics blocking ratio $I_{d2f}/I_{d1f>}$	S5	S55	S105	7...20 (%)
Harmonics blocking ratio $I_{d5f}/I_{d1f>}$	S6	S56	S106	10...50 (%)
Harmonics deblocking ratio $I_{d5f}/I_{d1f>>}$	S7	S57	S107	10...50 (%)
CT transforming ratio correction range on power transformer HV side	S8	S58	S108	0.40...1.50 (x I_n)
CT transforming ratio correction range on power transformer LV side	S9	S59	S109	0.40...1.50 (x I_n)
Reserved	S10	S60	S110	50 (% I_n)
Checksum, SGF1	S11	S61	S111	0...255
Checksum, SGF2	S12	S62	S112	0...255
Checksum, SGF3	S13	S63	S113	0...255
Checksum, SGF4	S14	S64	S114	0...255
Checksum, SGF5	S15	S65	S115	0...255
Checksum, SGF6	S16	S66	S116	0...255
Checksum, SGF7	S17	S67	S117	0...255
Checksum, SGF8	S18	S68	S118	0...255
Checksum, SGF9	S19	S69	S119	0...255
Checksum, SGF10	S20	S70	S120	0...255
Checksum, SGF11	S21	S71	S121	0...255
Checksum, SGB1	S22	S72	S122	0...255
Checksum, SGB2	S23	S73	S123	0...255
Checksum, SGB3	S24	S74	S124	0...255
Checksum, SGB4	S25	S75	S125	0...255
Checksum, SGB5	S26	S76	S126	0...255
Checksum, SGB6	S27	S77	S127	0...255
Checksum, SGB7	S28	S78	S128	0...255
Checksum, SGB8	S29	S79	S129	0...255
Checksum, SGR1	S30	S80	S130	0...255
Checksum, SGR2	S31	S81	S131	0...255
Checksum, SGR3	S32	S82	S132	0...255
Checksum, SGR4	S33	S83	S133	0...255
Checksum, SGR5	S34	S84	S134	0...255
Checksum, SGR6	S35	S85	S135	0...255
Checksum, SGR7	S36	S86	S136	0...255
Checksum, SGR8	S37	S87	S137	0...255

Control parameters

Data	Code	Data direction	Values
Resetting of front panel operation indicators and latched output relay	V101	W	1 = resetting
Resetting of front panel operation indicators, output relays registers and disturbance recording memory	V102	W	1 = resetting
Remote control of settings	V150	R,W	0 = main settings active 1 = second settings active
Switchgroup SGX	V152	R,W,P	0...1
Event masks for differential protection	V155	R,W	0...1023, see "Event codes"
Event masks for differential protection on phase L1	1V155	R,W	0...255, see "Event codes"
Event masks for differential protection on phase L2	2V155	R,W	0...255, see "Event codes"
Event masks for differential protection on phase L3	3V155	R,W	0..255, see "Event codes"
Event mask for external control signals	V156	R,W	0...255, see "Event codes"
Event mask for output signals	V157	R,W	0...255, see "Event codes"
Event mask for output signals	V158	R,W	0...255, see "Event codes"
Opening of password for remote setting	V160	W	1...999
Changing and closing the password for remote setting	V161	W(P)	0...999
Activation of self-supervision input	V165	W	1 = self-supervision input is activated and IRF LED is lit
EEPROM formatting	V167	W(P)	2 = formatting
Error code	V169	R	0...255
Rated frequency, Hz setting	V180	R,W,P	10...60 (Hz)
Rated frequency, mHz setting	V181	R,W,P	0...999 (mHz)
Address of relay module	V200	R,W	1...254
Data transfer rate	V201	R,W	4.8, 9.6, 19.2, 38.4 kBd
Programme version symbol	V205	R	187 A

Data	Code	Data direction	Values
Selection of internal signals to be used for triggering the disturbance recorder	V241	R,W	0...255

Internal signal	Function	Number representing function
3ΔI>	Used for triggering	1
	Not used for triggering	0
3ΔI>>	Used for triggering	2
	Not used for triggering	0
I_{d2f}/I_{d1f} blocking	Used for triggering	4
	Not used for triggering	0
I_{d5f}/I_{d1f} blocking	Used for triggering	8
	Not used for triggering	0
Factory setting V241		3

Data	Code	Data direction	Values
Selection of method for triggering the disturbance recorder	V242	R,W	0...255

Internal signal	Triggering	Number representing triggering point
3ΔI>	By falling edge	1
	By rising edge	0
3ΔI>>	By falling edge	2
	By rising edge	0
I_{d2f}/I_{d1f} blocking	By falling edge	4
	By rising edge	0
I_{d5f}/I_{d1f} blocking	By falling edge	8
	By rising edge	0
Factory setting V242		0

Data	Code	Data direction	Values
Selection of control signals to be used for triggering the disturbance recorder	V243	R,W	0...255

Control signal	Function	Number representing function
BS1	Used for triggering	1
	Not used for triggering	0
BS2	Used for triggering	2
	Not used for triggering	0
BS3	Used for triggering	4
	Not used for triggering	0
BS4	Used for triggering	8
	Not used for triggering	0
BS5	Used for triggering	16
	Not used for triggering	0
BS INT1	Used for triggering	32
	Not used for triggering	0
BS INT2	Used for triggering	64
	Not used for triggering	0
BS INT3	Used for triggering	128
	Not used for triggering	0
Factory setting V243		0

Data	Code	Data direction	Values
Selection of method for triggering the disturbance recorder	V244	R,W	0...255

Internal signal	Triggering	Number of triggering point
BS1	By falling edge	1
	By rising edge	0
BS2	By falling edge	2
	By rising edge	0
BS3	By falling edge	4
	By rising edge	0
BS4	By falling edge	8
	By rising edge	0
BS5	By falling edge	16
	By rising edge	0
BS INT1	By falling edge	32
	By rising edge	0
BS INT2	By falling edge	64
	By rising edge	0
BS INT3	By falling edge	128
	By rising edge	0
Factory setting V244		0

Data	Code	Data direction	Values
Length of recording following disturbance recorder triggering, in cycles	V245	R,W	0...38 Factory setting V245 = 5
Status/command register of recording	V246	R	0 = recording not triggered, i.e. the memory is empty 1 = recording triggered and recording memory is full
		W	0 = reset recording memory 1 = no function (NOP)
Reading of event register	L	R	Time, channel number (unless zero) and event code
Re-reading of event register	B	R	Time, channel number (unless zero) and event code
Type designation of relay module	F	R	SPCD 3D53
Reading of module status data	C	R	0 = normal status 1 = module 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
Time reading or setting	T	R,W	00.000...59.999 s
Date and time reading and setting	D	R,W	YY-MM-DD HH.MM;SS.mss

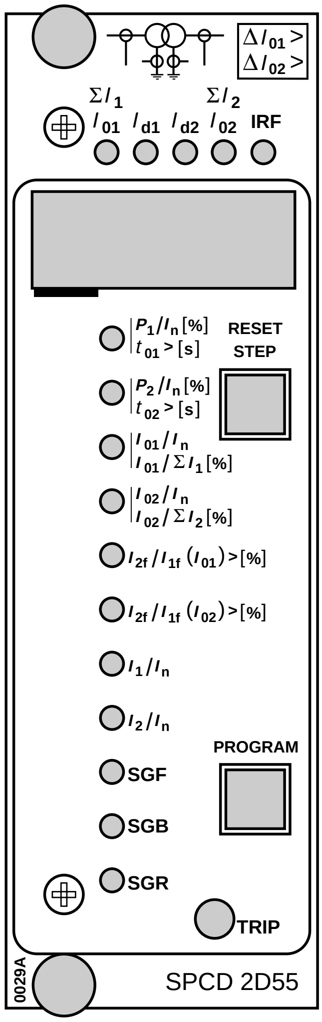
The event register can be read by the L command only once. Should a fault occur, say, in the data transfer, the B command can be used to re-read the contents of the register. When required, the B command can be repeated. In general, the control data communicator SRIO 1000M reads the event data and forwards the information to an output device. Under normal conditions the event register of the relay module is empty. The control data communicator also resets abnormal status data, so this data is normally zero.

Fault codes

1	Auxiliary voltage interrupted
4	Faulty trip relay path, TS1, or missing output relay card
5	Faulty trip relay path, TS2, or missing output relay card
6	Faulty trip relay path, TS3, or missing output relay card
7	Faulty trip relay path, TS4, or missing output relay card
20	The module has restarted, although no fault was detected by the self-supervision system.
21	The module has restarted more than 10 times, although no fault was detected by the self-supervision system.
23	Error during start-up of DSP
24	DSP halted due to unknown error
29	DSP code memory area checksum
30	Faulty program memory (EPROM)
49	DSP internal RAM faulty
50	MCU internal RAM faulty
51	Parameter memory (EEPROM) block 1 faulty
52	Parameter memory (EEPROM) block 2 faulty
53	Parameter memory (EEPROM) block 1 and block 2 faulty
54	Parameter memory (EEPROM) block 1 and block 2 faulty, different checksums
55	Faulty parameter area in RAM
56	Parameter memory (EEPROM) key fault. Parameter memory not formatted.
57	Gain/channel correction value checksum
58	Active setting bank checksum
59	DSP external RAM faulty
60	MCU external RAM faulty
100	DSP overloaded
195	The analog supply voltage measured is too low (rated voltage -12 V)
196	The analog supply voltage measured is too low (rated voltage +12 V)
203	The analog supply voltage measured is too high (rated voltage -12 V)
204	The analog supply voltage measured is too high (rated voltage +12 V)
252	Input filter faulty
253	A/D converter faulty
254	DSP does not interrupt

SPCD 2D55
Earth-fault relay module

User´s manual and Technical description



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SPCD 2D55
Earth-fault relay module

Contents

Features

Earth-fault relay module for the earth-fault protection of two-winding power transformers

Provides protection for both HV and LV side windings

The earth-fault protection can be implemented by four principles: the high-impedance principle, the numerical stabilized differential current principle, the residual overcurrent principle, or the neutral overcurrent principle

The earth-fault protection principles to be used on the HV side and the LV side are independent of each other

The relay module is entirely numerical - the fundamental component of the currents are used for calculating the residual current of the phase currents, the neutral current and the differential and stabilizing currents. The DC component and the harmonics of the currents are digitally filtered.

Separately adjustable basic setting and operate time for HV and LV side

High immunity to electrical and electromagnetic interference allows the relay to be used in severe environments

Stabilized against transformer inrush currents and faults outside the protected area

Blocking based on the ratio between the second harmonic and the fundamental frequency component of the neutral current prevents operation at transformer connection inrush currents

Display of measured, set and recorded values

Writing and reading of setting values via local display and front panel push-buttons, a PC with configuration software, or from higher system levels over the serial port and optical fibres.

Five programmable external control inputs

Output relay matrix allowing the operate and control signals to be linked to the desired output relay

Integrated circuit breaker failure protection

Integrated disturbance recorder capable of recording six phase currents, two neutral currents, the internal start and blocking signals, and the control signals linked to the relay

High immunity to electrical and electromagnetic interference allows the relay to be used in severe environments

Dynamic measuring functions

High availability - the integrated self-supervision system monitors the operation of the electronics and the software and gives an alarm signal in the event of a fault.

Description of function

The earth-fault relay measures the HV and LV side phase currents and neutral currents of the transformer. Four alternative principles can be used for implementing the HV side and LV side earth-fault protection of the transformer to be protected:

- the stabilized differential current principle (low-impedance type protection)
- the residual overcurrent principle
- the neutral overcurrent principle
- the high-impedance principle

The protection principle to be used depends on the connection of the windings of the power transformer and on the requirements for the earth-fault protection.

The stabilized differential current principle, the residual overcurrent principle and the neutral overcurrent principle are based on the fundamental frequency components of the currents measured. The fundamental frequency components are digitally filtered in the relay module. The high-impedance principle is based on the instantaneous peak values of the measured current.

The switches SGF1/1...8 are used to select the desired protection principle. The protection stages of the HV side and the LV side operate quite independently of each other, so the protection principle used on the HV side can be the same as that used on the LV side, or another. At the same time, however, one protection principle only can be used on one or the other side of the transformer.

Rated frequency

The earth-fault relay module can be used in the frequency range 16 $^2/_3$....60 Hz. The rated frequency setting is accurate to within 1 mHz. Two settings are available, i.e. Hz and mHz, which are separately set from 16.667 Hz up to 60 Hz.

The frequency is selected with the push-buttons on the front panel, via subregister 5 and 6 in register A, or over the serial bus, in which case the parameters V180 and V181 are used.

Stabilized differential current principle

The numerical stabilized differential current principle is selected for the earth-fault protection on the HV side and on the LV side with the settings SGF1/1 = 1 and SGF1/5 = 1, respectively. No external stabilizing resistor or non-linear resistor is required.

Operation according to the differential current principle is based on comparing the amplitude and phase difference between the sum of the fundamental frequency zero-sequence currents of the phase currents (ΣI) and the fundamental frequency component of the neutral current (I_0) flowing in the conductor between the transformer neutral point and earth. The differential current I_d is calculated as the absolute value of the difference between the residual current (i.e. the sum of the zero-sequence currents in the phases) and the neutral current.

$$I_d = \left| \Sigma I - I_0 \right| \qquad (1)$$

An earth fault occurring in the protected area (that is, between the phase CTs and the neutral connection CT) will cause differential current. In addition, the direction of the residual current and the neutral current and also the ratio of the neutral current and the residual current ($I_0/\Sigma I$) on the side to be protected have to be considered in order to maintain selectivity.

During an earth fault in the protected area the currents $\Sigma 1$ and I_0 are directed towards the protected area. The calculation of the directional differential current $I_d\cos\varphi$ is based on the differential current I_d and the angle between the residual current and the neutral current. $\cos\varphi$ is specified to be 1, when the phase difference of the residual current and the neutral current is 180°, that is, when the currents are in opposite direction at earth faults within the protected area. $\cos\varphi$ is specified to be 0, when the phase difference between the residual current and the neutral current is less than 90° in situations with no earth fault in the protected area. Thus tripping is possible when the phase difference between the residual current and the neutral current is above 90°.

The stabilizing current I_b used with the stabilizing differential current principle is calculated as an average of the phase currents on the side of the winding to be protected:

$$I_b = \frac{|I_{L1}| + |I_{L2}| + |I_{L3}|}{3} \qquad (2)$$

The basic settings P_1/I_n and P_2/I_n are used for setting the characteristic of the stabilized differential current principle. The differential current value P_1/I_n or P_2/I_n required for tripping is constant at the stabilizing current values I_b/I_n = 0...1. When the stabilizing current is higher than the rated current, the slope of the operation characteristic is constantly 50% as shown in Fig. 1. That means that the relationship between the change in the directional differential current $\Delta I_d\cos\varphi$ and the change in the stabilizing current ΔI_b is constant.

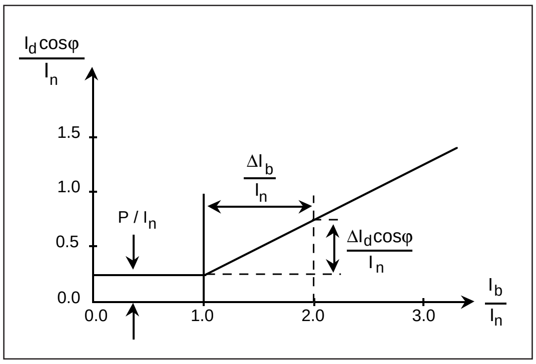


Fig. 1. Operation characteristic for the stabilized differential current principle of the earth-fault relay module SPCD 2D55

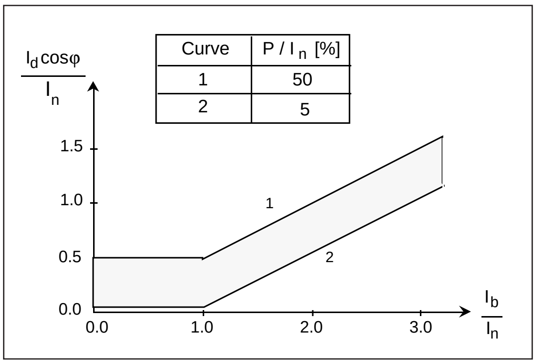


Fig. 2. Setting range of the operation characteristic for the stabilized differential current principle of the earth-fault relay module SPCD 2D55

To be able to calculate the directional differential current $I_d\cos\varphi$ the amplitude of the fundamental frequency component of both the residual current of the phase currents and the neutral current has to be above 4% of the rated current. Should one condition only be fulfilled, $\cos\varphi = 1$.

The relay module has a separate setting that takes into account the distribution of the earth-fault current between the star-point of the transformer and the network on the side to be protected. The ratio of the neutral current and the residual current of the phase currents must be greater than the setting $I_{01}/\Sigma I_1$ on the HV side and the setting $I_{02}/\Sigma I_2$ on the LV side to allow the protection stage on the concerned side to start. The setting range of the ratio is 0...20%. When the setting $I_{01}/\Sigma I_1$ (or $I_{02}/\Sigma I_2$) is more than 0%, the minimum value of the neutral current of that side required for tripping is 2% x I_n.

So, the protection stage starts provided the following conditions are fulfilled at the same time on the side to be protected:

- the ratio of the neutral current and the residual current of the phase currents exceeds the setting $I_{01}/\Sigma I_1$ on the HV side and the setting $I_{02}/\Sigma I_2$ on the LV side
- the directional differential current exceeds the value of the operation characteristic (the phase difference between the residual current of the phase currents and the neutral current has to be greater than 90°)
- the blocking based on the second harmonic of the neutral current I_{01} or I_{02} of the concerned side does not prevent starting.

Should the CT secondary currents deviate from the rated current of the protected transformer at rated load, the relay module allows the transformation ratios of the neutral connection CTs and the phase CTs to be corrected. The transformation ratio corrections can be made both on the HV and LV side by selecting a value for the front panel settings I_{01}/I_n and I_{02}/I_n, and I_1/I_n and I_2/I_n in the range 0.40...1.50 x I_n. The default setting is 1.00.

The influence of the connection of the phase current transformers and the neutral connection CT on the operation of the stabilized differential current principle is determined by the setting of the switches SGF2/1...2.

Residual overcurrent principle and neutral current principle

Should the transformer have no star point, the star point be unearthed or no neutral current be available, the residual overcurrent principle can be employed for the protection against earth-fault. The sum of the zero-sequence currents in the phases is calculated inside the relay module on the basis of the phase currents linked to the relay. The overcurrent principle is used on the HV side, when SGF1/2 = 1, and on the LV side, when SGF1/6 = 1. The protection stage starts when the amplitude of the fundamental frequency component of the residual current exceeds the basic setting P_1/I_n or P_2/I_n. When the residual current ΣI_1 or ΣI_2 is calculated from the phase currents inside the relay module the blocking based on the second harmonic of the neutral current cannot be used.

The residual current of the phase currents can also be formed via an external connection by connecting the neutral terminals of the windings of the relay's phase current matching transformers to the 5 A or 1 A terminal of the neutral current matching transformer I_{01} or I_{02}. Naturally, it is also possible to connect the neutral current of the neutral connection current transformer to the terminals, and use the neutral overcurrent principle. When external summing of the phase currents or the neutral current principle is used on the HV side, the switch SGF1/3 has to be in position 1.When external summing of the phase currents or the neutral current principle is used on the LV side, the switch SGF1/7 has to be in position 1. The blocking based on the second harmonic of the neutral current can be used in combination with these types of protection.

High-impedance principle

High-impedance type protection can be applied to a star-connected winding. This type of protection employs four CTs, i.e. three phase CTs and one neutral connection CT. To be able to use the high-impedance principle an external stabilizing resistor and often also a non-linear voltage limiting resistor are required. The high-impedance principle can be used on the HV side, if SGF1/4 = 1, and on the LV side, if SGF1/8 = 1. When the high-impedance principle is used the protection stage start when the instantaneous peak value of the neutral current exceeds the basic setting P_1/I_n on the HV side or the basic setting P_2/I_n on the LV side. The blocking based on the second harmonic of the neutral current cannot be used in combination with the high-impedance principle.

Blocking based on the second harmonic of the neutral current

Blocking of the starting at power transformer connection inrush currents is based on the ratio between the second harmonic and the fundamental frequency component calculated from the neutral current I_{01} or I_{02}. The start of the protection stage is blocked, if blocking is enabled and if the ratio of the second harmonic and the fundamental frequency component exceeds the set blocking limit I_{2f}/I_{1f} (I_{01})> or I_{2f}/I_{1f} (I_{02})>.

Start inhibition based on the second harmonic can be used in combination with the switch settings SGF1/1 = 1, SGF1/3 = 1, SGF1/5 = 1, SGF1/7 = 1. The blocking is enabled by SGF2/3 on the HV side and switch SGF2/4 on the LV side. The HV side blocking does not affect the LV side protection stage and the LV side blocking does not affect the LV side protection stage.

The HV and LV side earth-fault protection principles and blocking arrangement are selected in accordance with the following tables:

HV side protection principle ΔI_{01}>	Switches SGF1/1	SGF1/2	SGF1/3	SGF1/4	Weight. value	Blocking $I_{2f}/I_{1f}(I_{01})$>
No protection	0	0	0	0	0	Not in use
Stab. diff. current principle	1	0	0	0	1	Can be used
Residual overcurrent principle	0	1	0	0	2	Not in use
Neutral current principle	0	0	1	0	4	Can be used
High-impedance principle	0	0	0	1	8	Not in use

LV side protection principle ΔI_{02}>	Switches SGF1/5	SGF1/6	SGF1/7	SGF1/8	Weight. value	Blocking $I_{2f}/I_{1f}(I_{02})$>
No protection	0	0	0	0	0	Not in use
Stab. diff. current principle	1	0	0	0	16	Can be used
Residual overcurrent principle	0	1	0	0	32	Not in use
Neutral current principle	0	0	1	0	64	Can be used
High-impedance principle	0	0	0	1	128	Not in use

Protection stages

Switchgroup SGR1 is used to link the start signals of the HV side protection stage ΔI_{01}> to the specified output relays, provided starting is not inhibited by a blocking function based on the ratio of the second harmonic and the fundamental frequency component of the neutral current. Correspondingly, switchgroup SGR4 is used to link the start signals of the LV side protection stage ΔI_{02}> to the specified relays.

The operate time can be separately set for the HV and LV side in the setting ranges t_{01}> = 0.03...100 s and t_{02}> = 0.03...100 s, respectively. When the operate time t_{01}> of the HV side protection stage ΔI_{01}> has elapsed, the stage delivers an operate signal to the output relays specified by switchgroup SGR2, provided operation is not inhibited by an external control signal or an intermodular blocking signal.

In the same way the LV side protection stage ΔI_{02}> delivers an operate signal to the output relays specified by switchgroup SGR5, provided operation is not inhibited.

The blocking of the HV side protection stage, I_{2f}/I_{1f} (I_{01})>, is routed to the output relays specified by switchgroup SGR3, provided the HV side start conditions are fulfilled. In the same way the blocking of the LV side protection stage, I_{2f}/I_{1f} (I_{02})>, is routed to the output relays specified by switchgroup SGR6, provided the LV side start conditions are fulfilled.

External control signals

Five external control signals BS1...BS5 are available to the earth-fault relay module SPCD 2D55. The control signals can be used to control the output signals or block the operation of the module (protection stages). In addition the control signals BS1, BS2 and BS3 can be used for switching between main and second settings and for resetting the operation indicator, output relays, registers and recording memory. The switches of the SGB switchgroups are used for configuring the external control signals.

Intermodular signals

The signals BS INT1, BS INT2 and BS INT3 are intermodular blocking signals which can be used to block the operation of a relay module fitted in another card location of the same protection relay. An intermodular blocking signal is activated when the corresponding blocking signal of one relay module is activated. The blocking signals BS INT1, BS INT2 and BS INT3 are not capable of controlling the output relays. Switchgroup SGB1 is used for selecting the logic active state of the external control signals and the intermodular blocking signals. So, the input can be activated when energized or when non-energized.

The signals AR1, AR2 and AR3 can be used to trigger the disturbance recorder SPCR 8C27 fitted in one of the card locations of the relay. These signals cannot be used to control the output relays.

Output signals

The switchgroups SGR1...SGR11 can be used to link the start and operate signals of the protection stages, the internal blocking signals and the external control signals BS1...BS5 to the desired output relays SS1...SS4 or TS...TS4.

The switchgroup SGF4 allows a latching feature to be selected for the output signals SS1...SS4 and TS1...TS4. When this function has been selected, the output signal remains active, even though the signal that caused the operation resets. The means of resetting the output relays are shown in the table in paragraph "Resetting".

The operation of the TRIP operation indicator on the front panel can be configured to be initiated by the activation of any TS signal. The operation indicator remains lit when the signal resets. The switchgroup SGF5 is used for the programming. The means of resetting are shown in the table in paragraph "Resetting".

Circuit-breaker failure protection

The relay module is provided with circuit-breaker failure protection (CBFP), which provides an operate signal TS1 0.1...1 s after the operate signal TS2, TS3 or TS4, unless the fault has disappeared during this time. In the range 100...440 ms the operate time can be adjusted in steps of 20 ms and in the range 440....1000 ms in steps of 40 ms. The heavy-duty output relay TS1 of the circuit-breaker failure protection can be used to operate the circuit breaker in front of the circuit breaker of the feeder of the object to be protected. The switches SGF3/1...3 are used to enable the circuit-breaker failure protection and the switches SGF3/4...8 are used for setting the operate time of the CBFP.

Second settings

Two different setting values are available for the relay: main setting values and second setting values. Switching between these two types of setting value can be done in three ways as follows:

1) Over the serial bus, using command V150
2) By means of an external control signal: BS1, BS2 or BS3
3) Via the push-buttons on the front panel of the relay module and subregister 4 of register A. Selecting the value 0 for the subregister brings the main settings into effect, whereas the value 1 activates the second settings.

The S parameters allow the main setting values and second setting values to be read and set over the serial bus. The push-buttons on the front panel can be used for reading and setting actual setting values only.

N.B. If external control signals have been used for selecting the main or second settings, it is not possible to switch between main settings and second settings via the serial bus or the push-buttons on the front panel.

Resetting

The operation indicators on the front panel of the relay module, the operation codes on the display, latched output relays, and the registers and the recording memory of the relay module can be reset in three ways: with the push-buttons on the front panel, via an external control signal or a serial communication parameter as shown in the table below.

Means of resetting	Operation indicators	Output relays	Registers & recording memory
RESET	x		
PROGRAM	x	x	
RESET & PROGRAM	x	x	x
External control signal BS1, BS2 or BS3, when			
SGB5/1...3 = 1	x		
SGB6/1...3 = 1	x	x	
SGB7/1...3 = 1	x	x	x
Parameter V101	x	x	
Parameter V102	x	x	x

Integrated disturbance recorder

The integrated disturbance recorder records the waveforms of the currents to be measured, the digital control inputs of the module and the internal signals. The module has eight analog and 12 digital channels. The memory has a capacity of one record the length of which is 30 cycles. The recording has to be downloaded before a new recording sequence can be started. The memory is also emptied when the values recorded by the module are reset. The sampling frequency of the disturbance recorder is 40 times the rated frequency of the module, which means that the sampling frequency at 50 Hz is 2000 Hz.

The recording can be triggered by the internal signals of the relay module or the control signals linked to the module. Internal signals to be recorded and available for triggering are the start signals of the HV side and LV side earth-fault protection, and the HV and LV side blocking signals. The control signals linked to the module are the signals BS1...5 and BS INT1...3. Recording can be triggered by the rising or falling edge of any (one or several) of these signals. Triggering at rising edge means that the recording sequence starts when the signal is activated. Correspondingly, triggering by falling edge means that the recording sequence starts when the active signal resets.

The serial communication parameters V241... V245 are used for configuring the disturbance recorder. Parameter V241 specifies the internal signals to be used for triggering and parameter V242 specifies whether the recording is to be started by the rising or falling edge of the signal specified by parameter V241. Parameter V243 defines the control signals to be used for triggering, and parameter V244 specifies whether the rising or falling edge of the control signal is to start the recording sequence.

Parameter V245 is used for setting the length of the recording. The number of the recording cycles following triggering is equal to the value of parameter V245. The total recording length is fixed and always about 30 cycles.

When the serial communication parameter V246 = 0, the disturbance recorder has not been triggered, i.e. the recording memory is empty. When V246 = 1, the disturbance recorder has been triggered and the memory is full. The recording memory is emptied by giving parameter V246 the value 0. The memory has to be empty before the disturbance recorder is able to start a new recording sequence. A memorized recording is indicated by the letter "d" to the right of the display, when no measured, set or recorded value is displayed.

The recorded data of the integrated disturbance recorder are downloaded, for instance, with the help of a PC program and the serial communication parameter V247.

Block schematic diagram

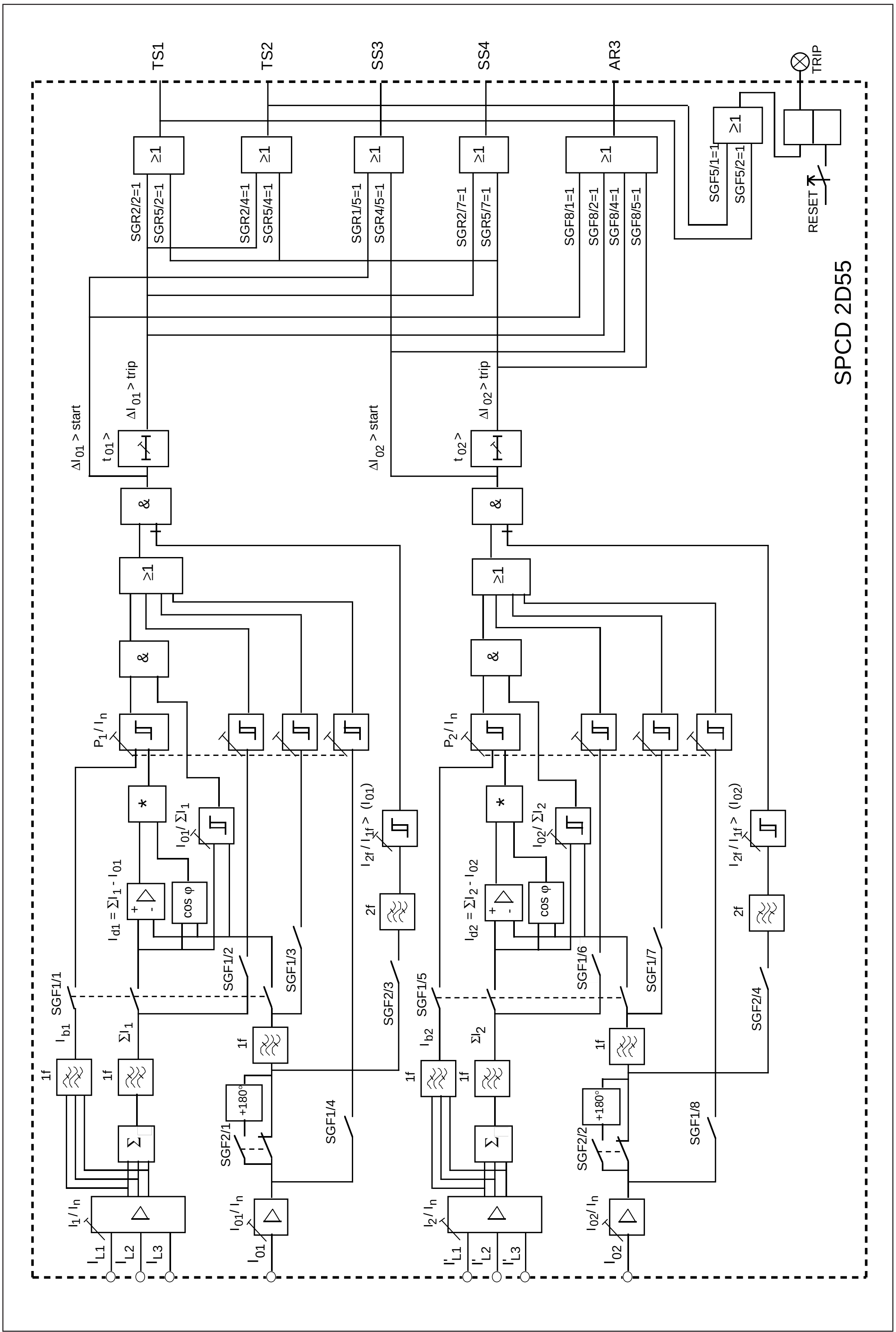


Fig. 3. Block schematic diagram for earth-fault relay module SPCD 2D55 with switchgroup default settings

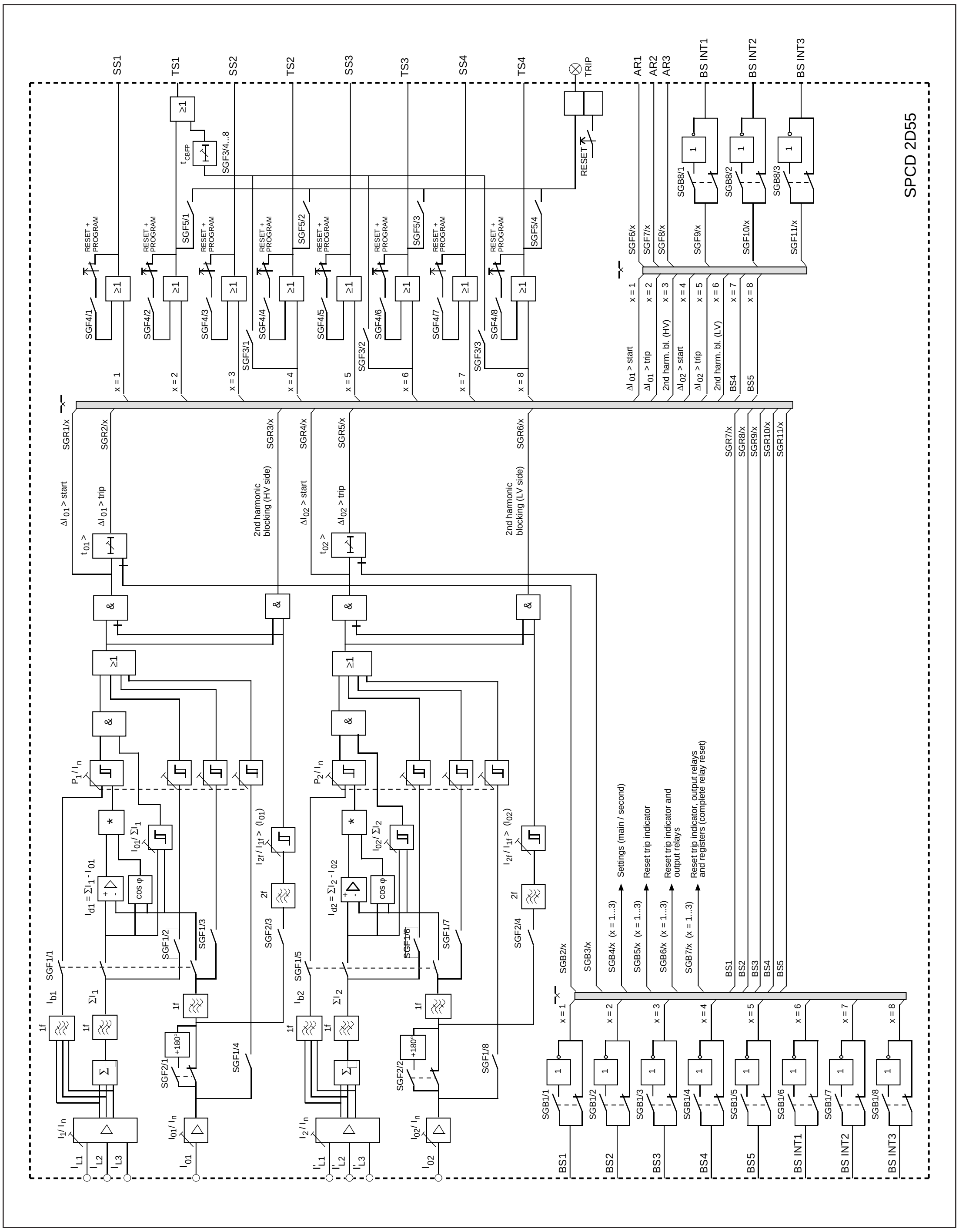


Fig. 4. Block schematic diagram for earth-fault relay module SPCD 2D55

Symbols and signal abbreviations used

I_{L1}, I_{L2}, I_{L3}	Phase currents measured on HV side
I'_{L1}, I'_{L2}, I'_{L3}	Phase currents measured on LV side
I_{01}	HV side neutral current
I_{02}	LV side neutral current
I_n	Rated current
Σ	Summing of phase currents
1f	Digital filtering of fundamental frequency component
ΣI_1	Residual current of HV side phase currents
ΣI_2	Residual current of LV side phase currents
I_{d1}	Differential current calculated as $SI_1 - I_{01}$
I_{d2}	Differential current calculated as $SI_2 - I_{02}$
$\cos\varphi$	Cosine of the phase angle between the residual current of the phase currents and neutral current
I_b	Stabilizing current used with the numerical differential current principle
2f	Digital filtering of the second harmonic component
I_{2f}	Amplitude of the second harmonic of the neutral current
I_{1f}	Amplitude of the fundamental frequency component of the neutral current
$\Delta I_{01}>$	HV side protection stage
$\Delta I_{02}>$	LV side protection stage
SGF1...SGF11	Switchgroups for configuring the functions
SGB1...SGB8	Switchgroups for configuring external control and blocking signals
SGR1...SGR11	Output relay matrix switchgroups
BS1...BS5	External control inputs
SS1...SS4	Output signals
TS1...TS4	Output signals to heavy-duty output relays
BS INT1...BS INT3	Intermodular blocking and control signals
AR1...AR3	Intermodular control signals
t_{CBFP}	Adjustable operate time for circuit-breaker failure protection

Note!
All input and output signals of the module are not necessarily wired to the terminals of every relay assembly using this module. The signals wired to the terminals are shown in the diagram illustrating the flow of signals between the plug-in modules of the relay assembly.

Front panel

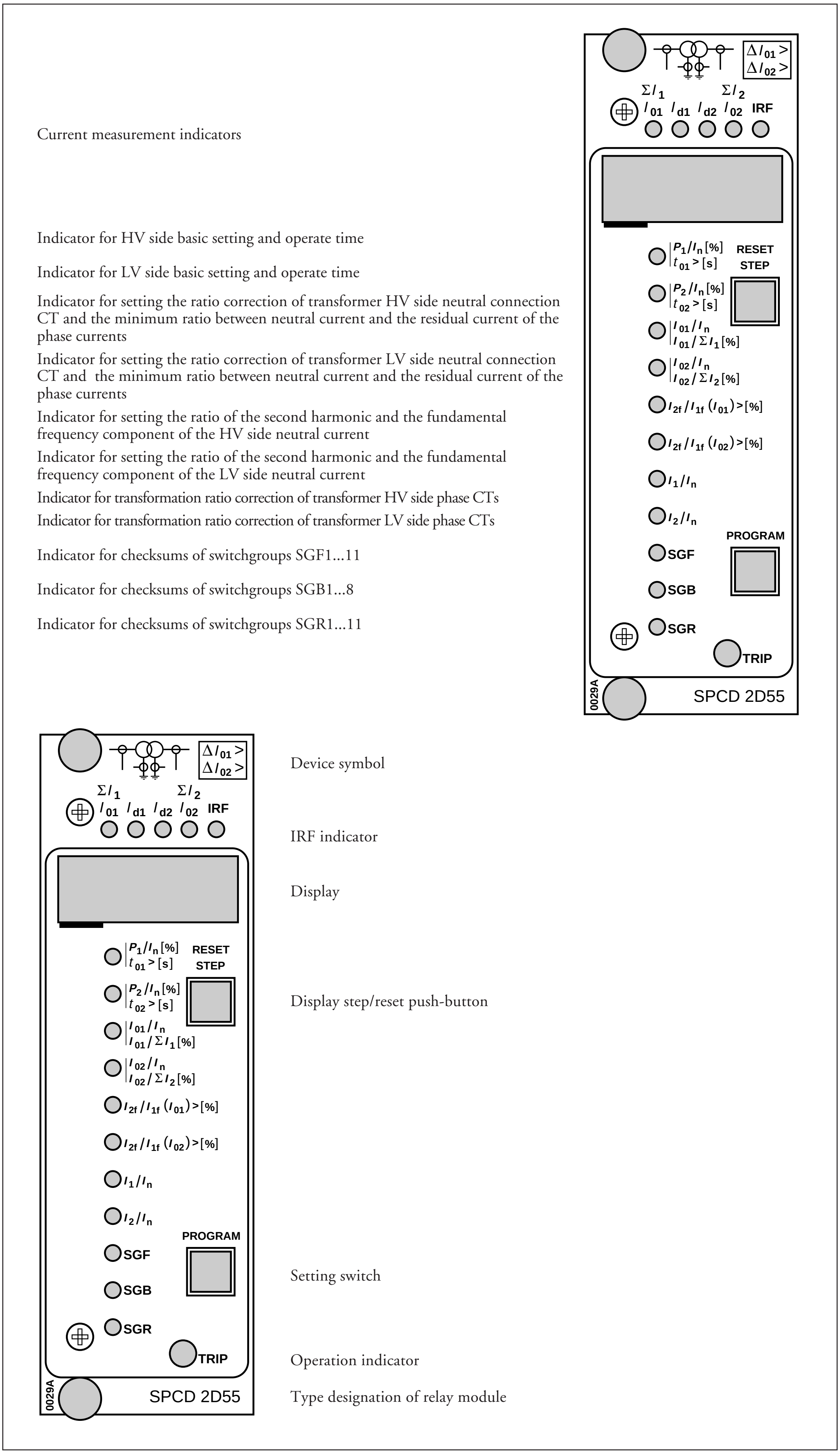


Fig. 5. Front panel for earth-fault relay module SPCD 2D55

Operation indicators

The operation indicators of the earth-fault relay module are the red operation code of the display and the TRIP indicator that indicates operation.

When the HV side protection stage $\Delta I_{01}>$ starts, the red operation code 1 is lit on the display. Operation of the stage is indicated by the code number 2. Start and operation of the LV side protection stage $\Delta I_{02}>$ are indicated by the red operation codes 4 and 5 respectively. The codes indicating start and operation remain lit until reset. Should the circuit-breaker failure protection have operated, the operation indicator A remains lit until the operation indicators are reset.

When an operate signal is issued by a HV or LV side protection stage of the earth-fault relay module the TRIP indicator is lit, provided the concerned operate signal is linked to a heavy-duty output relay TS1, TS2, TS3 or TS4 via a switch of switchgroup SGR2 or SGR5. Should the red operation code 2 or 5 be indicated on the display the TRIP indicator still being dark, the operate signal is not linked to one of the heavy-duty output relays.

Activation of the external control signals BS1... BS5 is indicated on the display by the respective red operation code 7, 8, 9, 0 or II. The operation code remains lit as long as the control signal is active. If the control signal was programmed (switchgroups SGB4...7) to be used for switching main settings into second settings or vice versa, or to reset the operation indicators, latched output relays, registers or recording memory, the activation of the control signal is not indicated on the display.

The external control signals can be linked to operate as trip or alarm signals by routing the concerned signal to the desired output relay (switchgroups SGR7...SGR11). Operation initiated by an external control signal is indicated on the display by the operation code of the respective control signal. The operation codes remain lit until reset.

When relay operation is initiated by an external control signal, the TRIP indicator is automatically lit, if the output relay selected is one of the heavy-duty output relays TS1...TS4 configured to be controlled by stage $\Delta I_{01}>$ or stage $\Delta I_{02}>$. Otherwise the TRIP indicator will be lit only if the output signal of the control signal has been set to light the indicator (switchgroup SGF5).

Activation of the blocking based on the ratio between the amplitudes of the second harmonic and the fundamental frequency component of the HV side neutral current, $I_{2f}/I_{1f}\ (I_{01})>$, is indicated by the operation code 3, whereas the activation of the LV side blocking $I_{2f}/I_{1f}(I_{02})>$ is indicated by the operation code 6.

The table below describes the red operation codes shown on the display to indicate start, operation, blocking, an activated control signal or operation of the circuit-breaker failure protection.

Code	Description
1	HV side protection stage $\Delta I_{01}>$ started
2	HV side protection stage $\Delta I_{01}>$ operated
3	Blocking based on the second harmonic of HV side, $I_{2f}/I_{1f}(I_{01})>$, is active
4	LV side protection stage $\Delta I_{02}>$ started
5	LV side protection stage $\Delta I_{02}>$ operated
6	Blocking based on the second harmonic of LV side, $I_{2f}/I_{1f}(I_{02})>$, is active
7	External control signal BS1 activated/active
8	External control signal BS2 activated/active
9	External control signal BS3 activated/active
0	External control signal BS4 activated/active
II	External control signal BS5 activated/active
A	Circuit-breaker failure protection operated
Yellow d	Disturbance recorder triggered, recording memorized

When a protection stage or a control signal resets, the TRIP indicator and the red operation code remain lit. The operation indicators can be reset via the push-buttons on the front panel of the relay, an external control signal or over the serial bus, see the table in paragraph "Resetting". Unreset operation indicators do not affect the operation of the relay module. If the output relay has a latching feature, the operation indicators remain lit until the latching is reset.

The self-supervision alarm indicator IRF indicates internal relay faults. Once the self-supervision system of the relay module has detected a permanent fault, the red indicator is lit. At the same time the relay module delivers a control signal to the self-supervision system output relay of the relay assembly. In addition, a fault code is lit on the display to show the type of the fault that has occurred. This fault code that consists of a red figure one and a green code number cannot be removed by resetting. It should be recorded and stated when service is ordered.

The table below shows the priority of the operation codes representing certain events. If the priorities of the events to be indicated are the same, the operation indicator of the latest event is indicated on the display.

Priority	Event to be indicated
1.	Self-supervision fault code
2.	Circuit-breaker failure operation
3.	Stage ΔI_{01}> or stage ΔI_{02}> operated, or operation initiated by an external control signal
4.	Stage ΔI_{01}> or stage ΔI_{02}> started
5.	Activation of external control signal when the output signal controlled by the external control signal has a latching feature
6.	Activation of external control signal
7.	Activation of blocking $I_{2f}/I_{1f}(I_{01})$> or $I_{2f}/I_{1f}(I_{02})$>

Settings

The setting values are indicated by the three right-most green digits on the display. When a LED in front of a setting value symbol is lit it shows that the particular setting value is indicated on the display. If the same LED represents several settings, a red digit is used to indicate the setting displayed. The default setting is given in parentheses under the setting range.

The second settings can be activated via subregister 4 in register A. The setting ranges are the same as those of the main settings. A flashing light of the setting indicators shows that the second settings are active.

Setting	Description	Setting range (Default)
P_1/I_n(%)	Basic setting of HV side start, step 1%	5...50% (5%)
t_{01}> (s)	Operate time on HV side, step 0.01 s at settings in the range 0.03…9.99 s and 0.1 s at settings in the range 10.0…100 s	0.03...100 s (0.03 s)
P_2/I_n(%)	Basic setting of LV side start, step 1%	5...50% (5%)
t_{02}> (s)	Operate time on LV side, step 0.01 s at settings in the range 0.03…9.99 s and 0.1 s at settings in the range 10.0…100 s	0.03...100 s (0.03 s)
I_{01}/I_n	Transformation ratio correction of HV side neutral connection CT, step 0.01	0.40...1.50 (1.00)
$I_{01}/\Sigma I_1$	Minimum ratio of HV side neutral current and residual current of the phase currents, when the numerical differential principle is used, step 1%	0...20% (10%)
I_{02}/I_n	Transformation ratio correction of LV side neutral connection CT, step 0.01	0.40...1.50 (1.00)
$I_{02}/\Sigma I_2$	Minimum ratio of LV side neutral current and residual current of the phase currents, when the numerical differential principle is used, step 1%	0...20% (10%)
$I_{2f}/I_{1f}(I_{01})$>(%)	Ratio of second harmonic and fundamental frequency component of HV side neutral current, step 1%	10...50% (30%)
$I_{2f}/I_{1f}(I_{02})$>(%)	Ratio of second harmonic and fundamental frequency component of LV side neutral current, step 1%	10...50% (30%)
I_1/I_n	Transformation ratio correction of HV side phase current transformers, step 0.01	0.40...1.50 (1.00)
I_2/I_n	Transformation ratio correction of LV side phase current transformers, step 0.01	0.40...1.50 (1.00)

The setting of the switchgroups SGF1...11, SGB1...8 and SGR1...11 are described in the following paragraph "Configuration switches"

Configuration switches

The switches of switchgroups SGF1...11, SGB1...8 and SGR1...11 can be used to select additional functions required for different applications. The switch number, 1...8, and position, 0 or 1, are displayed during the setting procedure. In normal service conditions the checksums of the switchgroups are displayed. These are found in the main menu of the relay module, see chapter "Main menus and submenus of settings and registers". The default settings with checksums are also mentioned in the tables. The calculation of the checksum ∑ is described in the end of this paragraph.

Switchgroup SGF1

The switchgroup SGF1 is used to select the protection principle to be used on the HV side and LV side. When the switch is in position 1 the protection principle is used. It should be noted that one protection principle at a time can be used on the HV side or the LV side.

Switch	Function	Default
SGF1/1	Stabilized differential current principle on HV side	0
SGF1/2	Calculated residual overcurrent principle on HV side	0
SGF1/3	Measured residual overcurrent principle or neutral current principle on HV side	0
SGF1/4	High-impedance principle on HV side	0
SGF1/5	Stabilized differential current principle on LV side	0
SGF1/6	Calculated residual overcurrent principle on LV side	0
SGF1/7	Measured residual overcurrent principle or neutral current principle on LV side	0
SGF1/8	High-impedance principle on LV side	0
∑SGF1		0

Switchgroup SGF2

The switches of switchgroup SGF2 are used to define the influence of the directions of the connected currents and to configure the blockings based on the second harmonic of the neutral current.

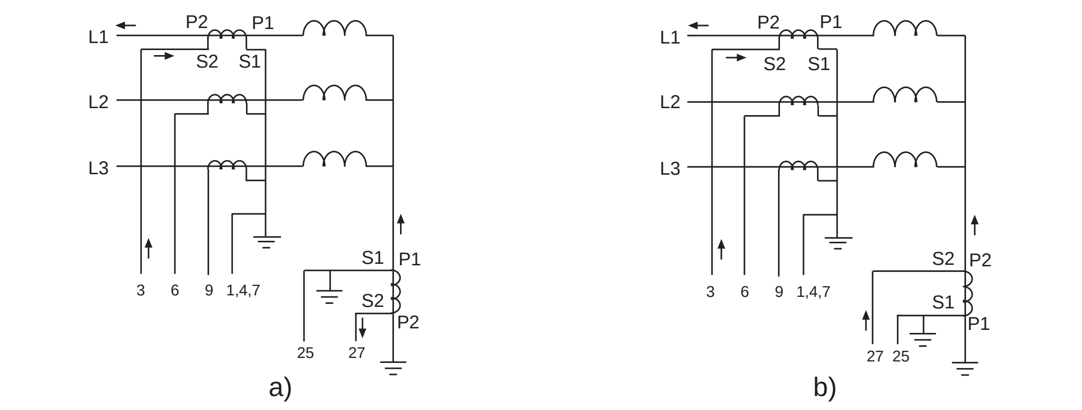


Fig. 6. The connected phase currents and neutral current have
a) opposite directions
b) equal directions
at an external earth fault situation. The CT wires are numbered according to the 1 A nominal current input terminals of the relay.

Switch	Function	Default
SGF2/1	The switch is used to define the influence of the directions of the connected HV side phase currents and that of neutral current on the operation of the stabilized differential current principle applied on HV side. When SGF2/1 = 1, the HV side phase currents and neutral current have opposite directions, see Fig. 6. a). When SGF2/1 = 0, the HV side phase currents and neutral current have equal directions, see Fig. 6. b).	0
SGF2/2	The switch is used to define the influence of the directions of the connected LV side phase currents and that of neutral current on the operation of the stabilized differential current principle applied on LV side. When SGF2/2 = 1, the LV side phase currents and neutral current have opposite directions, see Fig. 6. a). When SGF2/2 = 0, the LV side phase currents and neutral current have equal directions, see Fig. 6. b).	0
SGF2/3	The switch is used to select whether the start of the HV side earth-fault protection is to be blocked when the ratio of the second harmonic and the fundamental frequency component of the neutral current exceeds the setting value. When SGF2/3 = 1, blocking is enabled. When SGF2/3 = 0, blocking is disabled.	0
SGF2/4	The switch is used to select whether the start of the LV side earth-fault protection is to be blocked when the ratio of the second harmonic and the fundamental frequency component of the neutral current exceeds the setting value. When SGF2/4 = 1, blocking is enabled. When SGF2/4 = 0, blocking is disabled.	0
SGF2/5	Not in use. Has to be in position 0.	0
SGF2/6	Not in use. Has to be in position 0.	0
SGF2/7	Not in use. Has to be in position 0.	0
SGF2/8	Not in use. Has to be in position 0.	0
∑SGF2		0

Switchgroup SGF3 Circuit-breaker failure protection (CBFP)

Switch	Function	Default
SGF3/1	Circuit-breaker failure protection (CBFP) start initiated by signal TS2	0
SGF3/2	Circuit-breaker failure protection (CBFP) start initiated by signal TS3	0
SGF3/3	Circuit-breaker failure protection (CBFP) start initiated by signal TS4	0
	When the switch is in position 1, the output signal TS_ starts the CBFP operate time. Should the operate time expire the output signal still being active, the relay provides an operate signal TS1. When the switch is in position 0, the circuit-breaker failure protection is not in use.	
SGF3/4...8	Circuit-breaker failure protection operate time t_{CBFP}, see the table below.	0
∑SGF3		0

Circuit-breaker failure protection operate times t_{CBFP} to be selected with switches SGF3/4...8.

t_{CBFP} / ms	SGF3/4	SGF3/5	SGF3/6	SGF3/7	SGF3/8	∑SGF3/4…8
100	0	0	0	0	0	0
120	1	0	0	0	0	8
140	0	1	0	0	0	16
160	1	1	0	0	0	24
180	0	0	1	0	0	32
200	1	0	1	0	0	40
220	0	1	1	0	0	48
240	1	1	1	0	0	56
260	0	0	0	1	0	64
280	1	0	0	1	0	72
300	0	1	0	1	0	80
320	1	1	0	1	0	88
340	0	0	1	1	0	96
360	1	0	1	1	0	104
380	0	1	1	1	0	112
400	1	1	1	1	0	120
420	0	0	0	0	1	128
440	1	0	0	0	1	136
480	0	1	0	0	1	144
520	1	1	0	0	1	152
560	0	0	1	0	1	160
600	1	0	1	0	1	168
640	0	1	1	0	1	176
680	1	1	1	0	1	184
720	0	0	0	1	1	192
760	1	0	0	1	1	200
800	0	1	0	1	1	208
840	1	1	0	1	1	216
880	0	0	1	1	1	224
920	1	0	1	1	1	232
960	0	1	1	1	1	240
1000	1	1	1	1	1	248

Switchgroup SGF4

Self-holding of output signals

Switch	Function	Default
SGF4/1	Selection of self-holding for output signal SS1	0
SGF4/2	Selection of self-holding for output signal TS1	0
SGF4/3	Selection of self-holding for output signal SS2	0
SGF4/4	Selection of self-holding for output signal TS2	0
SGF4/5	Selection of self-holding for output signal SS3	0
SGF4/6	Selection of self-holding for output signal TS3	0
SGF4/7	Selection of self-holding for output signal SS4	0
SGF4/8	Selection of self-holding for output signal TS4	0
∑SGF4		0
	When a switch is in position 0, the output signal resets when the measured signal that caused operation falls below the setting value. When a switch is in position 1, the output signal remains active even if the signal that caused operation falls below the setting value.	
	When the self-holding feature has been selected the output signal has to be reset with the push-buttons on the front panel, via an external control input or over the serial bus, see paragraph "Description of operation".	

Switchgroup SGF5

Activation of TRIP indicator LED

Selection of the output signal to control the TRIP indicator LED on the front panel. When the switch linked to a certain output signal is in position 1, the TRIP operation indicator is lit by the activation of the signal. The switches SGF5/5...8 are not in use.

Switch SGF5/	Controlling signal	Switch position TRIP dark	Switch position TRIP is lit	Factory setting
1	TS1	0	1	1
2	TS2	0	1	1
3	TS3	0	1	0
4	TS4	0	1	0
∑ SGF5				3

Note!
The HV and LV side operate signals of the earth-fault relay module light the TRIP indicator irrespective of the setting of switchgroup SGF5, provided the operate signal is linked to a heavy-duty output relay via an output signal TS1, TS2, TS3 or TS4.

Special attention should be paid to the setting of switchgroup SGF5 when the operate signal can be initiated by an external control signal BS1, BS2, BS3, BS4 or BS5.

The operation indicators of the earth-fault relay module are described in detail in the paragraph "Operation indicators".

Switchgroups SGF6...11

Selection of the start and operate signals of the protection stages, the blocking signals and the external control signals BS4 and BS5 to be used as intermodular signals AR1...3 and BS1 INT1...3. The signal configuration is presented in Fig 7 below.

The signals of the protection stages, the blocking signals and the control signals are linked with the desired intermodular signal lines, for example, by circling the intersection of the signal lines. The switch number is marked at each intersection point and the weighting value of the switch is given to the right of the matrix. Adding the weighting values of the switches selected from each switchgroup gives the switchgroup checksums at the bottom of the matrix. The checksums of the factory settings are given under the calculated checksums.

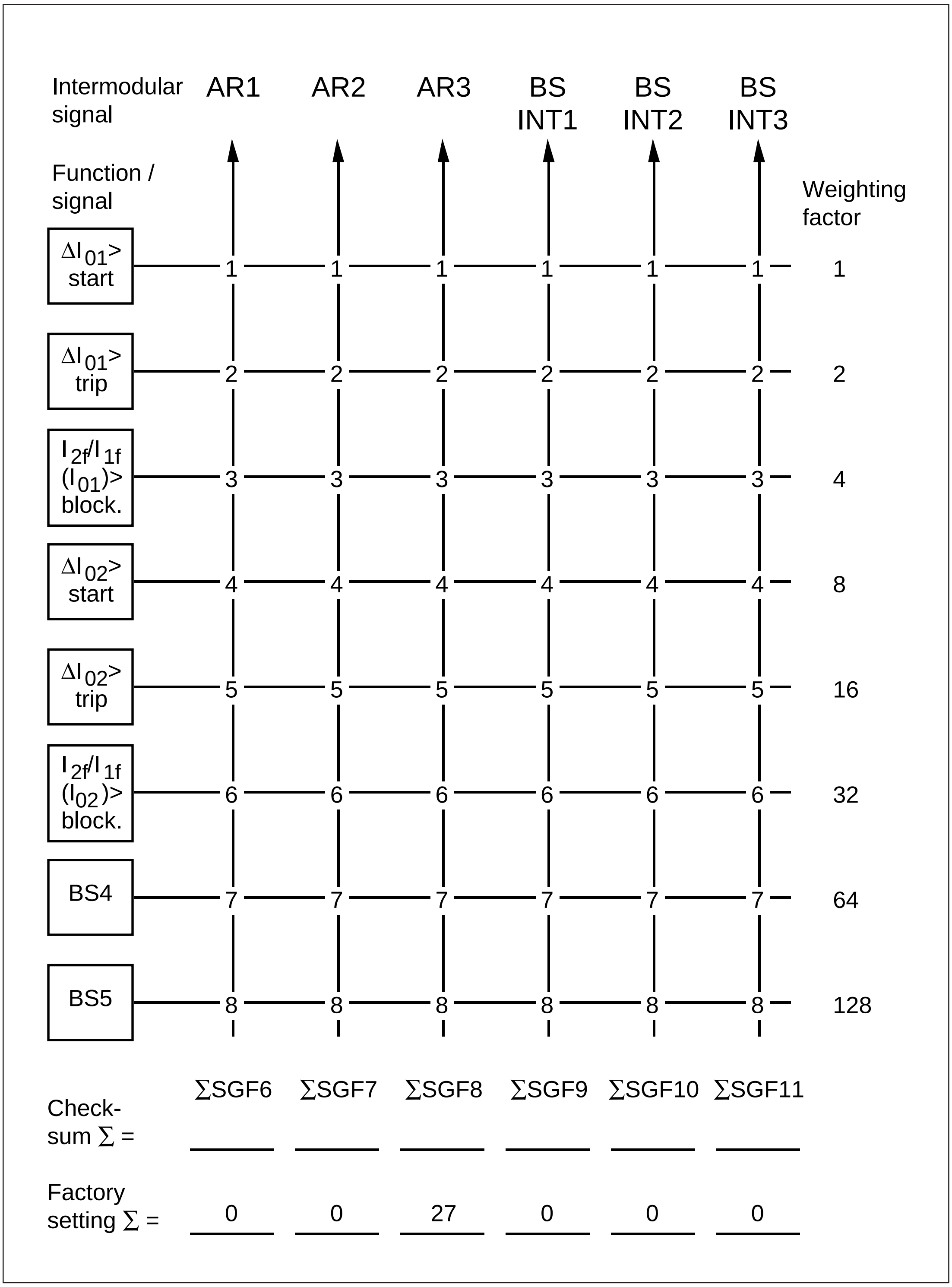


Fig. 7. Programming matrix for intermodular signals

Switchgroup SGB1

Selection of the logic active state of the external control signals BS1...5 and the intermodular blocking signals BS INT1...3.

When the switch is in position 0, the signal is active (state 1), when voltage, either DC voltage 18...265 V or AC voltage 80...265 V, is applied to the control input. When the switch is in position 1, the signal is active when no voltage is applied to the control input.

Switch	Function	Default
SGB1/1	Selection of active state, signal BS1	0
SGB1/2	Selection of active state, signal BS2	0
SGB1/3	Selection of active state, signal BS3	0
SGB1/4	Selection of active state, signal BS4	0
SGB1/5	Selection of active state, signal BS5	0
SGB1/6	Selection of active state, signal BS INT1	0
SGB1/7	Selection of active state, signal BS INT2	0
SGB1/8	Selection of active state, signal BS INT3	0
∑SGB1		0

Switchgroup SGB2...7

The switchgroups SGB2...7 are used to configure the function of the control signals BS1...5 and BS INT1...3. The matrix below can be used for the configuration. The control signals are linked with the desired function by circling the intersections of the lines. The switch number is marked at each intersection point and the corresponding weighting factor to the right of the matrix. Adding the weighting factors of the selected switches of each switchgroup gives the switchgroup checksums below the matrix. Switches not mentioned are not used and should be in position 0.

Note!
Before starting the programming check whether all control signals of the relay module SPCD 2D55 are used in the relay.

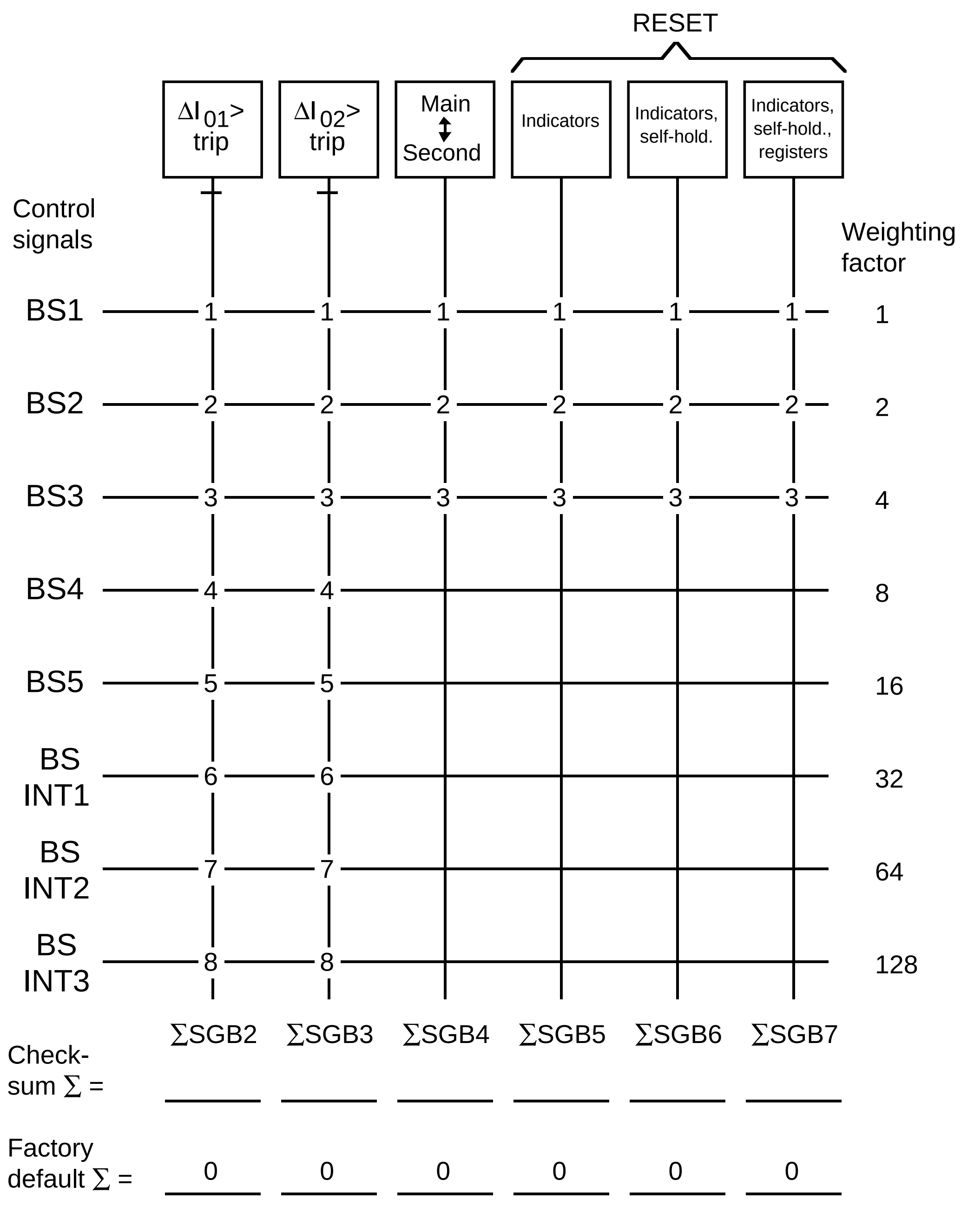


Fig. 8. Matrix for programming external control signals

Switches	Function
SGB2/1...8	Selection of the blocking signals for the operation of HV side stage ΔI_{01}>. When the switch is in position 1, and the blocking signal linked to the concerned switch is activated, the operation of the stage is blocked.
SGB3/1...8	Selection of the blocking signals for the operation of LV side stage ΔI_{02}>. When the switch is in position 1, and the blocking signal linked to the concerned switch is activated, the operation of the stage is blocked.
SGB4/1...3	Switching between main and second setting values. When an external control signal is used, the main setting values are effective when the signal is active. When the signal is not active the second settings are effective. When SGB4/1...3 = 0, an external control signal cannot be used to switch between the settings. Then the push-buttons on the front panel or a command over the serial bus have to be used. When SGB4/1...3 = 1, the actual setting values (main settings or second settings) depend entirely on the status of the control signal. Note! When SGB4/1...3 = 1, the relay module does not respond to switch-over commands given over the serial bus or with the push-buttons on the front panel. When both main setting values and second setting values are used, it is important that the switches SGB4/1...3 are in the same positions in the main setting and the second setting. Otherwise there may be a conflict situation when settings are changed.
SGB5/1...3	Resetting of front panel operation indicators, see "Resetting"
SGB6/1...3	Resetting of latched output relays and front panel operation indicators, see "Resetting"
SGB7/1...3	Resetting of front panel operation indicators, latched output relays, registers and recording memory, see "Resetting"

Switchgroup SGB8

The logic active state of the blocking signals BS INT1, BS INT2 or BS INT3 of the relay module in relation to the logic state of the signal linked to the blocking signal.

Switch	Function	Default
SGB8/1	When SGB8/1 = 0, the active state of BS INT1 is not changed. When SGB8/1 = 1, the active state of BS INT1 is changed.	0
SGB8/2	When SGB8/2 = 0, the active state of BS INT2 is not changed. When SGB8/2 = 1, the active state of BS INT2 is changed.	0
SGB8/3	When SGB8/3 = 0, the active state of BS INT3 is not changed. When SGB8/3 = 1, the active state of BS INT3 is changed.	0
SGB8/4	Not in used. Has to be in position 0.	0
SGB8/5	Not in used. Has to be in position 0.	0
SGB8/6	Not in used. Has to be in position 0.	0
SGB8/7	Not in used. Has to be in position 0.	0
SGB8/8	Not in used. Has to be in position 0.	0
∑SGB8		0

Switchgroups SGR1...SGR11

The switchgroups SGR1...11 are used to configure the start and operate signals of the protection stages and various control signals to operate as desired output signals SS1...SS4 or TS...TS4.

The matrix below can be used for programming. The signals are connected with the desired output signal SS1...SS4 or TS1...TS4 by circling the intersections of the signal lines. The switch number is marked at each intersection and the weighting value of the switch is given below the matrix. By adding the weighting values of the switches selected from each switchgroup the checksums of the switchgroups are obtained to the right of the matrix. (The checksums of the factory setting are given in parenthesis).

Note!
Before starting the programming check that all output signals of the relay module SPCD 2D55 are in use in the concerned protection relay.

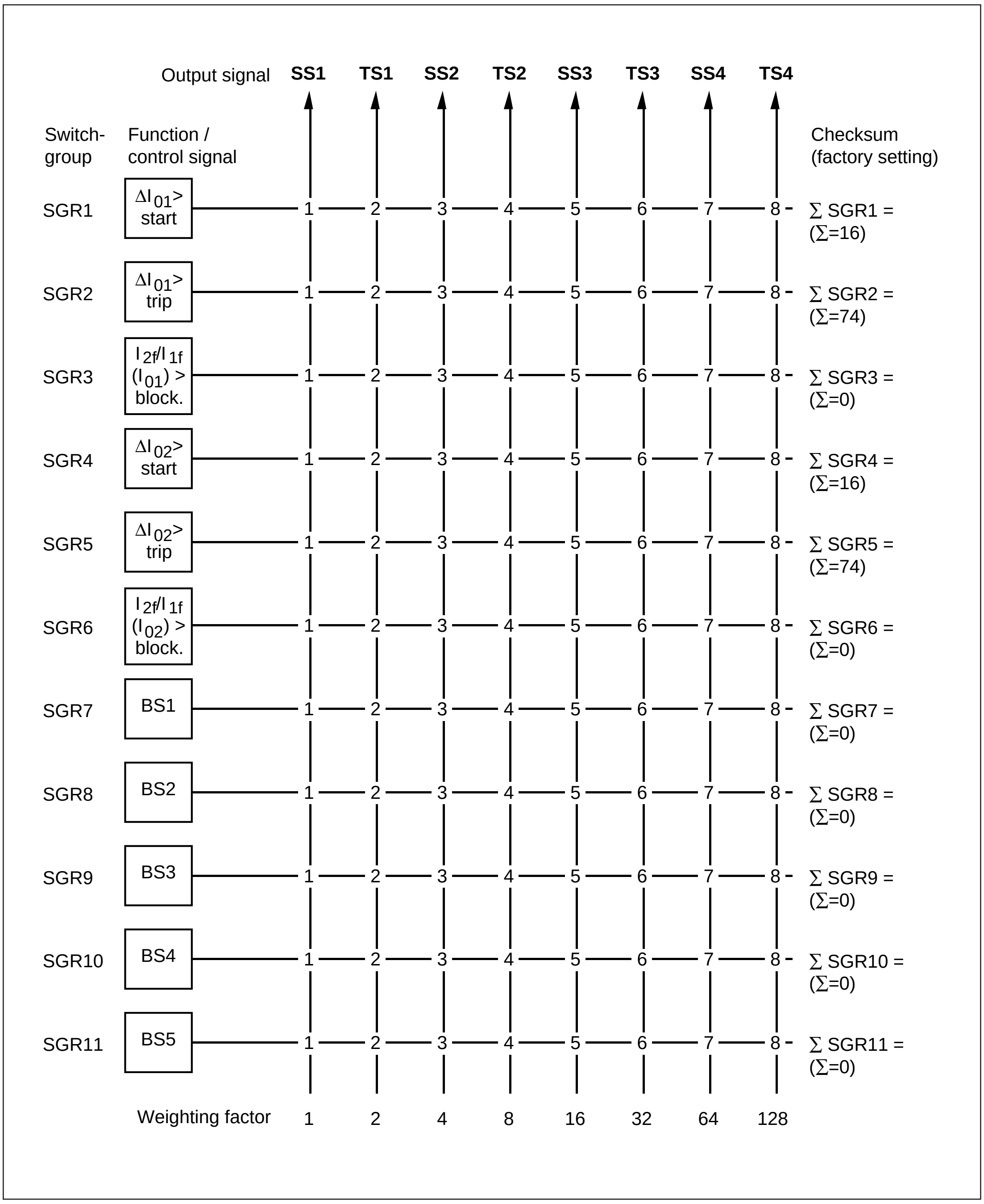


Fig. 9. Output relay matrix for differential relay module SPCD 2D55

Measured data

Measured values are indicated by the three green right-most digits on the display. Data that is being measured at the moment is indicated by a LED above the display and a red digit or letter to the left on the display.

Note! The measured data displayed allow for the effect of the transformation ratio corrections. When the phase difference between the residual current of the phase currents and neutral current is less than 90°, the directional differential current $I_d\cos\varphi$ is zero. Then the measured data displayed is zero too.

Measured data of main menu

LED indicator	Red symbol	Measured data
ΣI_1, I_{01}	S	Residual current ΣI_1 calculated on the basis of the transformer HV side phase currents, expressed as a percentage of the rated current
ΣI_1, I_{01}	0	Neutral current I_{01} of transformer HV side, expressed as a percentage of the rated current
I_{d1}	d	Directional differential current $I_{d1}\cos\varphi_1$ of HV side, expressed as a percentage of the rated current
I_{d2}	d	Directional differential current $I_{d2}\cos\varphi_2$ of LV side, expressed as a percentage of the rated current
ΣI_2, I_{02}	S	Residual current ΣI_2 calculated on the basis of the transformer LV side phase currents, expressed as a percentage of the rated current
ΣI_2, I_{02}	0	Neutral current I_{02} of transformer LV side, expressed as a percentage of the rated current

Measured data of submenu

The measured data available in submenus are described in the table below. The red symbol on main menu level shows the main register which contains the subregister with the measured data concerned.

LED indicator	Main register red symbol	Subregister red number	Measured data
ΣI_1, I_{01}	S	1	Transformer HV side phase current on phase L1 as a multiple of the rated current
ΣI_1, I_{01}	S	2	Transformer HV side phase current on phase L2 as a multiple of the rated current
ΣI_1, I_{01}	S	3	Transformer HV side phase current on phase L3 as a multiple of the rated current
I_{d1}	d	1	Phase angle difference between the residual current of the phase currents and neutral current on HV side
I_{d2}	d	1	Phase angle difference between the residual current of the phase currents and neutral current on LV side
ΣI_2, I_{02}	S	1	Transformer LV side phase current on phase L1 as a multiple of the rated current
ΣI_2, I_{02}	S	2	Transformer LV side phase current on phase L2 as a multiple of the rated current
ΣI_2, I_{02}	S	3	Transformer LV side phase current on phase L3 as a multiple of the rated current

Recorded information

The values recorded are stored in a pushdown storage at the moment of relay start, relay operation, and during transformer connection inrush currents. Both the HV side and the LV side values are recorded at relay start or relay operation, irrespective of whether the relay start or operation took place on the HV side or the LV side. The values are also recorded when the operate signal is obtained via an external control output BS1...5

The pushdown storage contains the five latest values recorded (n)...(n-4). Each new value is stored in the first location (n) in the storage and pushes all the previous items one step forward (n-1). When a sixth item is stored the oldest item (n-4) of the storage will be lost.

The most recently stored values (n) are available in the main registers. At a maximum four of the previous values are in the subregisters. The leftmost digit indicates the address of the storage location and the other three digits the numerical value of the parameter stored.

Register number	Recorded value
1	Directional differential current $I_{d1}\cos\varphi_1$ measured on the HV side at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the directional differential current at the moment of the event (n-1)...(n-4).
2	Stabilizing current I_{b1} at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the stabilizing current at the moment of the event (n-1)...(n-4).
3	Directional differential current $I_{d2}\cos\varphi_2$ measured on the LV side at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the directional differential current at the moment of the events (n-1)...(n-4).
4	Stabilizing current I_{b2} at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the stabilizing current at the moment of the event (n-1)...(n-4).
5	Neutral current I_{01} measured on the HV side at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the neutral current at the moment of the event (n-1)...(n-4).
6	Duration of the starting situation of the HV side earth-fault protection, expressed as a percentage of the set operate time $t_{01}>$. The subregisters 1...4 contain the durations of the starting situations at the moment of the events.
7	Neutral current I_{02} measured on the LV side at the moment of relay start or operation, expressed as a percentage of the rated current. The subregisters 1...4 contain the values of the neutral current at the moment of the events (n-1)...(n-4).
8	Duration of the starting situation of the LV side earth-fault protection, expressed as a percentage of the set operate time $t_{02}>$. The subregisters 1...4 contain the durations of the starting situations at the moment of the events (n-1)...(n-4).

Register number	Recorded value
9	Minimum value of the ratio of the second harmonic and the fundamental frequency component of the HV side neutral current during the latest connection inrush current. Subregister 1...4 contain the minimum values during the connection inrush current (n-1)...(n-4).
0	Status of external blocking and control signals. The number indicated on the display shows the status of the external blocking and control signals BS1...5 and BS INT1...3. The numbers representing active signal status are given below. The value of the register is equal to the sum of the numbers representing the active signals. The register has a value in the range 0...255. Control signal — Number representing active status of the control signal: BS1 — 1 BS2 — 2 BS3 — 4 BS4 — 8 BS5 — 16 BS INT1 — 32 BS INT2 — 64 BS INT3 — 128 From this register it is possible to enter the test mode of the output relays. In this mode the output signals and the settings of the SGR switchgroups of the output relay matrix can be tested. The output signals to be activated are indicated by a flashing LED adjacent to the settings, one LED flashing at a time. The test mode is described in detail in the following paragraph "Testing of output relays".
A	Address code of the relay module, required for serial communication. Register A contains the following additional subregisters: 1. Setting of the data transfer rate of the relay module: 4.8 or 9.6 kBd. Default setting 9.6 kBd. 2. Bus traffic monitor. If the relay module is connected to a data communication system and the communication operates properly, the value of the monitor is 0. Otherwise the numbers 0...255 are rolling. 3. Password required for remote setting. The password (parameter V160) must always be entered before a setting can be changed over the serial bus. 4. Selection of main and second settings (0 = main settings, 1 = second settings). Default setting 0. 5. Hz setting of rated frequency f_n. Default setting 50 Hz. 6. mHz setting of rated frequency f_n. Default setting 0 mHz. So, the default setting of the rated frequency is 50.000 Hz

When the display is dark, access to the beginning of the main menu is gained by pressing the STEP push-button on the front panel for more than 0.5 s. Pressing the push-button for less than 0.5 s gives direct access to the end of the main menu of the relay module.

The information recorded in registers 1...9 can be reset with the push-buttons on the front panel, via an external control signal or a serial communication parameter, see section "Resetting" in paragraph "Description of function". The registers are also cleared by an auxiliary power supply failure. The setting values, the address code, the data transfer rate and the password of the relay module are not affected by voltage failures. Instructions for setting the address code and data transfer rate are given in the document "General characteristics of D-type relay modules".

Main menus and submenus of settings and registers

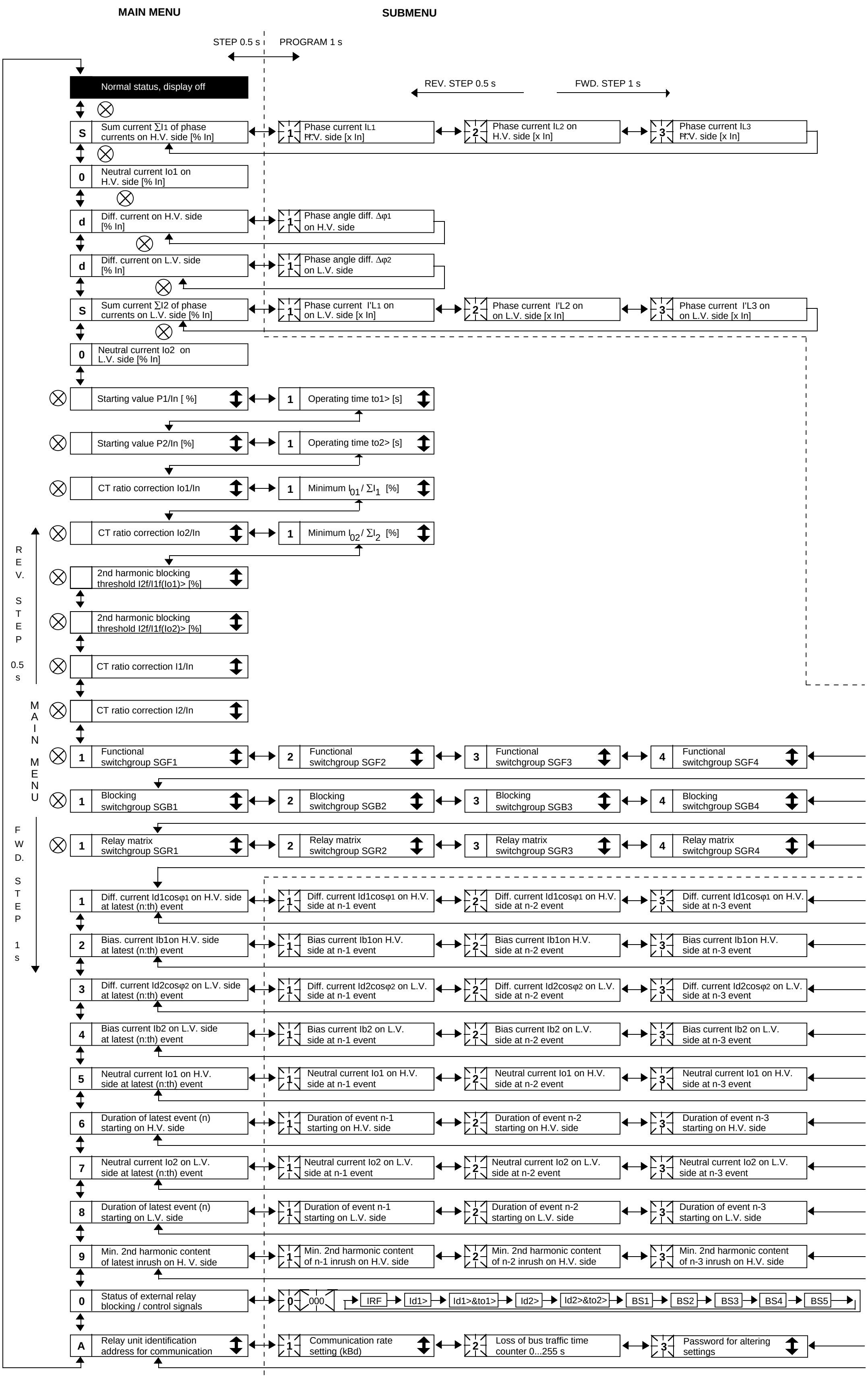
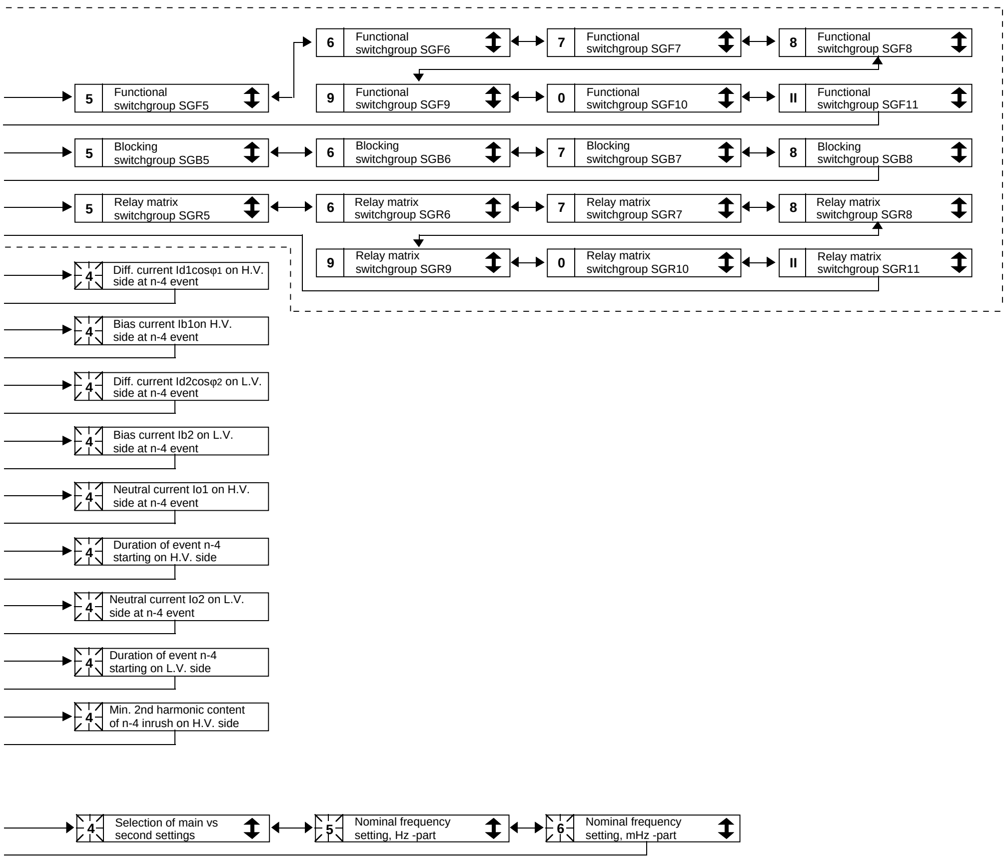


Fig. 10. Main menus and submenus for settings and registers of earth-fault relay module SPCD 2D55.

The procedure for entering a submenu or a setting mode and configuring the module is described in detail in the manual 34 SPC 3 EN1 "General characteristics of D-type SPC relay modules. Below a simplified instruction.

Desired step or function	Push-button	Action
One step forward in main menu or submenu	STEP	Press for more than 0.5 s
Rapid browse forwards in main menu	STEP	Keep depressed
One step backwards in main menu or submenu	STEP	Press for less than 0.5 s
Entering a submenu from the main menu	PROGRAM	Press for 1 s (activated when push-button is released)
Entering or quitting a setting mode	PROGRAM	Press for 5 s
Increasing a value in the setting mode	STEP	
Moving the cursor in the setting mode	PROGRAM	Press for about 1 s
Storing a setting value in the setting mode	STEP & PROGRAM	Press simultaneously
Resetting of memorized values	STEP & PROGRAM	
Resetting of latched output relays	PROGRAM	Note! Display must be dark



Testing of output relays

In the test mode, entered from the submenu of register 0, it is possible to activate the output signals of the relay one by one.

When the PROGRAM push-button is pressed for about five seconds the three digits to the right start flashing as an indication of the relay module being in the test mode. Initially, the self-supervision output is tested. The LEDs in front of the settings show the output signals to be activated at the moment. The desired output signal is selected by pressing PROGRAM for about one second.

The setting LEDs on the front panel and their respective output signals are as follows:

No LED	Self-supervision IRF
P_1/I_n (%)	Start of HV side stage ΔI_{01}>
P_2/I_n(%)	Operation of HV side stage ΔI_{01}>
I_{01}/I_n	HV side neutral current $I_{f2}/I_{1f}(I_{01})$> blocking
I_{02}/I_n	Start of LV side stage ΔI_{02}>
$I_{2f}/I_{1f}(I_{01})$>	Operation of LV side stage ΔI_{02}>
$I_{2f}/I_{1f}(I_{02})$>	LV side neutral current $I_{2f}/I_{1f}(I_{02})$> blocking
I_1/I_n	External control signal BS1
I_2/I_n	External control signal BS2
SGF	External control signal BS3
SGB	External control signal BS4
SGR	External control signal BS5

Pressing the push-buttons STEP and PROGRAM simultaneously activates the selected output signal, which remains active as long as the push-buttons are being pressed. The effect on the functions of the output relays depends on the configuration of the switchgroups SGR1... SGR11.

When the push-button STEP is being pressed in the IRF test mode, the self-supervision output relay operates in about 1 second. Return to the main menu is possible at any stage of the test sequence by pressing the PROGRAM push-button for about five seconds.

The signals are selected in the sequence illustrated in the Fig. 11.

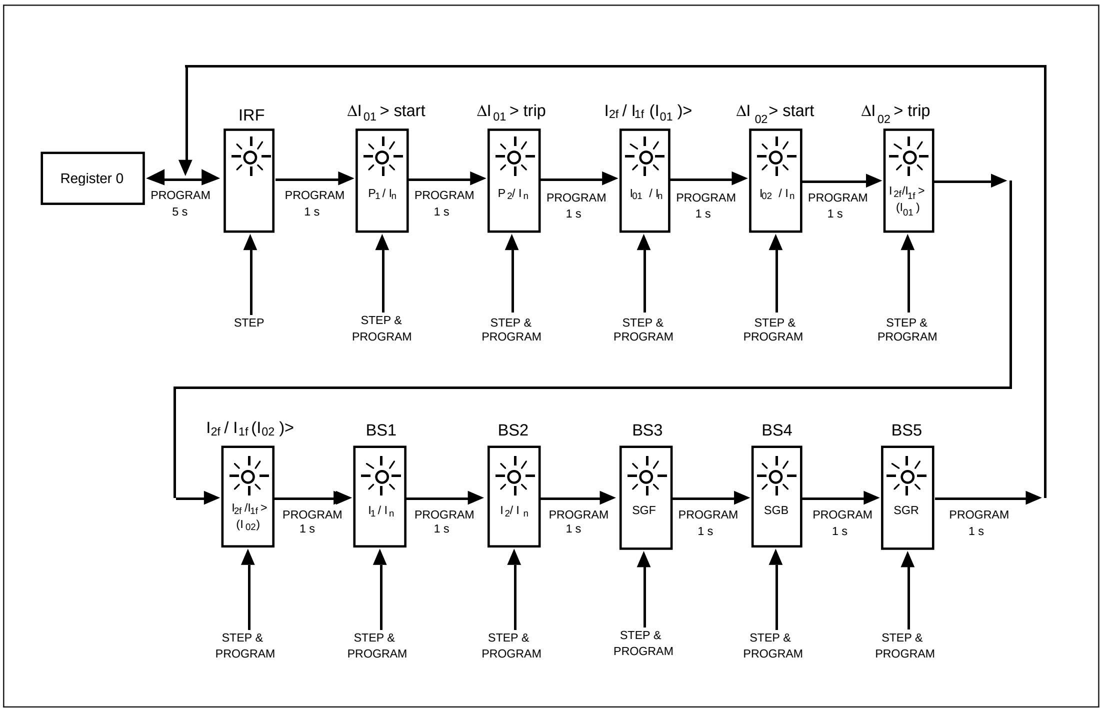


Fig. 11. Sequence for selecting the output signals in output relay testing.

Technical data

Selectable rated frequency f_n	$16^2/_3$...60 Hz

Stabilized differential principle (low-impedance type earth-fault protection)

Basic setting on HV side P_1/I_n	5...50%
Operate time setting on HV side $t_{01}>$	0.03...100 s
Basic setting on LV side P_2/I_n	5...50%
Operate time setting on LV side $t_{02}>$	0.03...100 s
Correction range of HV side neutral connection CT ratio I_{01}/I_n	0.40...1.50
Setting of minimum ratio of HV side neutral current and residual current of phase currents $I_{01}/\Sigma I_1$	0...20%
Correction range of LV side neutral connection CT ratio I_{02}/I_n	0.40...1.50
Setting of minimum ratio of LV side neutral current and residual current of phase currents $I_{02}/\Sigma I_2$	0...20%
Harmonics blocking ratio I_{2f}/I_{1f} of HV side neutral current I_{01}	10...50%
Harmonics blocking ratio I_{2f}/I_{1f} of LV side neutral current I_{02}	10...50%
Correction range of HV side phase CTs I_1/I_n	0.40...1.50
Correction range of LV side phase CTs I_2/I_n	0.40...1.50
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±4% of set value or ±2% x I_n

Principle based on calculated residual current

Basic setting on HV side P_1/I_n	5...50%
Operate time setting on HV side $t_{01}>$	0.03...100 s
Basic setting on LV side P_2/I_n	5...50%
Operate time setting on LV side $t_{02}>$	0.03...100 s
Correction range of HV side phase CTs I_1/I_n	0.40...1.50
Correction range of LV side phase CTs I_2/I_n	0.40...1.50
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±4% of set value or ±2% x I_n

Principle based on measured residual current or on neutral current

Basic setting on HV side P_1/I_n	5...50%
Operate time setting on HV side $t_{01}>$	0.03...100 s
Basic setting on LV side P_2/I_n	5...50%
Operate time setting on LV side $t_{02}>$	0.03...100 s
Correction range of HV side neutral connection CT ratio I_{01}/I_n	0.40...1.50
Correction range of LV side neutral connection CT ratio I_{02}/I_n	0.40...1.50
Harmonics blocking ratio I_{2f}/I_{1f} of HV side neutral current I_{01}	10...50%
Harmonics blocking ratio I_{2f}/I_{1f} of LV side neutral current I_{02}	10...50%
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±4% of set value or ±2% x I_n

Restricted earth-fault principle (high-impedance type earth-fault protection)

Basic setting on HV side P_1/I_n	5...50%
Operate time setting on HV side $t_{01}>$	0.03...100 s
Basic setting on LV side P_2/I_n	5...50%
Operate time setting on LV side $t_{02}>$	0.03...100 s
Correction range of HV side neutral connection	
CT ratio I_{01}/I_n	0.40...1.50
Correction range of LV side neutral connection	
CT ratio I_{02}/I_n	0.40...1.50
Operate time accuracy	±2% of set value or ±25 ms
Operation accuracy	±4% of set value or ±2% x I_n

Circuit-breaker failure protection

Operate time	0.1...1.0 s

Integrated disturbance recorder

Recording length	30 cycles
Recording memory capacity	1 recording = 30 cycles
Sampling frequency	40 samples/cycle
Signals to be recorded	8 analog signals 12 digital signals
Triggering	
- when the selected digital signal	is activated
- when the selected digital signal	resets
Length of recording preceding triggering	0...30 cycles

Note!
Operate times are valid at rated frequency 50 Hz and 60 Hz.

Serial communication parameters

Event codes

Special codes have been specified to represent different events such as starting and operation of protection stages, blocking, and activation of control and output signals. These event codes can be transferred to higher-level systems over the serial bus.

An event to be included in event reporting is marked with 1. The event mask is obtained by adding the weighting values of the events included, see the tables below.

Event mask	Codes	Setting range	Default
V155	E1...E6	0...63	5
V156	E7...E14	0...255	5
V157	E15...E24	0...1023	0
V158	E25...E32	0...255	12
V159	E33...E40	0...255	0

Channel	Code	Event	Number of event	Default
0	E1	Start of stage ΔI_{01}>	1	1
0	E2	Start of stage ΔI_{01}> reset	2	0
0	E3	Operation of stage ΔI_{01}>	4	1
0	E4	Operation of stage ΔI_{01}> reset	8	0
0	E5	$I_{2f}/I_{1f}(I_{01})$> blocking activated	16	0
0	E6	$I_{2f}/I_{1f}(I_{01})$> blocking reset	32	0
		Default of event mask V155		5
0	E7	Start of stage ΔI_{02}>	1	1
0	E8	Start of stage ΔI_{02}> reset	2	0
0	E9	Operation of stage ΔI_{02}>	4	1
0	E10	Operation of stage ΔI_{02}> reset	8	0
0	E11	$I_{2f}/I_{1f}(I_{02})$> blocking activated	16	0
0	E12	$I_{2f}/I_{1f}(I_{02})$> blocking reset	32	0
0	E13	CBFP operated	64	0
0	E14	CBFP reset	128	0
		Default of event mask V156		5
0	E15	Control signal BS1 activated	1	0
0	E16	Control signal BS1 reset	2	0
0	E17	Control signal BS2 activated	4	0
0	E18	Control signal BS2 reset	8	0
0	E19	Control signal BS3 activated	16	0
0	E20	Control signal BS3 reset	32	0
0	E21	Control signal BS4 activated	64	0
0	E22	Control signal BS4 reset	128	0
0	E23	Control signal BS5 activated	256	0
0	E24	Control signal BS5 reset	512	0
		Default of event mask V157		0

Channel	Code	Event	Number of event	Default
0	E25	Output signal SS1 activated	1	0
0	E26	Output signal SS1 reset	2	0
0	E27	Output signal TS1 activated	4	1
0	E28	Output signal TS1 reset	8	1
0	E29	Output signal SS2 activated	16	0
0	E30	Output signal SS2 reset	32	0
0	E31	Output signal TS2 activated	64	0
0	E32	Output signal TS2 reset	128	0
		Default of event mask V158		12
0	E33	Output signal SS3 activated	1	0
0	E34	Output signal SS3 reset	2	0
0	E35	Output signal TS3 activated	4	0
0	E36	Output signal TS3 reset	8	0
0	E37	Output signal SS4 activated	16	0
0	E38	Output signal SS4 reset	32	0
0	E39	Output signal TS4 activated	64	0
0	E40	Output signal TS4 reset	128	0
		Default of event mask V159		0
	E50	Restarting of microprocessor		
	E51	Overflow of event register		
	E52	Temporary disturbance in data communication		
	E53	The relay module does not respond over the data bus.		
	E54	The module responds again over the data bus		

The event codes E50...E54 and the events represented by these are always reported and cannot be excluded. The capacity of the event register is 60 events. The event codes E52... E54 are generated by the control data communicator (e.g. SRIO 1000M).

Remote transfer data

In addition to the event codes input data (I data), output data (O data), setting values (S data) memorized data (V data), and some other data can be read from the module over the serial bus. The values of parameters marked with the letter W can be changed over the SPA bus.

When a setting value is to be changed, either via the push-buttons on the front panel or over the serial bus, the relay module checks whether the given parameter value is legal. A value outside the permitted setting range will not be memorized, but the previous setting will be retained.

Changing a setting parameter over the serial bus requires a password in the range 1..999. The default setting is 1.

The password is opened by giving the serial communication parameter V160 the desired numerical value. Parameter V161 is used for closing the password. The password is also closed by failures in the voltage supply.

The push-buttons of the relay module or a command over the serial bus can be used to change the password. To be able to change the password over the serial bus, the password first has to be opened. The new password is entered by means of parameter V161. When using the push-buttons, the new password is written in the place of the old one in subregister 3 of register A.

Should the wrong password be given 7 successive times, it turns into a zero and can no longer be opened over the serial bus. Then the password can be given a new numerical value via the push-buttons only.

R = data to be read from the module
W = data to be written to the module
(P) = writing allowed through a password

Input data

Measured data	Parameter	Values
Current on HV side phase L1	I1	0.00...65.5 (x I_n)
Current on HV side phase L2	I2	0.00...65.5 (x I_n)
Current on HV side phase L3	I3	0.00...65.5 (x I_n)
Residual current $\sum I_1$ calculated from HV side phase currents	I4	0.0...6554 (%I_n)
HV side neutral current I_{01}	I5	0.0...3000 (%I_n)
Directional differential current $I_{d1}\cos\varphi_1$ on HV side	I6	0.0...6554 (%I_n)
Current on LV side phase L1	I7	0.00...65.5 (x I_n)
Current on LV side phase L2	I8	0.00...65.5 (x I_n)
Current on LV side phase L3	I9	0.00...65.5 (x I_n)
Residual current $\sum I_2$ calculated from LV side phase currents	I10	0.0...6554 (%I_n)
LV side neutral current I_{02}	I11	0.0...3000 (%I_n)
Directional differential current $I_{d2}\cos\varphi_2$ on LV side	I12	0.0...6554 (%I_n)
Phase difference between residual current and neutral current on HV side	I13	0...359°
Phase difference between residual current and neutral current on LV side	I14	0...359°
Status data of control signals BS1...5 and BS INT1...BS INT3	I15	0...255, see table in "Recorded information"

Output data

The actual status data provide information about the present status of the signals. The events stored in the memory indicate those signal activations which have taken place after the latest resetting of the register. When the value is 0, the signal is not activated and when the value is 1, the signal is activated.

Status data of protection stages and control signals

Protection stage/ signal	Actual status data (R)	Memorized events (R)	Values
Stage ΔI_{01}>, start signal	O1	O21	0 or 1
Stage ΔI_{01}>, operate signal	O2	O22	0 or 1
$I_{2f}/I_{1f}(I_{01})$> blocking	O3	O23	0 or 1
Stage ΔI_{02}>, start signal	O4	O24	0 or 1
Stage ΔI_{02}>, operate signal	O5	O25	0 or 1
$I_{2f}/I_{1f}(I_{02})$> blocking	O6	O26	0 or 1
Output relay control			
by control signal BS1	O7	O27	0 or 1
by control signal BS2	O8	O28	0 or 1
by control signal BS3	O9	O29	0 or 1
by control signal BS4	O10	O30	0 or 1
by control signal BS5	O11	O31	0 or 1
Trip signal of CBFP	O12	O32	0 or 1

Signal activations

Output signal	Actual status data (R,W,P)	Memorized events (R)	Values
Output signal SS1	O13	O33	0 or 1
Output signal TS1	O14	O34	0 or 1
Output signal SS2	O15	O35	0 or 1
Output signal TS2	O16	O36	0 or 1
Output signal SS3	O17	O37	0 or 1
Output signal TS3	O18	O38	0 or 1
Output signal SS4	O19	O39	0 or 1
Output signal TS4	O20	O40	0 or 1
Remote control of output signals	O41		0 or 1

The parameters V11...V59 can be used to read (R) the latest five values stored in the registers. Event n = the most recent value recorded, event n-1 = the value before that, and so on. The registers are described in detail in the paragraph "Recorded information".

Value measured	Event					Measuring range
	n	n-1	n-2	n-3	n-4	
Directional differential current $I_{d1}\cos\varphi_1$	V11	V21	V31	V41	V51	0...6554 (%I_n)
Stabilizing current I_{b1}	V12	V22	V32	V42	V52	0...6554 (%I_n)
Directional differential current $I_{d2}\cos\varphi_2$	V13	V23	V33	V43	V53	0...6554 (%I_n)
Stabilizing current I_{b2}	V14	V24	V34	V44	V54	0...6554 (%I_n)
Neutral current I_{01}	V15	V25	V35	V45	V55	0...3000 (%I_n)
Duration of start situation, stage $\Delta I_{01}>$	V16	V26	V36	V46	V56	0...100 (%)
Neutral current I_{02}	V17	V27	V37	V47	V57	0...3000 (%I_n)
Duration of start situation, stage $\Delta I_{02}>$	V18	V28	V38	V48	V58	0...100 (%)
Min. ratio I_{2f}/I_{1f}, of HV side neutral current, during the latest connection inrush current	V19	V29	V39	V49	V59	0...127%
Stage that initiated tripping	V1					1: $\Delta I_{01}>$ 2: $\Delta I_{02}>$ 3: $\Delta I_{01}>$ and $\Delta I_{02}>$

Setting values

Setting	Actual values(R)	Main setting values (R,W,P)	Second setting values (R,W,P)	Setting range
Basic setting P_1/I_n	S1	S51	S101	5...50 (%)
Basic setting P_2/I_n	S2	S52	S102	5...50 (%)
Operate time $t_{01}>$	S3	S53	S103	0.03...100 (s)
Operate time $t_{02}>$	S4	S54	S104	0.03...100 (s)
Harmonics blocking ratio $I_{2f}/I_{1f}(I_{01})>$	S5	S55	S105	10...50 (%)
Harmonics blocking ratio $I_{2f}/I_{1f}(I_{02})>$	S6	S56	S106	10...50 (%)
Transformation ratio correction I_{01}/I_n	S7	S57	S107	0.40...1.50 (x I_n)
Transformation ratio correction I_{02}/I_n	S8	S58	S108	0.40...1.50 (x I_n)
Transformation ratio correction I_1/I_n	S9	S59	S109	0.40...1.50 (x I_n)
Transformation ratio correction I_2/I_n	S10	S60	S110	0.40...1.50 (x I_n)
Checksum, SGF1	S11	S61	S111	0...255
Checksum, SGF2	S12	S62	S112	0...255
Checksum, SGF3	S13	S63	S113	0...255
Checksum, SGF4	S14	S64	S114	0...255
Checksum, SGF5	S15	S65	S115	0...255
Checksum, SGF6	S16	S66	S116	0...255
Checksum, SGF7	S17	S67	S117	0...255
Checksum, SGF8	S18	S68	S118	0...255
Checksum, SGF9	S19	S69	S119	0...255
Checksum, SGF10	S20	S70	S120	0...255
Checksum, SGF11	S21	S71	S121	0...255
Checksum, SGB1	S22	S72	S122	0...255
Checksum, SGB2	S23	S73	S123	0...255
Checksum, SGB3	S24	S74	S124	0...255
Checksum, SGB4	S25	S75	S125	0...255
Checksum, SGB5	S26	S76	S126	0...255
Checksum, SGB6	S27	S77	S127	0...255
Checksum, SGB7	S28	S78	S128	0...255
Checksum, SGB8	S29	S79	S129	0...255
Checksum, SGR1	S30	S80	S130	0...255
Checksum, SGR2	S31	S81	S131	0...255
Checksum, SGR3	S32	S82	S132	0...255
Checksum, SGR4	S33	S83	S133	0...255
Checksum, SGR5	S34	S84	S134	0...255
Checksum, SGR6	S35	S85	S135	0...255
Checksum, SGR7	S36	S86	S136	0...255
Checksum, SGR8	S37	S87	S137	0...255
Checksum, SGR9	S38	S88	S138	0...255
Checksum, SGR10	S39	S89	S139	0...255
Checksum, SGR11	S40	S90	S140	0...255
Min. ratio $I_{01}/\Sigma I_1$ of neutral current and residual current	S41	S91	S141	0...20 (%)
Min. ratio $I_{02}/\Sigma I_2$ of neutral current and residual current	S42	S92	S142	0...20 (%)

Control parameters

Data	Code	Data direction	Values
Resetting of front panel operation indicators and latched output relay	V101	W	1 = resetting
Resetting of front panel operation indicators, output relays, registers and recording memory	V102	W	1 = resetting
Remote control of settings	V150	R,W	0 = main settings active 1 = second settings active
Event mask for $\Delta I_{01}>$ stage	V155	R,W	0...63, see "Event codes"
Event mask for $\Delta I_{02}>$ stage	V156	R,W	0...255, see "Event codes"
Event mask for external control signals	V157	R,W	0...1023, see "Event codes"
Event mask for output signals	V158	R,W	0...255, see "Event codes"
Event mask for output signals	V159	R,W	0...255, see "Event codes"
Opening of password for remote setting	V160	W	1...999
Changing or closing password for remote setting	V161	W(P)	0...999
Activation of self-supervision input	V165	W	1 = self-supervision input is activated and IRF LED is lit
EEPROM formatting	V167	W(P)	2 = formatting
Error code	V169	R	0...255
Rated frequency, Hz setting	V180	R,W,P	10...60 (Hz)
Rated frequency, mHz setting	V181	R,W,P	0...999 (mHz)
Data communication address of relay module	V200	R,W	1...254
Data transfer rate	V201	R,W	4.8, 9.6, 19.2, 38.4 kBd
Program version symbol	V205	R	124 C

Data	Code	Data direction	Values
Selection of internal signals to be used for triggering the disturbance recorder	V241	R,W	0...15

Internal signal	Function	Number representing function
ΔI_{01}> start	Used for triggering	1
	Not used for triggering	0
ΔI_{02}> start	Used for triggering	2
	Not used for triggering	0
Blocking $I_{2f}/I_{1f}(I_{01})$>	Used for triggering	4
	Not used for triggering	0
Blocking $I_{2f}/I_{1f}(I_{02})$>	Used for triggering	8
	Not used for triggering	0
Factory setting V241		3

Selection of method for triggering the disturbance recorder	V242	R,W	0...15

Control signal	Triggering	Number representing triggering point
ΔI_{01}> start	By falling edge	1
	By rising edge	0
ΔI_{02}> start	By falling edge	2
	By rising edge	0
Blocking $I_{2f}/I_{1f}(I_{01})$>	By falling edge	4
	By rising edge	0
Blocking $I_{2f}/I_{1f}(I_{02})$>	By falling edge	8
	By rising edge	0
Factory setting V242		0

Selection of control signals to be used for triggering the disturbance recorder	V243	R,W	0...255

Control signal	Function	Number representing function
BS1	Used for triggering	1
	Not used for triggering	0
BS2	Used for triggering	2
	Not used for triggering	0
BS3	Used for triggering	4
	Not used for triggering	0
BS4	Used for triggering	8
	Not used for triggering	0
BS5	Used for triggering	16
	Not used for triggering	0
BS INT1	Used for triggering	32
	Not used for triggering	0
BS INT2	Used for triggering	64
	Not used for triggering	0
BS INT3	Used for triggering	128
	Not used for triggering	0
Factory setting V243		0

Data	Code	Data direction	Values
Selection of method for triggering the disturbance recorder	V244	R,W	0...255

Internal signal	Triggering	Number representing triggering point
BS1	By falling edge	1
	By rising edge	0
BS2	By falling edge	2
	By rising edge	0
BS3	By falling edge	4
	By rising edge	0
BS4	By falling edge	8
	By rising edge	0
BS5	By falling edge	16
	By rising edge	0
BS INT1	By falling edge	32
	By rising edge	0
BS INT2	By falling edge	64
	By rising edge	0
BS INT3	By falling edge	128
	By rising edge	0
Factory setting V244		0

Data	Code	Data direction	Values
Length of recording following disturbance recorder triggering, in cycles	V245	R,W	0...30 Factory setting V245 = 5
Status/command register of recording memory	V246	R	0 = recording not triggered, i.e. memory empty 1 = recording triggered and recording memory is full
		W	0 = reset recording memory 1 = no function (NOP)
Reading of event register	L	R	Time, channel number (unless zero) and event code
Re-reading of event register	B	R	Time, channel number (unless zero) and event code
Type designation of relay module	F	R	SPCD 2D55
Reading of module status data	C	R	0 = normal status 1 = module 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
Time reading or setting	T	R,W	00.000...59.999 s
Date and time reading and setting	D	R,W	YY-MM-DD HH.MM;SS.mss

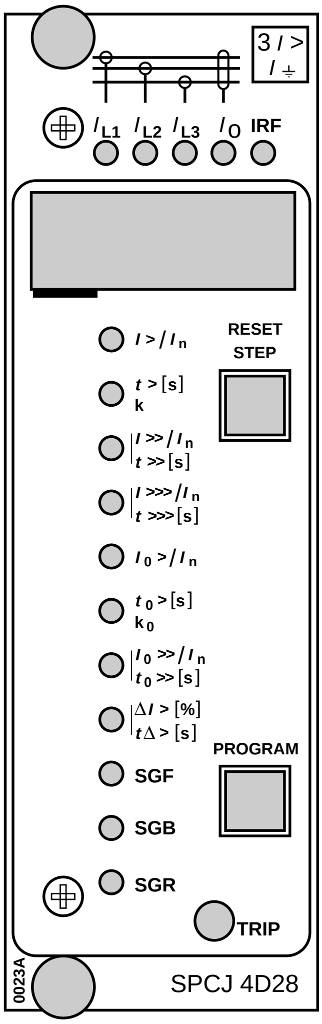
The event register can be read by the L command only once. Should a fault occur, say, in the data communication, the B command can be used to re-read the contents of the register. When required, the B command can be repeated. In general, the control data communicator SRIO 1000M reads the event data and forwards the information to an output device. Under normal conditions the event register of the relay module is empty. The control data communicator also resets abnormal status data, so this data is normally zero.

Fault codes

1	Auxiliary voltage interrupted
4	Faulty trip relay path, TS1, or missing output relay card
5	Faulty trip relay path, TS2, or missing output relay card
6	Faulty trip relay path, TS3, or missing output relay card
7	Faulty trip relay path, TS4, or missing output relay card
20	The module has restarted, although no fault was detected by the self-supervision system.
21	The module has restarted more than 10 times, although no fault was detected by the self-supervision system.
23	Error during start-up of DSP
24	DSP halted due to unknown error
29	DSP code memory area checksum
30	Faulty program memory (EPROM)
49	DSP internal RAM faulty
50	MCU internal RAM faulty
51	Parameter memory (EEPROM) block 1 faulty
52	Parameter memory (EEPROM) block 2 faulty
53	Parameter memory (EEPROM) block 1 and block 2 faulty
54	Parameter memory (EEPROM) block 1 and block 2 faulty, different checksums
55	Faulty parameter area in RAM
56	Parameter memory (EEPROM) key fault. Parameter memory not formatted.
57	Gain/channel correction value checksum
58	Active setting bank checksum
59	DSP external RAM faulty
60	MCU external RAM faulty
100	DSP overloaded
195	The analog supply voltage measured is too low (rated voltage -12 V)
196	The analog supply voltage measured is too low (rated voltage +12 V)
203	The analog supply voltage measured is too high (rated voltage -12 V)
204	The analog supply voltage measured is too high (rated voltage +12 V)
252	Input filter faulty
253	A/D converter faulty
254	DSP does not interrupt

SPCJ 4D28
Overcurrent and earth-fault relay module

User´s manual and Technical description



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SPCJ 4D28
Overcurrent and earth-fault relay module

Data subject to change without notice

Contents

Characteristics

Low-set overcurrent stage I> with definite time or inverse definite time characteristic, the latter with six selectable inverse-time curves.

High-set overcurrent stage I>> with definite time characteristic. The high-set stage can be set out of operation.

Superhigh-set overcurrent stage I>>> with definite time characteristic. The superhigh-set stage can be set out of operation.

Low-set neutral overcurrent stage I_0> with definite time or inverse definite time characteristic, the latter with six selectable inverse-time curves.

High-set neutral current stage I_0>> with definite time characteristic. The high-set stage can be set out of operation.

Phase discontinuity stage with definite time characteristic. The phase discontinuity stage can be set out of operation.

Output relay matrix allowing any start or trip signal from the protection stages to be routed to the desired output relay.

Flexible configuration of auto-reclose start initiation signals.

Local display of measured and set values and data recorded at the moment of a fault. Reading and writing of setting values either via local display and front panel push-buttons or from higher-level systems over the serial interface and the fibre-optic bus.

Self-supervision system continuously monitoring the operation of the electronics and the microprocessor. When a permanent fault is detected the alarm output relay operates and the other relay outputs are blocked.

Description of operation

Overcurrent unit

The overcurrent unit of the combined overcurrent and earth-fault relay module SPCJ 4D28 is designed to be used for single-phase, two-phase and three-phase overcurrent protection. The overcurrent unit includes three overcurrent stages: a low-set stage I>, a high-set stage I>> and a superhigh-set stage I>>>.

An overcurrent stage starts if the current on one or more of the phases exceeds the set start value of the concerned stage. On starting the stage provides a start signal which can be routed to the desired output relay. At the same time a numerical code indicating starting appears on the display. Should the duration of the overcurrent situation exceed the set operate time of the stage at definite time operation or, at inverse time operation of stage I>, a time depending on the level of the measured current, the stage operates issuing an operate signal, which can be routed to the desired output relay.

The operation of the overcurrent stages I> and I>> can be inhibited by an external control signal BS1, BS2 or RRES(BS3) applied to the relay module. The external blocking signals are configured with switchgroups SGB1...3.

The operation of the overcurrent stage I> can be based on definite time or inverse time characteristic. When inverse time characteristic is selected four internationally standardized and two special type time/current curves are available. Both the mode of operation and the desired time/current curve is selected with switchgroup SGF1.

Note! At inverse time characteristic the effective setting range of the low-set overcurrent stage is 0.5…2.5 x I_n, although start current settings within the range 2.5…5.0 x I_n can be set on the relay. At inverse time characteristic any start current setting above 2.5 x I_n of the low-set stage will be regarded as being equal to 2.5 x I_n.

If the high-set stage I>> is given a setting from the lower part of the the setting range, the relay module will contain two nearly identical operation stages. In this case the relay module SPCJ 4D28 can be used in two-stage load shedding applications.

The set start current value I>>/I_n of stage I>> can be automatically doubled in a start situation, i.e. when the object to be protected is connected to the network. Thus a set start current value below the connection inrush current level may be selected for the overcurrent stage I>>. A start situation is defined as a situation where the phase currents rise from a value below 0.12 x I> to a value above 1.5 x I> in less than 60 ms. The start situation ends when the currents fall below 1.25 x I>.

The I>> stage or the I>>> stage can be set out of operation completely, if not needed. When an overcurrent stage is set out of operation the set start current of the stage is displayed with three dashes "- - -".

The inverse time function of stage I> can be inhibited, when stage I>> or stage I>>> is starting, in which case the operate time is determined by these stages.

Earth-fault unit

The earth-fault unit of the combined overcurrent and earth-fault relay module SPCJ 4D28 is provided with two protection stages: a low-set neutral overcurrent stage I_0> and a high-set neutral overcurrent stage I_0>>.

The low-set stage or the high-set stage starts, if the neutral or residual current measured exceeds the set start current of the concerned stage. On starting the stage provides a start signal, which can be routed to the desired output relay. At the same time a numerical code indicating starting appears on the display. Should the duration of the neutral overcurrent situation exceed the set operate time of the stage at definite time operation or, at inverse time operation of stage I_0>, a time depending on the level of the measured current, the stage operates issuing an operate signal, which can be routed to the desired output relay.

The operation of the overcurrent stages I_0> and I_0>> can be inhibited by an external control signal BS1, BS2 or RRES(BS3) applied to the relay module. The external blocking signals are configured with switchgroups SGB1...3.

The operation of the low-set stage I_0> can be based on definite time or inverse time characteristic. When inverse time characteristic is selected four internationally standardized and two special type time/current curves are available. Both the mode of operation and the desired time/current curve is selected with switchgroup SGF1.

The I_0>> stage can be set out of operation completely, if not needed. When a neutral overcurrent stage is set out of operation the set start current of the stage is displayed with three dashes "- - -".

The inverse time function of stage I_0> can be inhibited, when stage I_0>> is starting, in which case the operate time is determined by stage I_0>>.

Filter characteristics of the measuring inputs

A low-pass filter suppresses the harmonics of the phase currents and the earth-fault current measured by the module. Figure 1 shows the signal suppression as a function of the frequency.

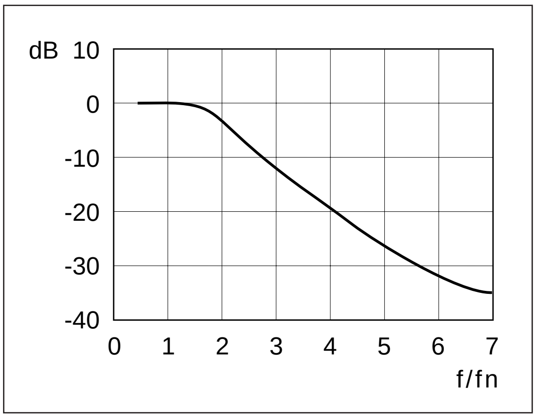


Fig. 1. Filter characteristics of the measuring inputs of the module SPCJ 4D28

Phase discontinuity protection unit

The overcurrent and earth-fault relay module SPCJ 4D28 is provided with a phase discontinuity protection unit which monitors the minimum and maximum phase currents. The difference between these currents is calculated from the expression $\Delta I = (I_{max}-I_{min})/I_{max} \times 100\%$. The phase discontinuity protection is not in use when the measured currents fall below $0.1 \times I_n$.

The phase discontinuity protection stage starts, if the current difference exceeds the set start current ΔI of the stage. Should the duration of the phase discontinuity situation exceed the set operate time tΔ> of the stage the stage operates issuing an operate signal, which can be routed to the desired output relay. At the same time a red operation indicator code is lit on the display.

The phase discontinuity protection stage can be set out of operation completely, if not needed. When the stage is set out of operation the set start current is displayed with three dashes "- - -".

The operation of the phase discontinuity protection stage can be inhibited by an external control signal BS1 applied to the relay module. The external blocking signal is configured with switch SGB1/6.

Circuit breaker failure protection unit

The overcurrent and earth-fault relay module SPCJ 4D28 is provided with a circuit breaker failure protection unit (CBFP) which provides a trip signal TS1 within 0.1...1 s after the trip signal TS2, TS3 or TS4 has been delivered, provided the fault still persists after the time has elapsed. The CBFP normally controls the circuit breaker which precedes the circuit breaker in question. The CBFP can also be used to establish a redundant trip system by using two trip coils in the circuit breaker and controlling one of the coils with TS2, TS3 or TS4 and the other with TS1. The switches SGF4/5...7 are used for activating the circuit breaker failure protection. The operate time is set in submenu 5 of register A.

Output signals

Switchgroups SGR1...11 are used for routing the start or trip signals of any protection stage to the desired start outputs SS1...SS4 or trip outputs TS...TS4.

The output signals TS1…TS4 can be assigned a self-holding function with switches SGF4/1…4. In this case the output signal remains active, although the signal that caused the operation resets. The resetting functions are explained in paragraph "Resetting". The TRIP indicator on the front panel can be set to be lit on activation of any of the output signals. The operation indicator remains lit after the output signal has disappeared. The functions are selected with switchgroup SGF5.

Auto-reclose start initiation signals

The start signals AR1, AR2 and AR3 can be used as start initiation signals for the desired autoreclose shots. The initiation signal AR2 can be programmed to be activated by the desired start and operate signals of the overcurrent module. The start signal AR3 can be programmed to be activated by the desired start and operate signals of the earth-fault module and the initiation signal AR1 by the start and operate signals of both the overcurrent module and the earth-fault module.

Second settings

Either the main settings or the second settings can be selected as currently used settings. Switching between the main settings and the second settings can be done in three different ways:

1) By command V150 over the serial communication bus
2) By an external control signal BS1, BS2 or RRES (BS3)
3) Via the push-buttons of the relay module, see submenu 4 of register A. When the value of submenu 4 is 0 the main settings are used and when the value of submenu 4 is 1 the second settings are used.

The main and second settings can be read and set via the serial bus using the S parameters. Those settings only, which currently are used, can be read and set with the push-buttons and the display on the front panel. When the second settings are used the indicators of the settings are flashing.

Note!
If external control signals have been used for selecting the main or second settings, it is not possible to switch between the settings over the serial bus or using the push-buttons on the front panel.

Resettings

The LED operation indicators, the operation code numbers of the display, the latched output relays and the registers of the module can be reset with the push-buttons on the front panel, with an external control signal or by a command via the serial bus, see table below.

Way of resetting	Resetting of indicators	Unlatching of output relays	Erasing of registers
RESET	x		
PROGRAM (dark display)	x	x	
RESET & PROGRAM	x	x	x
External control signal BS1, BS2 or RRES (BS3), when			
SGB2…3/6 = 1	x		
SGB_7/ = 1	x	x	
SGB_8/ = 1	x	x	x
Parameter V101	x	x	
Parameter V102	x	x	x

Block diagram

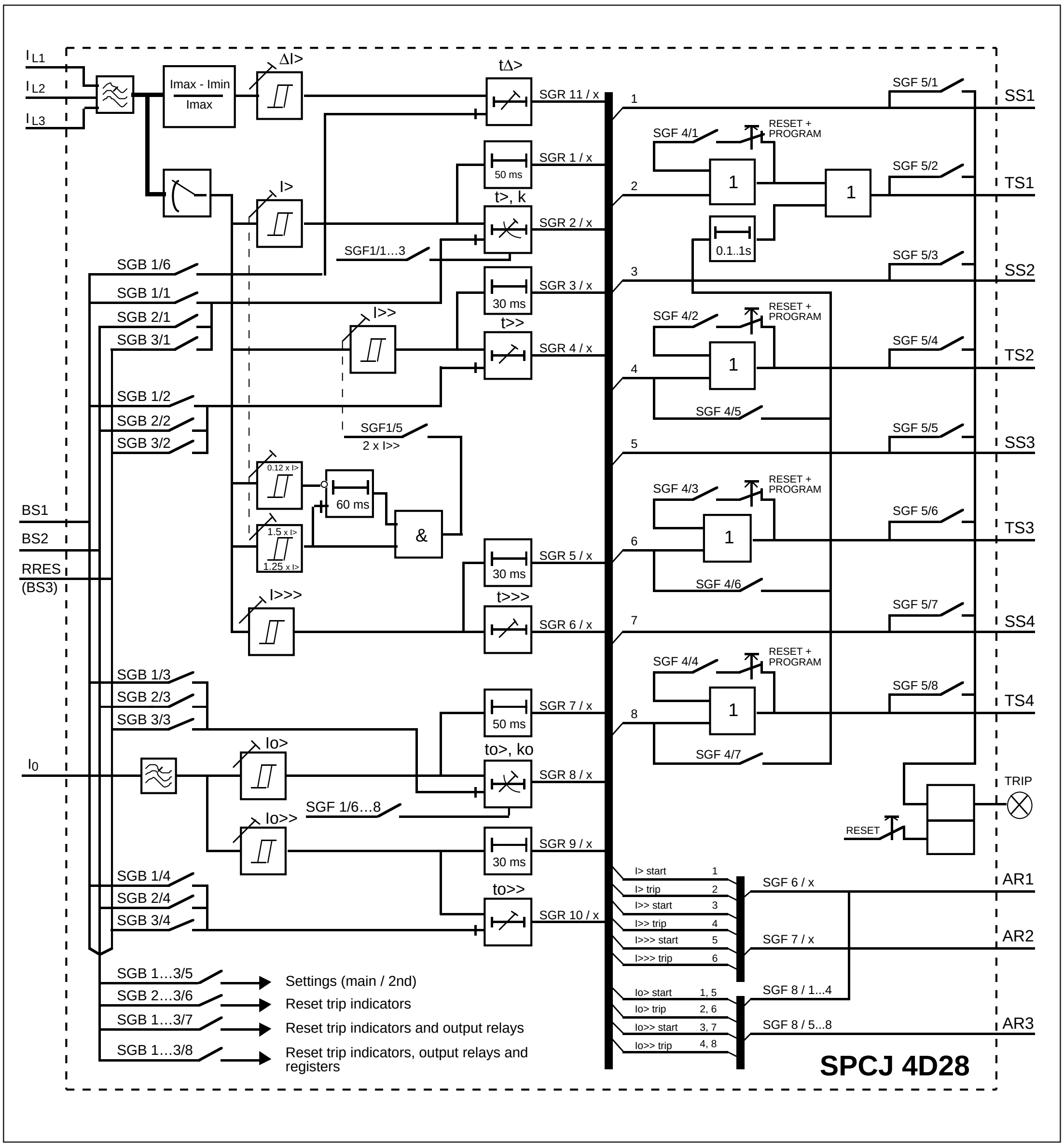


Fig. 2. Block diagram for overcurrent and earth-fault relay module SPCJ 4D28

I_{L1}, I_{L2}, I_{L3}	Phase currents
I_0	Neutral current
BS1, BS2, RRES (BS3)	External signals for blocking or resetting
SGF1..8	Selector switchgroups for relay functions
SGB1...3	Selector switchgroups for external control signals
SGR1...11	Selector switchgroups for configuration of output relays
SS1...SS4, TS1...TS4	Output signals
AR1, AR2, AR3	AR start initiation signal
TRIP	Red operation indicator

Note!
All input and output signals of the relay module are not necessarily wired to the terminals of each protection relay containing the SPCJ 4D28 module. The signals wired to the terminals are shown in the signal diagram of the concerned protection relay.

Front panel

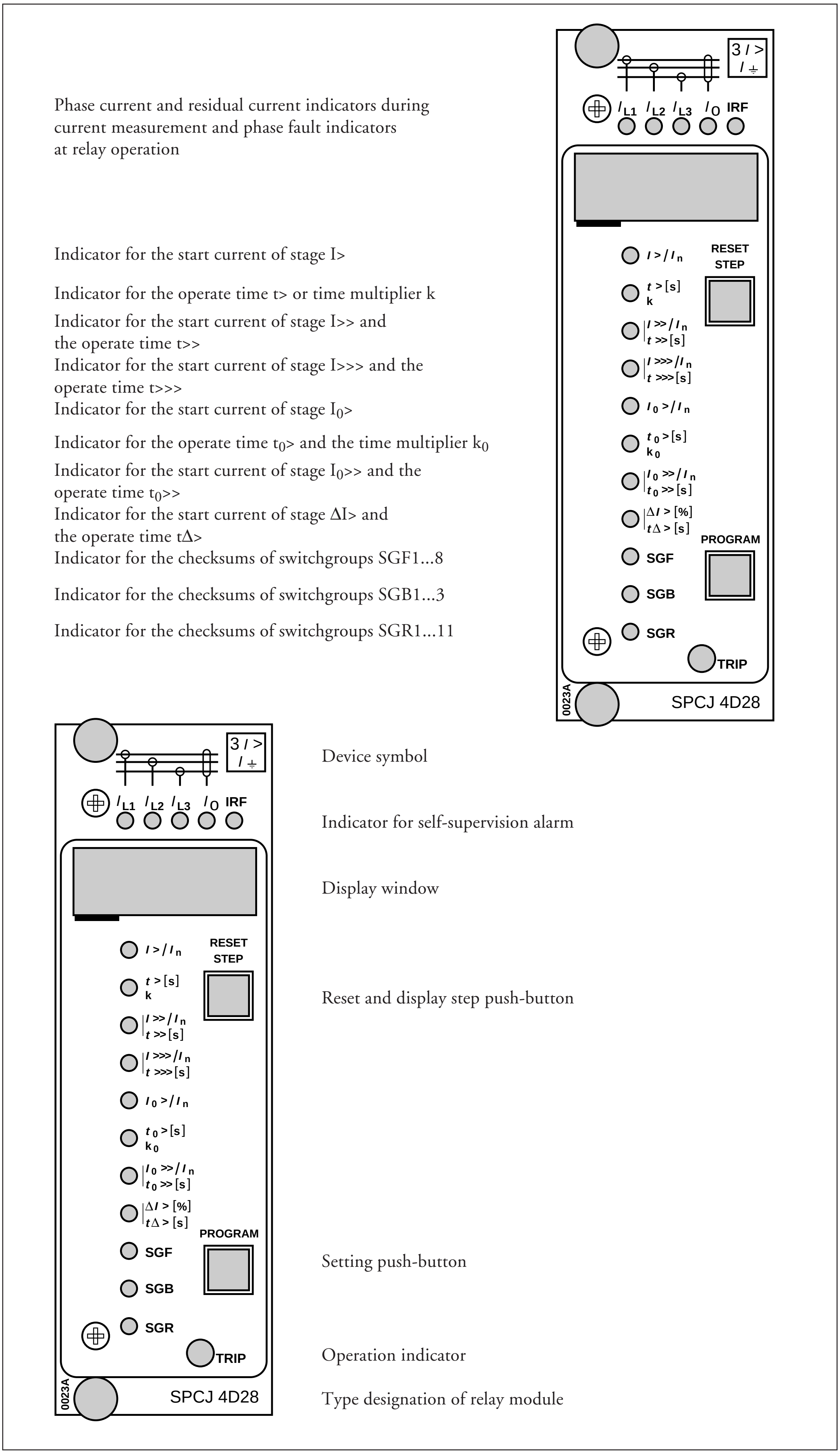


Fig. 3. Front panel of the combined overcurrent and earth-fault relay module SPCJ 4D28

Operation indicators

Each protection stage has its own red start and trip code shown as a number on the display. The TRIP indicator at the bottom right corner is shared by the different protection stages. Switchgroup SGF5 is used for defining the mode of function of the TRIP indicator.

The code numbers indicating tripping and the red TRIP indicator remain lit, when the protection relay has issued a trip signal. Thus it is easy to identify the tripping stage. The indicators remain lit even though the stage that caused the indication resets, and they have to be separately reset. On the other hand, the code numbers indication starting automatically turned off when the protection stage resets. If the stage that started also operates the code number indicating starting turns into a code number indicating operation. When desired, the code numbers indicating starting can be set to remain lit, by giving switches SGF2/1...5 proper settings.

Operation indicators that remain lit are reset either by pressing the RESET push-button on the front panel or by command V101 over the SPA bus. Unreset operation indicators do not affect the operation of the relay module.

The table below shows the code numbers of the display or the corresponding code numbers readable with parameter V9 indicating starting or operation of the relay module.

Indication	Parameter V9	Symbol	Explanation
1	1	I> START	Staring of overcurrent stage I>
2	2	I> TRIP	Operation of overcurrent I>
3	3	I>> START	Staring of overcurrent stage I>>
4	4	I>> TRIP	Operation of overcurrent stage I>>
5	5	I>>> START	Staring of overcurrent stage I>>>
6	6	I>>> TRIP	Operation of overcurrent stage I>>>
7	7	I_0> START	Starting of earth-fault stage I_0>
8	8	I_0> TRIP	Operation of earth-fault stage I_0>
9	9	I_0>> START	Starting of earth-fault stage I_0>>
0	0	I_0>> TRIP	Operation of earth-fault stage I_0>>
11	11	ΔI> TRIP	Operation of phase discontinuity protection stage ΔI>
A	12	CBFP	Operation of circuit breaker failure protection unit

When one of the protection stages of the module operates, the yellow LEDs on the upper part of the front panel show on which phase the current exceeded the set start current of the stage, named phase fault indication. If, for instance, code number 2 and indicators I_{L1} and I_{L2} are lit, operation was caused by overcurrent on the phases L1 and L2. The phase fault indication is reset with the RESET push-button.

The self-supervision alarm indicator IRF indicates that the self-supervision system of the relay module has detected a permanent fault. Once a fault has been detected the red indicator is lit. At the same time the relay module delivers a control signal to the self-supervision system output relay of the protection relay. In addition, in most fault cases, a fault code appears on the display to indicate the type of fault. This fault code, which consists of a red figure one (1) and a green 1...3 digit code number cannot be removed by resetting. The code number should be recorded after a fault situation and stated when service is ordered.

Settings

Numerical settings *(modified 99-10)*

The setting values are indicated by the three rightmost digits on the display. The LED indicators adjacent to the symbols of the quantities to be set indicates the quantity currently being displayed.

Setting	Explanation	Setting range (factory default)
$I>/I_n$	Start current of stage I> as a multiple of the energizing input used.	0.5…5.0 x I_n *) (0.5 x I_n)
t>	Operate time of stage I>, in seconds at definite time characteristic.	0.05...300 s (0.05 s)
k	Time multiplier k of stage I> at inverse time characteristic.	0.05...1.00 (0.05)
$I>>/I_n$	Start current of stage I>> as a multiple of the energizing input used.	0.5...40.0 x I_n and ∞ * *) (0.5 x I_n)
t>>	Operate time of stage I>>, in seconds.	0.04...300 s (0.04 s)
$I>>>/I_n$	Start current of stage I>>> as a multiple of the energizing input used.	0.5...40.0 x I_n and ∞ * *) (0.5 x I_n)
t>>>	Operate time of stage I>>>, in seconds.	0.04...30 s (0,04 s)
I_0/I_n	Start current of stage I_0> as a multiple of the energizing input used.	0.1...0.8 x I_n (0.1 x I_n)
t_0>	Operate time of stage I_0>, in seconds, at definite time characteristic.	0.05...300 s (0.05 s)
k_0	Time multiplier k_0 of stage I_0> at inverse time characteristic.	0.05...1.00 (0.05)
$I_0>>/I_n$	Start current of stage I_0>> as a multiple of the energizing input used.	0.1...10.0 x I_n and ∞ * *) (0.1 x I_n)
t_0>>	Operate time of stage I_0>>, in seconds.	0.05...300 s (0.05 s)
ΔI> [%]	Start current of stage ΔI> as the difference between the minimum and maximum phase current measured, expressed as percentage of the measured current of the energizing input used. 10...100%.	10...100% and ∞ * *) (10%)
tΔ>	Operate time of stage ΔI>, in seconds.	1...300 s (1 s)
CBFP	Operate time in seconds of the circuit breaker failure protection	0.1…1.0 s (0.2 s)

*) At inverse time characteristic the relay allows setting above 2.5 x I_n, but regards any setting >2.5 x I_n as being equal to 2.5 x I_n.
**) The stage can be set out of operation with SGF switches. This state is indicated as "- - -" on the display.

Note!
The continuous current carrying capacity of the energizing inputs is 4.0 x I_n.

Switch settings

Additional functions required for individual applications are selected with switchgroups SGF1...8, SGB1...3 and SGR1...11. The switch numbers, 1...8, and the switch positions, 0 and 1, are displayed when the switches are being set manually. Normally, the checksums of the switchgroups are displayed, see the main menu in section "Menu chart".

The tables below indicates the factory default settings of the switches and the corresponding checksums. The method for manual calculation of the checksum is shown at the end of this section.

The switchgroups SGF1...8 are used for configuring the desired functions as follows:

Switch	Function	Factory default
SGF1/1 SGF1/2 SGF1/3	Definite time or inverse time characteristic for stage I>. When the inverse time has been selected, the desired current/time characteristic is selected as follows:	0 0 0

SGF1/1	SGF1/2	SGF1/3	Characteristic	Operate time t> or time/current curve
0	0	0	Definite time	0.05...300 s
1	0	0	Inverse time	Extremely inverse
0	1	0	"	Very inverse
1	1	0	"	Normal inverse
0	0	1	"	Long-time inverse
1	0	1	"	RI type characteristic
0	1	1	"	RXIDG type characteristic
1	1	1	---	(Long-time inverse)

Switch	Function	Factory default
SGF1/4	Not in use	0
SGF1/5	Automatic doubling of the set start current of stage I>>, when the object to be protected is connected to the network. When SGF1/5 = 0, the doubling function is out of use. When SGF1/5 = 1, the set start current of stage I>> is automatically doubled. This feature allows the start current of stage I>> to be set below the level of the connection inrush current.	0
SGF1/6 SGF1/7 SGF1/8	Definite time or inverse time characteristic for stage I_0>. When the inverse time has been selected, the desired current/time characteristic is selected as follows:	0 0 0

SGF1/6	SGF1/7	SGF1/8	Characteristic	Operate time t_0> or time/current curve
0	0	0	Definite time	0.05...300 s
1	0	0	Inverse time	Extremely inverse
0	1	0	"	Very inverse
1	1	0	"	Normal inverse
0	0	1	"	Long-time inverse
1	0	1	"	RI type characteristic
0	1	1	"	RXIDG type characteristic
1	1	1	---	(Long-time inverse)

Switch	Function	Factory default
∑ SGF1		0

Switch	Function	Factory default
SGF2/1 SGF2/2 SGF2/3 SGF2/4 SGF2/5	Mode of operation of the start indicating code numbers of the different stages. When the switches are in position 0, the start indication code number automatically resets, once the fault disappears. When the switch is in position 1, the code number remains lit, although the fault disappears.	0 0 0 0 0

Switch	Stage	Switch position	
		Code resets	Code remains
SGF2/1	I>	0	1
SGF2/2	I>>	0	1
SGF2/3	I>>>	0	1
SGF2/4	I_0>	0	1
SGF2/5	I_0>>	0	1

Switch	Function	Factory default
SGF2/6 SGF2/7 SGF2/8	Inhibition of the operation of stage I>>, stage I>>> and stage I_0>>. When the operation is inhibited the display shows "- - -", when the set value is displayed	0 0 0

Switch	Stage	Switch position	
		Not inhibited	Inhibited
SGF2/6	I>>	0	1
SGF2/7	I>>>	0	1
SGF2/8	I_0>>	0	1

Switch	Function	Factory default
∑ SGF2		0

SGF3/1	Phase discontinuity protection stage ΔI> to be set out of use. When SGF3/1 = 1, the phase discontinuity protection stage is out of use. The out of use state is indicated as "- - -" on the display.	1
SGF3/2 SGF3/3 SGF3/4 SGF3/5	Resetting times of stage I> and I_0>.	0 0 0 0

Switch	Stage	Switch position			
		40 ms	100 ms	500 ms	1000 ms
SGF3/2	I>	0	1	0	1
SGF3/3		0	0	1	1
SGF3/4	I_0>	0	1	0	1
SGF3/5		0	0	1	1

SGF3/6	Inverse time operation of stage I> to be inhibited by the starting of stage I>>. When SGF3/6 = 1, the inverse time operation is inhibited.	0
SGF3/7	Inverse time operation of stage I> to be inhibited by the starting of stage I>>>. When SGF3/7 = 1, the inverse time operation is inhibited.	0
SGF3/8	Inverse time operation of stage I_0> to be inhibited by the starting of stage I_0>>. When SGF3/8 = 1, the inverse time operation is inhibited.	0
∑ SGF3		1

Switch	Function	Factory default
SGF4/1 SGF4/2 SGF4/3 SGF4/4	Selection of self-holding for output signal TS1 Selection of self-holding for output signal TS2 Selection of self-holding for output signal TS3 Selection of self-holding for output signal TS4 When the switch is in position 0, the output signal returns to its initial state, when the measuring signal that caused operation falls below the set start level. When the switch is in position 1 the output signal remains high although the measuring signal that caused operation falls below the set start level. At self-holding the output signal is reset with the push-buttons on the front panel, via an external control input or the serial bus, see section "Description of function".	0 0 0 0
SGF4/5 SGF4/6 SGF4/7	Starting of the circuit breaker failure protection (CBFP) by signal TS2 Starting of the circuit breaker failure protection (CBFP) by signal TS3 Starting of the circuit breaker failure protection (CBFP) by signal TS4 When the switch is in position 1, the output signal TS_ starts the circuit breaker failure protection. If the operate time of the CBFP expires while the output signal is active, the CBFP generates an operate signal TS1. When the switch is in position 0, the CBFP is set out of use.	0 0 0
SGF4/8	Not in use	0
∑ SGF4		0

SGF5/1 SGF5/2 SGF5/3 SGF5/4 SGF5/5 SGF5/6 SGF5/7 SGF5/8	Selection of the signal to control the TRIP indicator on the front panel. When the switch corresponding to a certain output signal is in position 1, the TRIP indicator is lit on activation of the output signal.	0 1 0 1 0 1 0 1
∑SGF5		170

Switch	Output signal	Switch position TRIP indicator not lit	TRIP indicator lit
SGF5/1	SS1	0	1
SGF5/2	TS1	0	1
SGF5/3	SS2	0	1
SGF5/4	TS2	0	1
SGF5/5	SS3	0	1
SGF5/6	TS3	0	1
SGF5/7	SS4	0	1
SGF5/8	TS4	0	1

Switchgroups SGF6…8

(modified 96-02)

Using the different start and operation signals as autoreclose start initiation signals AR1, AR2 or AR3. The signal selection possibilities are shown in Fig. 4 below.

In the figure the start and operate signals of the different protection stages are connected to the desired autoreclose start line AR1, AR2 or AR3, for instance, by encircling the signal crossing point. The numbers of the different switches and their weight factors are marked near the crossing points. The checksums for the different switch groups are obtained by adding the weight factors of the selected switches.

Switches SGF6/7…8 and SGF7/7…8 are not in use.

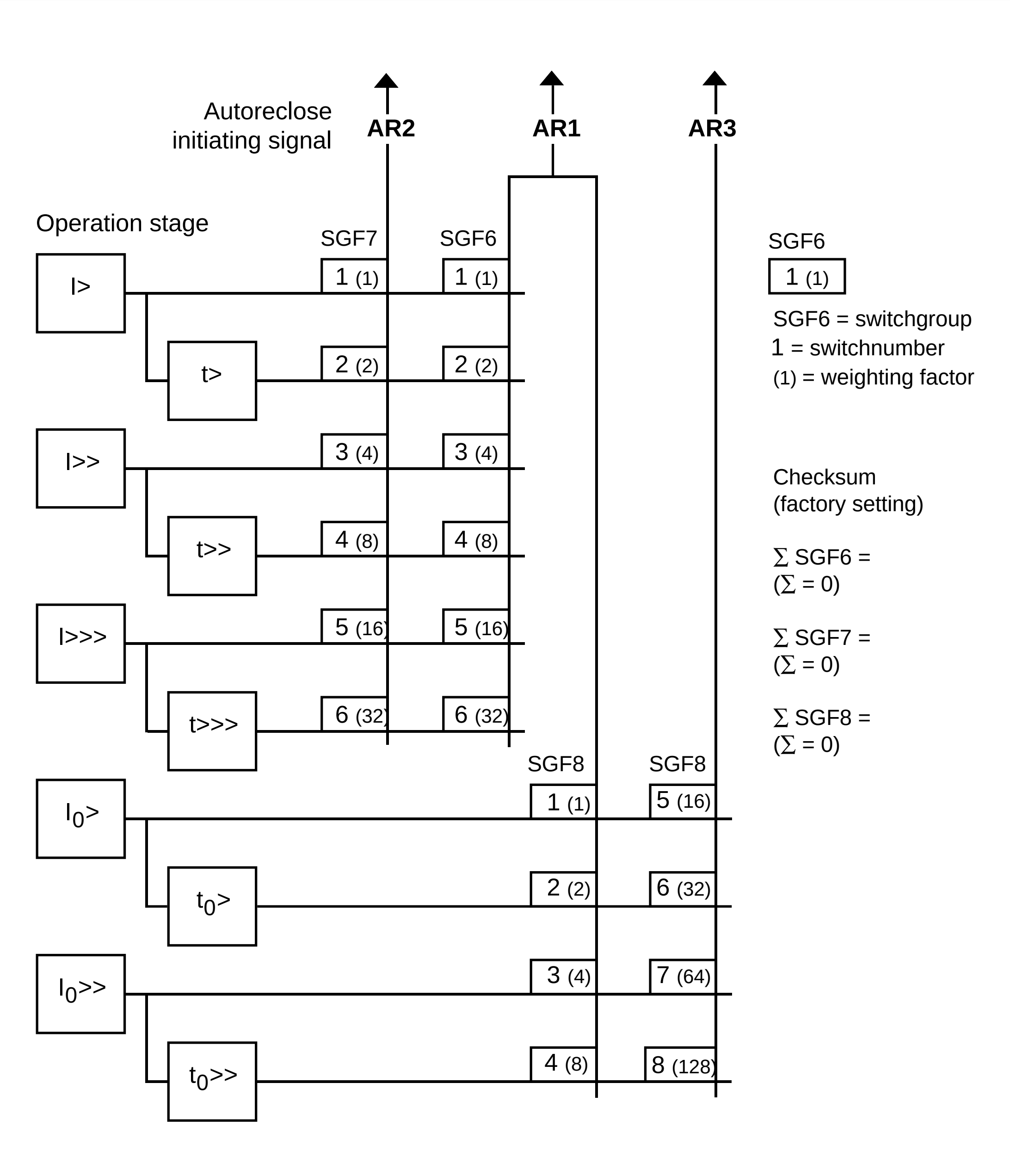


Fig. 4. Selection matrix for the autoreclose initiation signals

Switchgroups SGB1…3

The functions of the control signals BS1, BS2 and RRES (BS3) are defined with switchgroups SGB1…3. The matrix shown below can be used as an aid for making the desired selections. The control signals at the left side in the matrix can be combined with the functions at the upper side by encircling the desired intersection points. Each intersection point is marked with a switch number and the corresponding weight factor of the switch is shown at the bottom row of the matrix. By horizontally adding the weight factors of all the selected switches of a switchgroup the switchgroup checksums is obtained.

Note!
Check if all the control signals of the relay module SPCJ 4D28 are available in the protection relay in question.

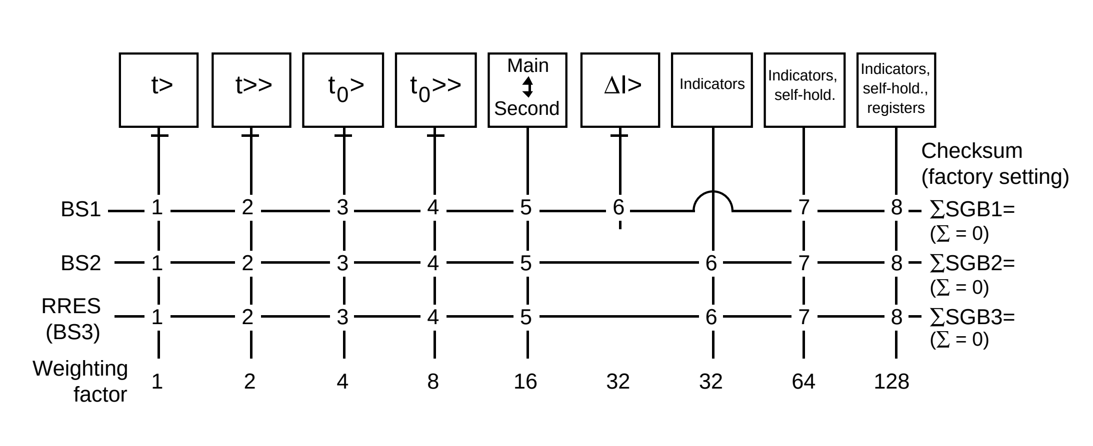


Fig. 5. Control signal matrix of the combined overcurrent and earth-fault relay module SPCJ 4D28.

Switch	Function
SGB_/1...4	Configuration of blocking signals to be applied to one or more protection stages via the external control signals BS1, BS2 and RRES (BS3). When a switch is in position 1, the operation of the concerned protection stage is blocked as long as the control signal is high.
SGB_/5	Switching between main setting values and second settings, either via the serial bus using command V 150, or using an external control signal. When SGB_/5 = 0, the setting values cannot be switched with an external control signal. When SGB1/5 = 1, the currently used setting values are determined exclusively by the state of the external control signal. Note! When the relay is provided with second settings in addition to the main settings, it is important that switch SGB_/5 has the same setting in the main settings and the second settings.
SGB1/6	Blocking of stage ΔI> via the external control signal BS1. The principle of operation is the same as for switches SGB_/1…4.
SGB2…3/6	Resetting of the operation indicators on the front panel, see section "Resetting"
SGB_/7	Resetting of the operation indicators and the latched output relays, see section "Resetting"
SGB_/8	Resetting of the operation indicators, the latched output relays and the registers, see section "Resetting"

Switchgroups SGR1...11

(modified 96-02)

The start and operate signals of the protection stages are combined with the outputs SS1... SS4 and TS1...TS4 with the switches of switchgroups SGR1...11.

The matrix shown below can be used as an aid for making the desired selections. The start and operate signals of the different protection stages can be combined with the output signals SS1...SS4 and TS1...TS4 by encircling the desired intersection points. Each intersection point is marked with a switch number and the corresponding weight factor of the switch is shown at the bottom row of the matrix. By horizontally adding the weight factors of all the selected switches of a switchgroup the switchgroup checksums is obtained.

Note!
Check if all the start and operate signals of the relay module SPCJ 4D28 are available in the protection relay in question.

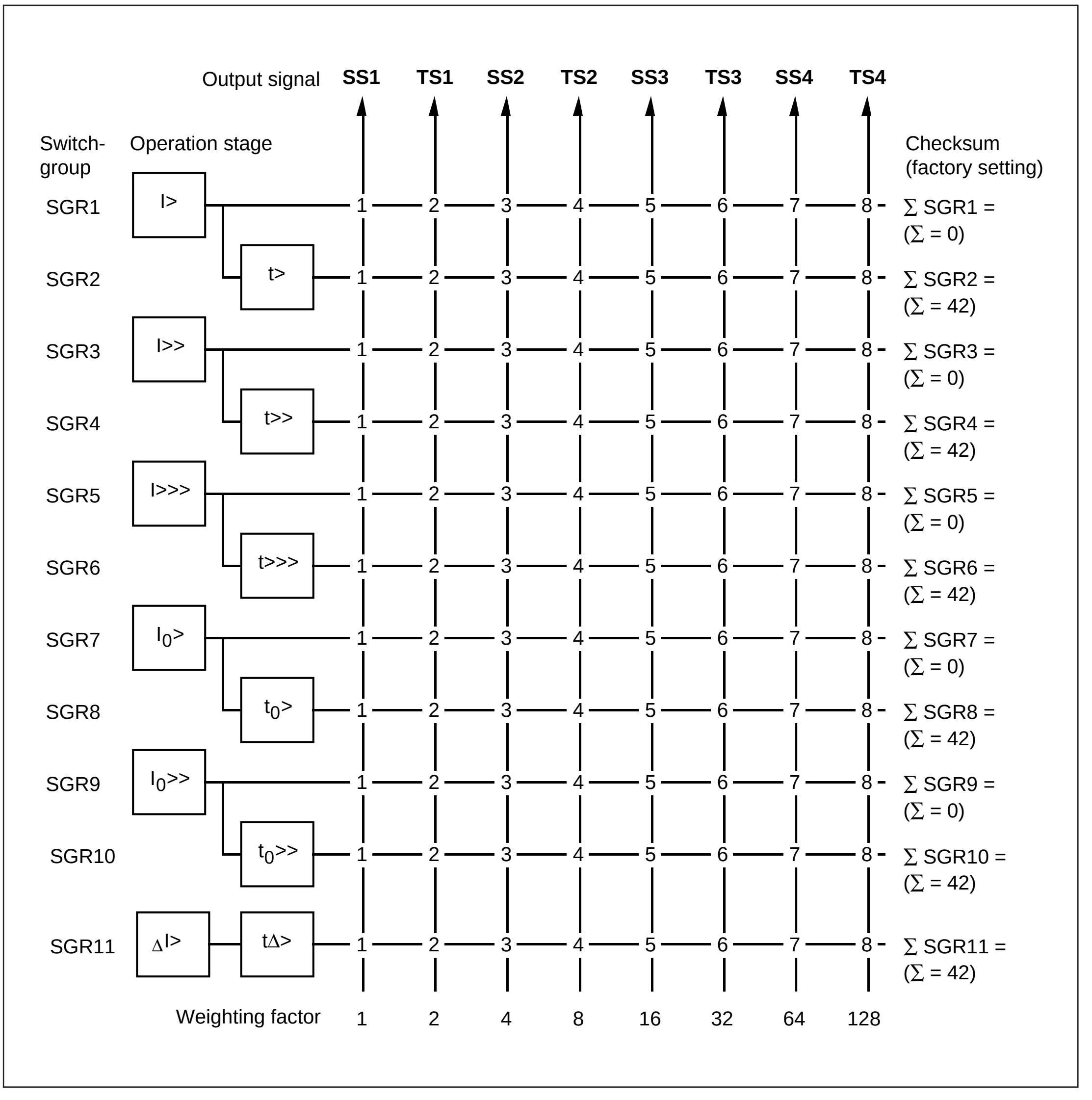


Fig. 6. Output signal matrix of the combined overcurrent and earth-fault relay module SPCJ 4D28.

Manual checksum calculation

Switch	Weight factor		Position		Value
SGF1/1	1	x	1	=	1
SGF1/2	2	x	0	=	0
SGF1/3	4	x	1	=	4
SGF1/4	8	x	0	=	0
SGF1/5	16	x	0	=	0
SGF1/6	32	x	0	=	0
SGF1/7	64	x	1	=	64
SGF1/8	128	x	0	=	0
Checksum of switchgroup SGF1 Σ			=		69

Measured data

The measured values are indicated by the three right-most digits on the display. The measured value currently presented is indicated by a yellow LED above the display.

Indicator	Measured data	Measuring range
I_{L1}	Measured line current on phase L1 as a multiple of the rated current I_n of the energizing input used.	0…63 x I_n
I_{L2}	Measured line current on phase L2 as a multiple of the rated current I_n of the energizing input used.	0…63 x I_n
I_{L3}	Measured line current on phase L3 as a multiple of the rated current I_n of the energizing input used.	0…63 x I_n
I_0	Residual current as a multiple of the rated current I_n of the energizing input used.	0…21 x I_n
I_0	In the submenu of the residual current the difference ΔI between the minimum phase current and the maximum phase current is available, expressed as a percentage.	0…100%

Recorded information

The left-most digit of the display shows the register address and the other three digits the recorded information. The structure of the registers is presented in the section "Main menus and submenus of settings and registers".

Register/ STEP	Recorded information
1	Current measured on phase L1, expressed as a multiple of the rated current I_n. The register is updated when one of the overcurrent stages (I>, I>> or I>>>) starts or operates. Then the previous current values will be pushed forwards one step in the stack while the oldest value is lost. The last five current values recorded are memorized so that the most recent value is stored in the main register and the other four values are stored in the subregisters. When the relay starts but does not operate, the relay module memorizes the maximum current measured on phase L1 during the start situation. When the stage operates, the value of the current measured at the moment of operation is recorded.
2	Register 2 records the events of phase L2. The operation principle is the same as that of register 1.
3	Register 3 records the events of phase L3. The operation principle is the same as that of register 1.
4	Duration of the latest start situation of stage I>, expressed as a percentage of the set operate time or, at IDMT mode of operation, of the calculated operate time. The register is updated, once the I> stage starts. Then the previously recorded values will be pushed forwards one step in the stack while the oldest value is lost. The last five current values recorded are memorized so that the most recently recorded value is stored in the main register and the other four values are stored in the subregisters. When the overcurrent stage operates, the counter reading is 100. Subregister 5 states the number of times stage I> has started, i.e. how many times the start value of the stage was exceeded, n(I>) = 0...255.
5	Duration of the latest start situation of stage I>>, expressed as a percentage of the set operate time. The operation principle is the same as that of register 4. Subregister 5 states the number of times stage I>> has started, i.e. how many times the set start current of the stage were exceeded, n(I>>) = 0...255.
6	Residual current I_0 measured, expressed as a multiple of the rated current I_n. The register is updated each time one of the residual current stages (I_0> or I_0>>) starts or operates. Then the previous current values will be pushed forwards one step in the stack while the oldest value is lost. The last five current values recorded are memorized in such a way that the most recent value is stored in the main register and the other four values in the subregisters. When the relay starts but does not operate, the relay module memorizes the maximum residual current measured during the start situation. When the stage operates, the value of the current measured at the moment of operation is recorded.

<table>
<tr><th>Register/ STEP</th><th>Recorded information</th></tr>
<tr><td>7</td><td>Duration of the latest start situation of stage I_0>, expressed as a percentage of the set operate time or, at IDMT mode of operation, of the calculated operate time. The register is updated each time the I_0> stage starts. Then the previous values recorded will be pushed forwards one step in the stack while the oldest value is lost. The last five current values recorded are memorized so that the most recent value is stored in the main register and the other four values are stored in the subregisters. When the stage operates, the counter reading is 100.

Subregister 5 states the number of times stage I_0> has started, i.e. how many times the set start current of the stage was exceeded, n(I_0>) = 0...255.</td></tr>
<tr><td>8</td><td>Duration of the latest start situation of stage I_0>>, expressed as a percentage of the set operate time. The operation principle is the same as that of register 7.

Subregister 5 states the number of times stage I_0>> has started, i.e. how many times the set start current of the stage was exceeded, n(I>>) = 0...255.</td></tr>
<tr><td>9</td><td>Unbalance ratio ΔI expressed as a percentage, i.e. the difference between the minimum phase current and the maximum phase current. When the phase discontinuity protection unit operates, the register is updated with the value at the moment of operation. Then the values recorded previously will be pushed forwards one step in the memory stack while the oldest value is lost. The last five current values recorded are available in the memory stack.</td></tr>
<tr><td>11</td><td>Continuous 15 min maximum demand current, updated once a minute.

Submenu 1 contains the highest maximum demand current value recorded after the last relay reset.</td></tr>
<tr><td>0</td><td>Display of external blocking and control signals.

The right-most digit indicates the status of the external control signals of the relay module as follows:

<table>
<tr><th rowspan="2">Displayed figure</th><th colspan="3">Activated signal</th></tr>
<tr><th>BS1</th><th>BS2</th><th>RRES (BS3)</th></tr>
<tr><td>0</td><td></td><td></td><td></td></tr>
<tr><td>1</td><td>x</td><td></td><td></td></tr>
<tr><td>2</td><td></td><td>x</td><td></td></tr>
<tr><td>3</td><td>x</td><td>x</td><td></td></tr>
<tr><td>4</td><td></td><td></td><td>x</td></tr>
<tr><td>5</td><td>x</td><td></td><td>x</td></tr>
<tr><td>6</td><td></td><td>x</td><td>x</td></tr>
<tr><td>7</td><td>x</td><td>x</td><td>x</td></tr>
</table>

The functions of the external control signals are defined with the switches of switchgroups SGB1...3.</td></tr>
</table>

Register/ STEP	Recorded information
	From register 0 it is possible to enter the TEST mode, in which the start and operate signals of the module can be activated one by one. The table below shows the activation order and the corresponding indicator lit when a signal is tested. Indicator — Signal activated I> — start signal of stage I> t> — operate signal of stage I> I>> — start and operate signal of stage I>> I>>> — start and operate signal of stage I>>> I_0> — start signal of stage I_0> t_0> — operate signal of stage I_0> I_0>> — start and operate signal of stage I_0>> ΔI> — operate signal of stage ΔI> activated For further information about the operation, see description "General characteristics of D-type SPC relay modules".
A	Address code of the relay module, required by the serial communication system. In addition, the following submenus are available in register A: 1. Selection of the data transfer rate, 4.8 kBd or 9.6 kBd, of the relay module. Default setting 9.6 kBd. 2. Bus traffic counter indicating the operating state of the serial communication system. If the relay module is connected to a system including a control data communicator and the communication system is operating, the counter reading is 0. Otherwise the numbers 0...255 are continuously scrolling in the counter. 3. Password required for remote setting. Settings cannot be changed over the serial communication system unless a password (remote setting parameter V160) has been given. 4. Selection of main and second settings (0 = main settings, 1 = second settings). Default setting 0. 5. Selection of operate time for the circuit breaker failure protection, setting range 0.1...1.0 s. Default setting 0.2 s

When the display is dark, press the STEP push-button for 1 second to go to the beginning of the display menu. To go to the end of the display menu, press the STEP push-button for a short moment only (<0.5 s).

The values stored in registers 1...11 are cleared by pressing the push-buttons RESET and PROGRAM simultaneously, by a command V102 over the serial communication system or by an external control signal BS1, BS2 or RRES. The registers are cleared by failures in the auxiliary power supply to the module. The setting values, the address code, the data transfer rate and the password of the relay module are not affected by supply voltage failures. Instructions for specifying the address code and the data transfer rate of the relay module are given in the description "General characteristics of D-type SPC relay modules".

Menu chart

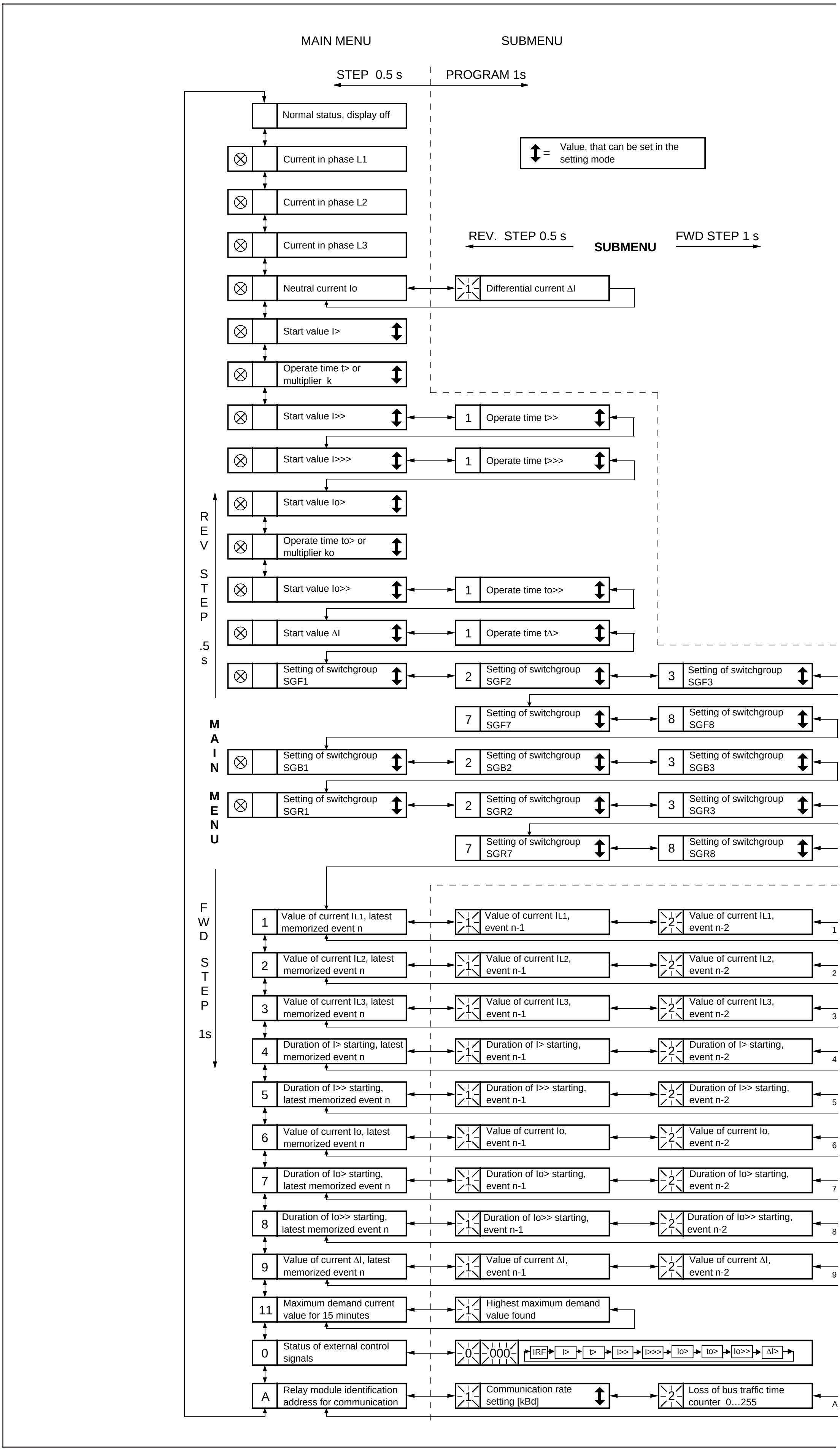
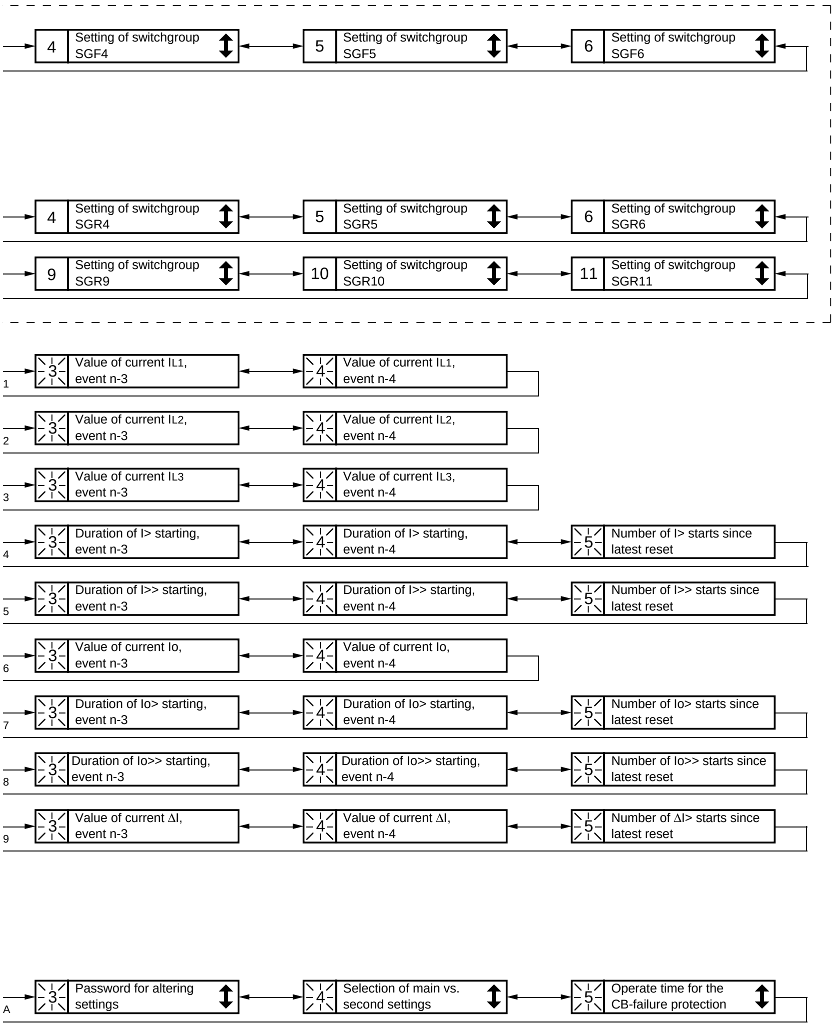


Fig. 7. Main and submenus of the combined overcurrent and earth-fault relay module SPCJ 4D28.

The procedure for entering a submenu or a setting mode, setting a value and entering the TEST mode is described in detail in the manual 1MRS 750066-MUM EN: "General characteristics of D-type SPC relay modules". A short guide follows:

Desired step	Push-button	Action
Forward step in main menu or submenu	STEP	Press for more than 0.5 s
Rapid scan forward in main menu	STEP	Keep depressed
Backward step in main or submenu	STEP	Press less than 0.5 s
Entering a submenu from the main menu	PROGRAM	Press for 1 s (activated when released)
Entering or leaving a setting mode	PROGRAM	Press for 5 s
Incrementation of value in setting mode	STEP	
Moving cursor in setting mode	PROGRAM	Press for about 1 s
Storing a setting value in setting mode	STEP and PROGRAM	Press simultaneously
Erasing of memorized values and re-setting of latched output relays	STEP and PROGRAM	
Resetting of latched output relays	PROGRAM	Note! Display must be dark



Time/current characteristics
(modified 2002-05)

The overcurrent stage I> and the low-set residual current stage I_0> can be given definite time or an inverse definite time operation characteristic. The settings of the switches SGF1/1...3 determine the mode of operation of stage I> and the switches SGF1/6…8 that of the stage I_0>. See section "Setting switches".

At the IDMT characteristic, the operate time of the stage will be a function of the current: the higher the current, the shorter is the operate time. Six time/current curve groups are available. Four of these comply with the BS 142 and IEC 255 standards and two curve groups, the RI and the RXIDG curve groups are special type curve groups according to ABB praxis.

Characteristics according to IEC 60255 and BS 142

The relay module incorporates four internationally standardized time/current curve groups named "extremely inverse", "very inverse", "normal inverse" and "long-time inverse". The relationship between time and current is in accordance with the standards BS 142 and IEC 60255-3, and can be expressed as follows:

$$t\,[s] = \frac{k \times \beta}{\left(\frac{I}{I>}\right)^{\alpha} - 1}$$

where t = operate time
k = time multiplier
I = phase current value
I> = set current value

The values of the constants α and β determine the slope as follows:

Time/current curve group	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

The standard BS 142.1966 defines the normal current range to be 2...20 times the setting value. In addition, the relay has to start at the latest when the current exceeds the setting value by 1.3 times, if the time/current characteristic is normal inverse, very inverse or extremely inverse. For the long-time inverse characteristic the normal current range is specified to be 2...7 times the setting and the relay is to start when the current exceeds the setting value by 1.1 times.

The operate time tolerances specified by the standard are as follows (E denotes accuracy in per cent, - = not specified):

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

In the normal current ranges specified above the inverse time stages of the overcurrent and earth-fault relay module SPCJ 4D28 fulfil the tolerance requirements of class 5 at all degrees of inversity.

The time/current characteristics according to the IEC and BS standards are illustrated in Fig. 8…11.

Note.
The actual operate time of the relay, presented in the graphs in Fig. 8…11, 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.

RI-type characteristic

The RI-type characteristic is a special characteristic that is principally used to obtain time grading with mechanical relays. The characteristic can be expressed by the mathematical expression

$$t\,[s] = \frac{k}{0.339 - 0.236 \times \frac{I>}{I}}$$

where t = operate time in seconds
k = time multiplier
I = phase current
I> = set start current

The characteristic is illustrated in Fig. 12.

RXIDG-type characteristic

The RXIDG-type characteristic is a special characteristic that is principally used in earth-fault protection, in which a high degree of selectivity is required also at high-resistance faults. In this case the protection can operate in a selective way, even if they are not directional.

Mathematically, the time/current characteristic can be expressed as follows:

$$t\,[s] = 5.8\text{-}1.35 \times \log_e \left(\frac{I}{k \times I>} \right)$$

where t = operate time in seconds
k = time multiplier
I = phase current
I> = set start current

The characteristic is illustrated in Fig. 13.

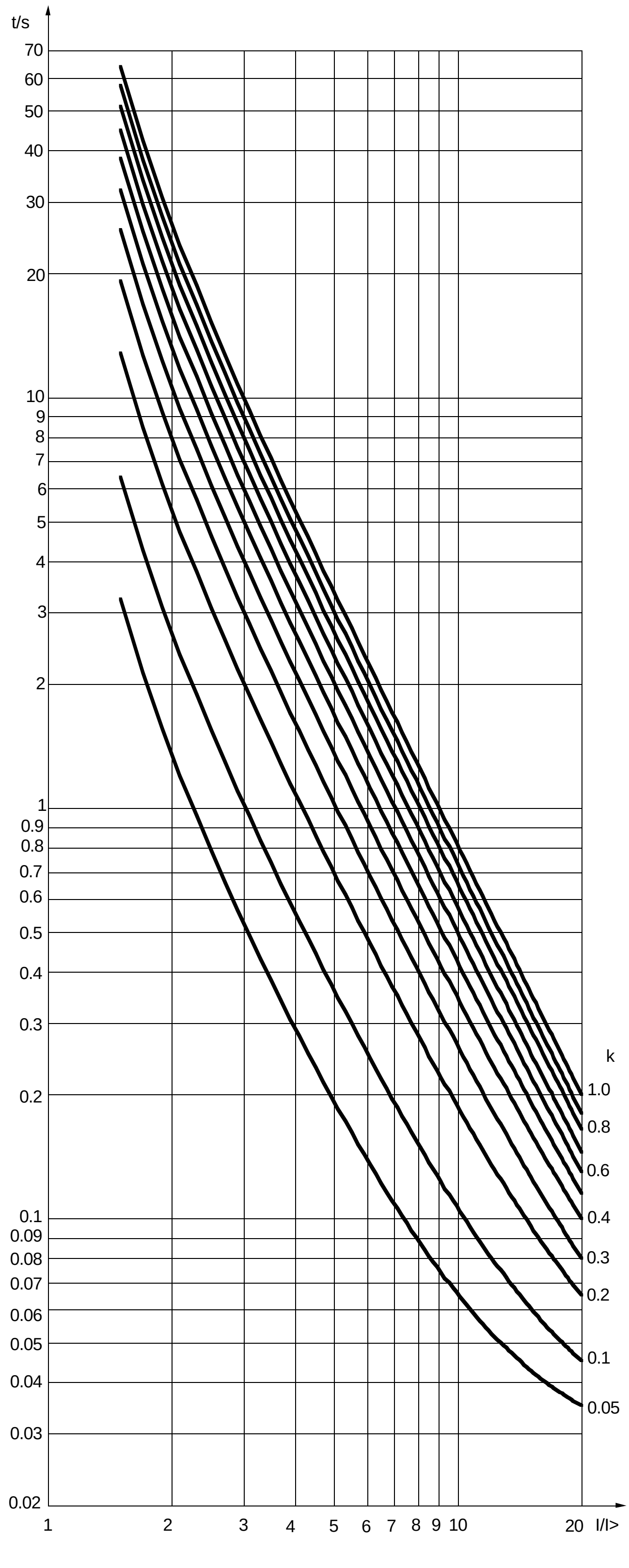


Fig. 8. Inverse-time characteristics of overcurrent and earth-fault relay module SPCJ 4D28

Extremely inverse

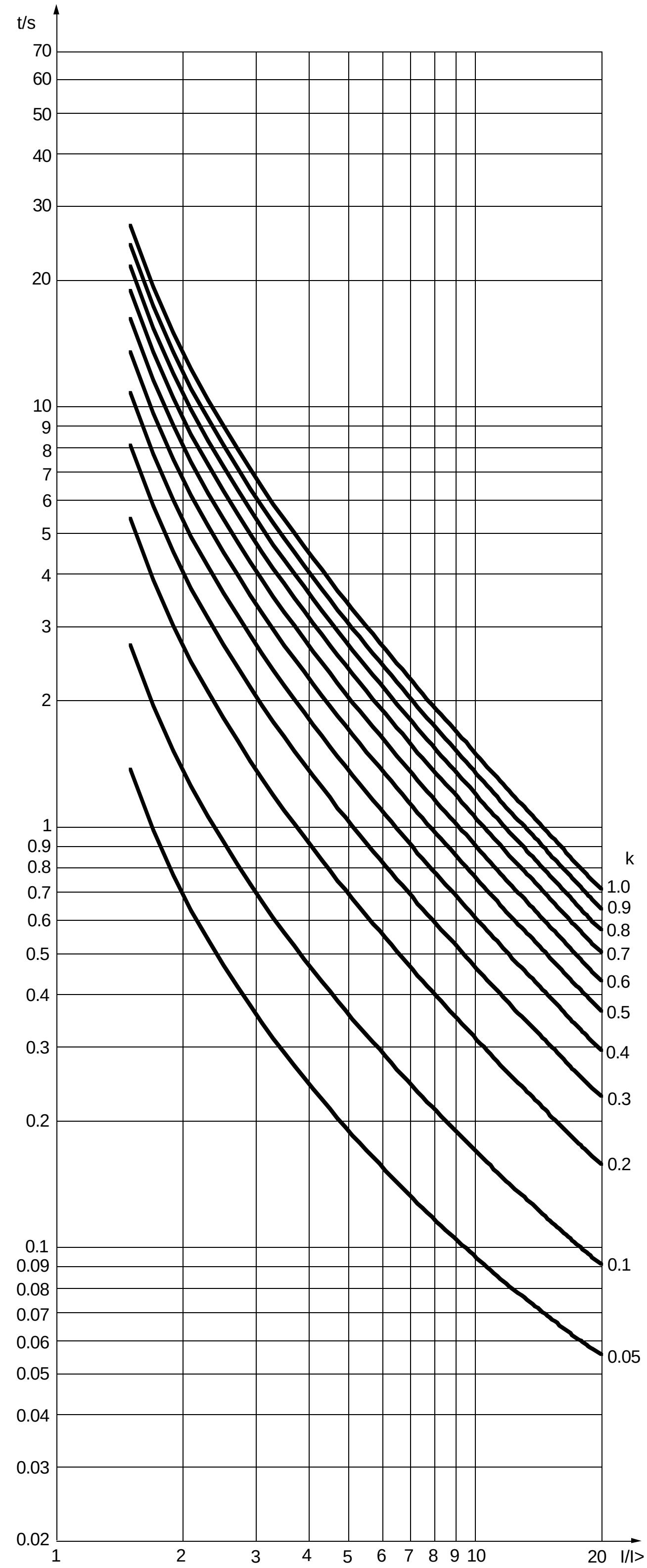


Fig. 9. Inverse-time characteristics of overcurrent and earth-fault relay module SPCJ 4D28

Very inverse

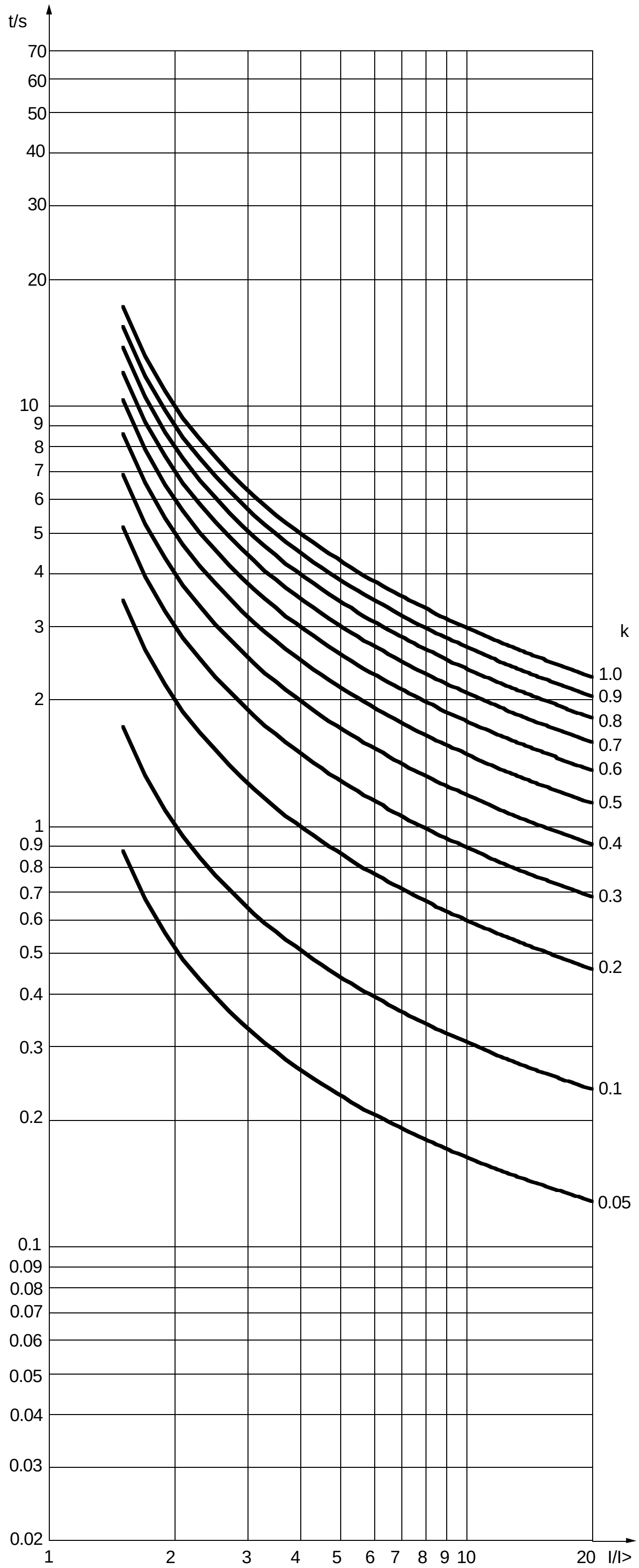


Fig. 10. Inverse-time characteristics of overcurrent and earth-fault relay module SPCJ 4D28

Normal inverse

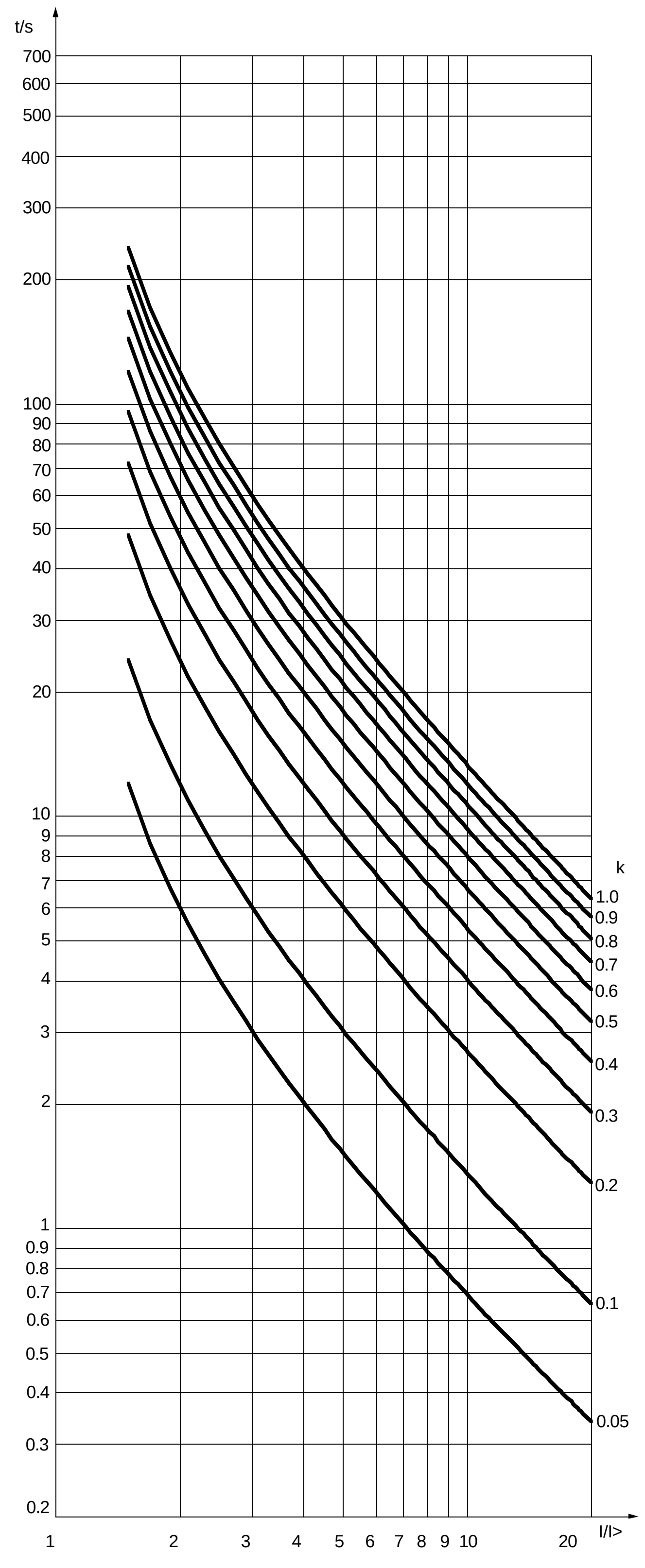


Fig. 11. Inverse-time characteristics of overcurrent and earth-fault relay module SPCJ 4D28

Long-time inverse

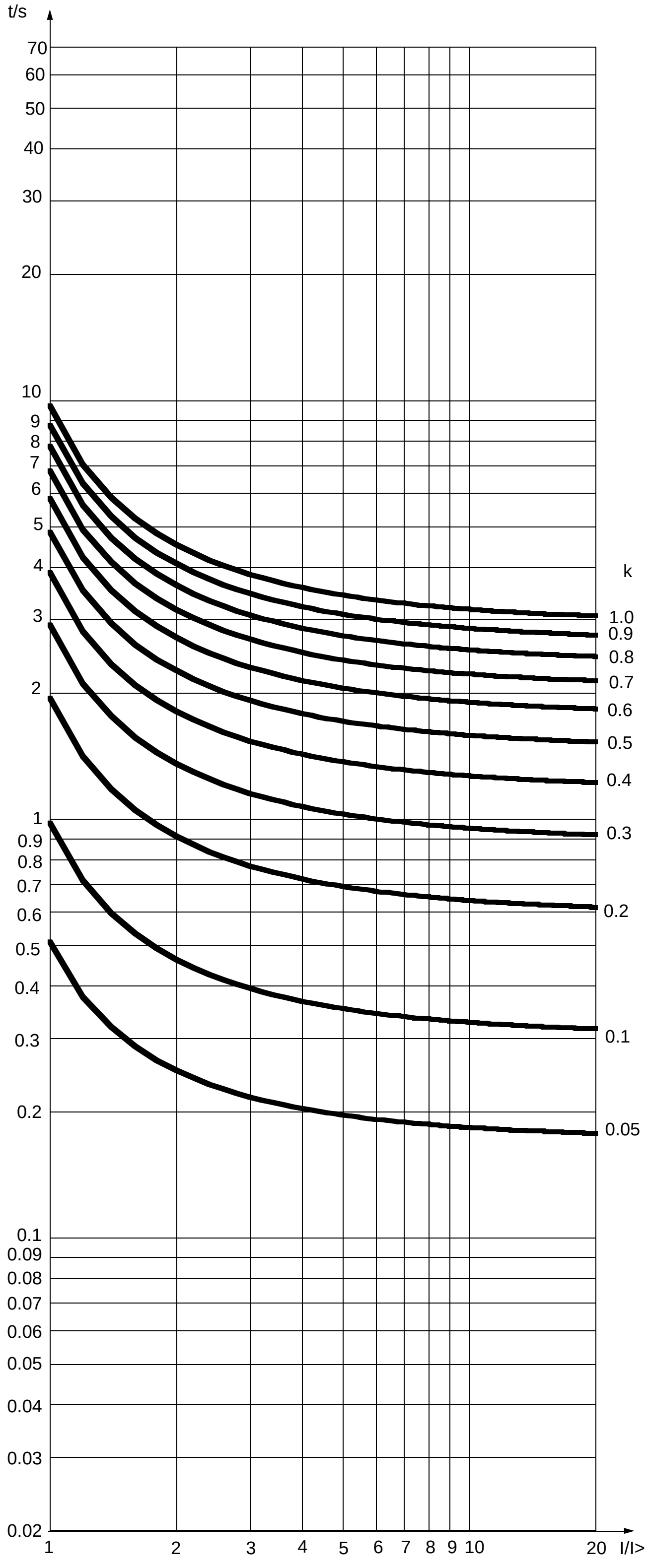


Fig. 12. Inverse-time characteristic of overcurrent and earth-fault relay module SPCJ 4D28

RI-type inverse

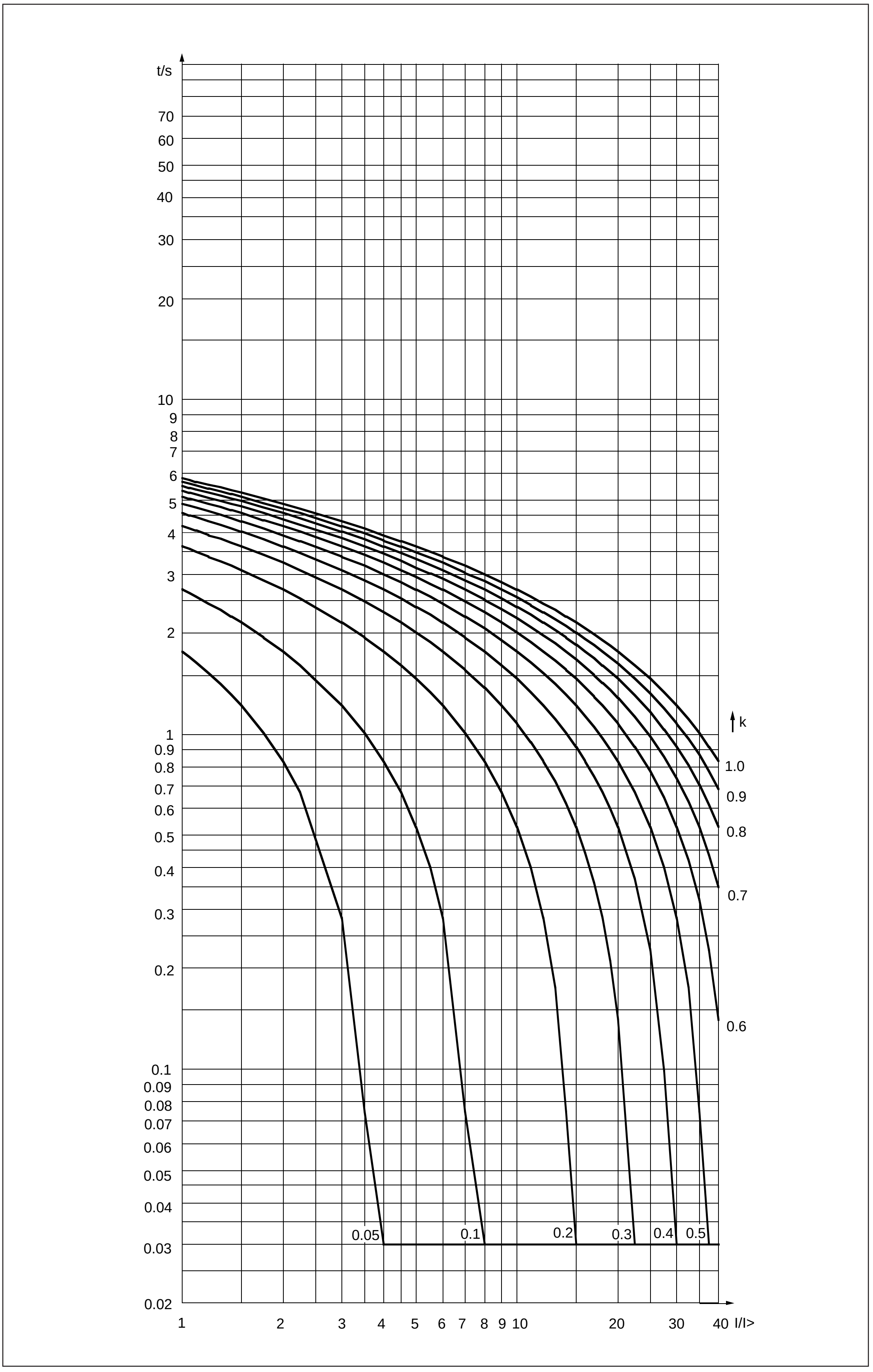


Fig. 13. Inverse-time characteristic of overcurrent and earth-fault relay module SPCJ 4D28

RXIDG-type inverse

Technical data

Feature	Stage I>	Stage I>>	Stage I>>>
Start current			
- at definite time	0.5…5.0 x I_n	0.5…40.0 x I_n and ∞	0.5…40.0 x I_n and ∞
- at inverse time	0.5…2.5 x I_n		
Start time, typ.	70 ms	40 ms	40 ms
Operate time at definite time characteristic	0.05…300 s	0.04…300 s	0.04…30 s
Time/current characteristic at inverse mode	Extremely inv. Very inv. Normal inv. Long-time inv. RI type inv. RXIDG type inv.		
Time multiplier k	0.05…1.0		
Reset time, typ.	40 ms	40 ms	40 ms
Retardation time	<30 ms	<30 ms	<30 ms
Reset ratio, typ.	0.96	0.96	0.96
Operate time accuracy at definite time mode	±2% of set value or ±25 ms	±2% of set value or ±25 ms	±2% of set value or ±25 ms
Accuracy class index E at inverse time mode	5		
Operation accuracy	±3% of set value	±3% of set value	±3% of set value

Feature	Stage I_0>	Stage I_0>>	Stage ΔI>
Start current	0.1…0.8 x I_n	0.1…10.0 x I_n and ∞	10…100% and ∞
Start time, typ.	70 ms	50 ms	150 ms
Operate time at definite time characteristic	0.05…300 s	0.05…300 s	1…300 s
Time/current characteristic at inverse mode	Extremely inv. Very inv. Normal inv. Long-time inv. RI type inv. RXIDG type inv.		
Time multiplier k	0.05…1.0		
Reset time, typ.	40 ms	40 ms	80 ms
Retardation time	<30 ms	<30 ms	
Reset ratio, typ.	0.96	0.96	0.90
Operate time accuracy at definite time mode	±2% of set value or ±25 ms	±2% of set value or ±25 ms	±2% of set value or ±25 ms
Accuracy class index E at inverse time mode	5		
Operation accuracy	±3% of set value	±3% of set value	±1 unit ±3% of set value

Serial communication parameters

Event codes

The start and operate situations of the protection stages and the states of the output signals are defined as events and provided with event codes, which can be transmitted to higher system levels via the serial bus. An event, which is to be communicated, is marked with a multiplier 1. The event mask is formed by the sum of the weight factors of all those events, that are to be communicated.

Event mask	Code	Setting range	Default setting
V155	E1…E12	0…4095	1365
V156	E13…E24	0…4095	1365
V157	E25…E32	0…255	192
V158	E33…E42	0…1023	12

Event codes of the combined overcurrent and earth-fault relay module SPCJ 4D28

Code	Event	No. representing the event	Default value
E1	Starting of stage I>	1	1
E2	Starting of stage I> reset	2	0
E3	Tripping of stage I>	4	1
E4	Tripping of stage I> reset	8	0
E5	Starting of stage I>>	16	1
E6	Starting of stage I>> reset	32	0
E7	Tripping of stage I>>	64	1
E8	Tripping of stage I>> reset	128	0
E9	Starting of stage I>>>	256	1
E10	Starting of stage I>>> reset	512	0
E11	Tripping of stage I>>>	1024	1
E12	Tripping of stage I>>> reset	2048	0
	Default value of event mask V155		1365

E13	Starting of stage I_0>	1	1
E14	Starting of stage I_0> reset	2	0
E15	Tripping of stage I_0>	4	1
E16	Tripping of stage I_0> reset	8	0
E17	Starting of stage I_0>>	16	1
E18	Starting of stage I_0>> reset	32	0
E19	Tripping of stage I_0>>	64	1
E20	Tripping of stage I_0>> reset	128	0
E21	Starting of stage ΔI>	256	1
E22	Starting of stage ΔI> reset	512	0
E23	Tripping of stage ΔI>	1024	1
E24	Tripping of stage ΔI> reset	2048	0
	Default value of event mask V156		1365

Code	Event	No. representing the event	Default value
E25	Output signal SS1 activated	1	0
E26	Output signal SS1 reset	2	0
E27	Output signal TS1 activated	4	0
E28	Output signal TS1 reset	8	0
E29	Output signal SS2 activated	16	0
E30	Output signal SS2 reset	32	0
E31	Output signal TS2 activated	64	1
E32	Output signal TS2 reset	128	1
	Default value of event mask V157		192

E33	Output signal SS3 activated	1	0
E34	Output signal SS3 reset	2	0
E35	Output signal TS3 activated	4	1
E36	Output signal TS3 reset	8	1
E37	Output signal SS4 activated	16	0
E38	Output signal SS4 reset	32	0
E39	Output signal TS4 activated	64	0
E40	Output signal TS4 reset	128	0
E41	Circuit breaker failure protection operated	256	0
E42	Circuit breaker failure protection reset	512	0
	Default value of event mask V158		12

E50	Restart of microprocessor	*	-
E51	Overflow of event register	*	-
E52	Temporary interruption in data communication	*	-
E53	No response from the module over the data communication	*	-
E54	The module responds again over the data communication	*	-

Explanations:
0 not included in event reporting
1 included in event reporting
* no code number
- cannot be programmed

Note.
The event represented by the codes E52...E54 are generated by a higher-level control data communicator, for example type SRIO 1000M.

Remote transfer data

In addition to the event data all input data (I data), setting values (S values), recorded information (V data) and certain other data of the overcurrent module can be read via the SPA bus. Parameters marked with a W letter can be altered via the SPA bus.

When setting values are altered via the MMI on the front panel or via the serial bus, the module checks that the entered parameter values are within the permitted setting range. The relay module refuses to accept a too high or a too low setting value, but keeps the old setting value unchanged.

Altering parameter values via the serial bus usually requires the use of a password. The password is a number within the range 1…999. The default password is 1.

The password is opened by writing the password number to parameter V160 and closed by writing the password number to parameter V161. The password is also closed on loss of auxiliary supply to the relay module.

The password can be changed via the serial bus or via the MMI of the module. When the password is to be changed via the serial bus, the password must be opened first. The new password is written to parameter V161. The change of the password via the MMI of the module is carried out in register A, subregister 3, in which case the new password is written over the old one.

If an incorrect password is given seven times in a row via the serial bus, the password is automatically set to zero and after this it cannot be opened via the serial bus. Now the password can be opened only via the MMI of the module.

R = readable data
W = writable data
(P) = writing enabled with password

Inputs

The measured currents and the status of the external control signals can be read (R) with parameters I1…I8.

When the value of parameters I6…I8 is 1, the corresponding control inputs are energized.

Information	Parameter	Value
Current measured on phase L1	I1	0...63 x I_n
Current measured on phase L2	I2	0...63 x I_n
Current measured on phase L3	I3	0...63 x I_n
Residual current measured	I4	0...21 x I_n
Maximum phase current difference	I5	10...100%
Control signal BS1	I6	0 or 1
Control signal BS2	I7	0 or 1
Control signal RRES (BS3)	I8	0 or 1

Outputs

The state information indicates the state of a signal at a certain moment. The recorded functions indicate such activations of signals, that happen after the last reset of the registers of the module. When the value = 0, the signal has not been activated and when the value = 1, the signal has been activated.

Output stages

States of the protection stages	State of stage (R)	Recorded functions (R)	Value
Starting of stage I>	O1	O21	0 or 1
Tripping of stage I>	O2	O22	0 or 1
Starting of stage I>>	O3	O23	0 or 1
Tripping of stage I>>	O4	O24	0 or 1
Starting of stage I>>>	O5	O25	0 or 1
Tripping of stage I>>>	O6	O26	0 or 1
Starting of stage I_0>	O7	O27	0 or 1
Tripping of stage I_0>	O8	O28	0 or 1
Starting of stage I_0>>	O9	O29	0 or 1
Tripping of stage I_0>>	O10	O30	0 or 1
Tripping of stage ΔI>	O11	O31	0 or 1

Output signals

Operation of output signals	State of output (R, W, P)	Recorded functions (R)	Value
Output signal SS1	O12	O32	0 or 1
Output signal TS1	O13	O33	0 or 1
Output signal SS2	O14	O34	0 or 1
Output signal TS2	O15	O35	0 or 1
Output signal SS3	O16	O36	0 or 1
Output signal TS3	O17	O37	0 or 1
Output signal SS4	O18	O38	0 or 1
Output signal TS4	O19	O39	0 or 1
Enable of output signals SS1…TS4	O41		0 or 1

Setting values

Variable	Used settings (R)	Main setting (R, W, P)	Second setting (R, W, P)	Setting range
Start current of stage I>	S1	S41	S81	0.5…5.0 x I_n
Operate time or time multiplier k of stage I>	S2	S42	S82	0.05…300 s 0.05…1.0
Start current of stage I>>	S3 *)	S43	S83	0.5…40 x I_n
Operate time of stage I>>	S4	S44	S84	0.04…300 s
Start current of stage I>>>	S5 *)	S45	S85	0.5…40 x I_n
Operate time of stage I>>>	S6	S46	S86	0.04…30 s
Start current of stage I_0>	S7	S47	S87	0.1…0.8 x I_n
Operate time or time multiplier k of stage I_0>	S8	S48	S88	0.05…300 s 0.05…1.0
Start current of stage I_0>>	S9 *)	S49	S89	0.1…10 x I_n
Operate time of stage I_0>>	S10	S50	S90	0.05…300 s
Start value of stage ΔI>	S11 *)	S51	S91	10…100%
Operate time of stage ΔI>	S12	S52	S92	1…300 s
Checksum, SGF 1	S13	S53	S93	0…255
Checksum, SGF 2	S14	S54	S94	0…255
Checksum, SGF 3	S15	S55	S95	0…255
Checksum, SGF 4	S16	S56	S96	0…255
Checksum, SGF 5	S17	S57	S97	0…255
Checksum, SGF 6	S18	S58	S98	0…255
Checksum, SGF 7	S19	S59	S99	0…255
Checksum, SGF 8	S20	S60	S100	0…255
Checksum, SGB 1	S21	S61	S101	0…255
Checksum, SGB 2	S22	S62	S102	0…255
Checksum, SGB 3	S23	S63	S103	0…255
Checksum, SGR 1	S24	S64	S104	0…255
Checksum, SGR 2	S25	S65	S105	0…255
Checksum, SGR 3	S26	S66	S106	0…255
Checksum, SGR 4	S27	S67	S107	0…255
Checksum, SGR 5	S28	S68	S108	0…255
Checksum, SGR 6	S29	S69	S109	0…255
Checksum, SGR 7	S30	S70	S110	0…255
Checksum, SGR 8	S31	S71	S111	0…255
Checksum, SGR 9	S32	S72	S112	0…255
Checksum, SGR 10	S33	S73	S113	0…255
Checksum, SGR 11	S34	S74	S114	0…255
Operate time of the circuit breaker failure protection	-	S121	S121	0.1…1.0 s

*) If the protection stage has been set out of function, the display shows 999 for the currently used value.

Measured and recorded parameter values

Measured value	Parameter	Data direction	Value
Last 15 min maximum demand current	V1	R	0…2.5 x I_n
Number of starts of stage I>	V2	R	0…255
Number of starts of stage I>>	V3	R	0…255
Number of starts of stage I_0>	V4	R	0…255
Number of starts of stage I_0>>	V5	R	0…255
Number of starts of stage ΔI>	V6	R	0…255
Stage/phase that caused operation	V7	R	1 = I_{L3}>, 2 = I_{L2}>, 4 = I_{L1}>, 8 = I_0>, 16 = I_{L3}>>, 32 = I_{L2}>>, 64 = I_{L1}>>, 128 = I_0>>
Stage/phase that caused operation	V8	R	1 = I_{L3}>>>, 2 = I_{L2}>>>, 4 = I_{L1}>>>
Operation indication code on the display	V9	R	0…12
Maximum 15 min demand current	V10	R	0…2.55 x I_n

The last five recorded values can be read (R) with parameters V11…V59. Event n denotes the youngest recorded value and n-1 the next youngest and so forth.

Registered value	Event n	Event n-1	Event n-2	Event n-3	Event n-4	Measuring range
Phase current I_{L1} (register 1)	V11	V21	V31	V41	V51	0…63 x I_n
Phase current I_{L2} (register 2)	V12	V22	V32	V42	V52	0…63 x I_n
Phase current I_{L3} (register 3)	V13	V23	V33	V43	V53	0…63 x I_n
Earth-fault current I_0 (register 6)	V14	V24	V34	V44	V54	0…21 x I_n
Difference current ΔI (register 9)	V15	V25	V35	V45	V55	0…100%
Start duration, stage I> (register 4)	V16	V26	V36	V46	V56	0…100%
Start duration, stage I>> (register 5)	V17	V27	V37	V47	V57	0…100%
Start duration, stage I_0> (register 7)	V18	V28	V38	V48	V58	0…100%
Start duration, stage I_0>> (register 8)	V19	V29	V39	V49	V59	0…100%

Control parameters

Information	Para-meter	Data direction	Value
Resetting of operation indicators and latched output relay	V101	W	1 = reset perfomed
Resetting of indicators and latched output relay and clearing of registers	V102	W	1 = reset perfomed
Remote control of setting	V150	R,W	0 = main settings enforced 1 = second settings enforced
Overcurrent even mask	V155	R,W	0...4096, see section "Event codes"
Residual/unbalance current event mask	V156	R,W	0...4096, see section "Event codes"
Output signal event mask	V157	R,W	0...255, see section "Event codes"
Output signal event mask	V158	R,W	0...1023, see section "Event codes"
Opening of password for remote setting	V160	W	1...999
Changing and closing of password for remote setting	V161	W, P	0...999
Activation of self-supervision system	V165	W	1 = self-supervision system activated and IRF LED lit
Formatting of EEPROM	V167	W, P	2 = formatting
Fault code	V169	R	0…255
Data communication address of relay module	V200	R,W	1...254
Data transfer rate	V201	R,W	4800 or 9600 Bd (R) 4.8 or 9.6 kBd (W)
Program version	V205	R	116 _
Reading of event register	L	R	Time, channel number and event code
Rereading of event register	B	R	Time, channel number and event code
Type designation of relay module	F	R	SPCJ 4D28
Reading of module state data	C	R	0 = normal state 1 = module been subject to automatic reset 2 = event register overflow 3 = events 1 and 2 together
Resetting of module state data	C	W	0 = resetting
Time reading and setting	T	R,W	00.000...59.999 s

The maximum capacity of the event register is 65 events. The content of the register can be read by the L command, 5 events at a time, only once. Should a fault occur, say, in the data communication, the B command can be used to re-read the contents of the register. When required, the B command can be repeated. In general, the control data communicator reads the event data and forwards the information to an output device. Under normal conditions the event register of the relay module is empty. The control data communicator also resets abnormal status data, so this data is normally zero.

Fault codes

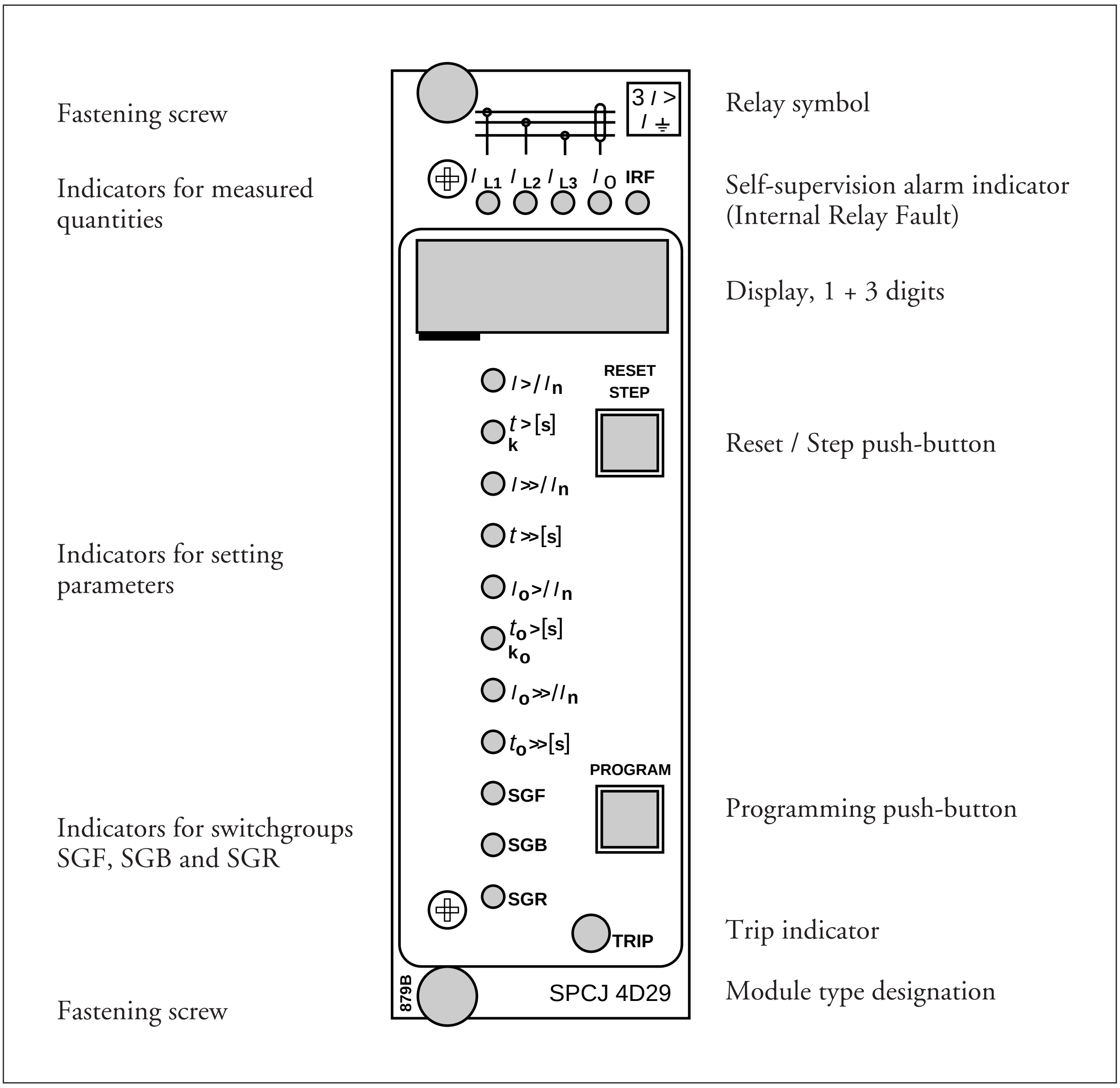
Once the self-supervision system has detected an internal relay fault, the IRF indicator on the front panel of the relay module is lit. At the same time the self-supervision alarm relay that is normally picked up, drops off. In most situations a fault code appears on the display of the relay module. This fault code consists of a red number one (1) and a green code number that identifies the fault type. The fault codes should be recorded and stated when service is ordered.

The table below lists some of the fault codes of the combined overcurrent and earth-fault relay module SPCJ 4D28.

Fault code	Type of fault
4	Relay control circuit faulty or missing
30	Read Only Memory (ROM) faulty
50	Random Access Memory (RAM) faulty
51	Parameter memory (EEPROM) faulty, block 1
52	Parameter memory (EEPROM) faulty, block 2
53	Parameter memory (EEPROM) faulty, blocks 1 and 2
54	Parameter memory (EEPROM) faulty, blocks 1 and 2 have different checksums
56	Parameter memory (EEPROM) key faulty. Formatting by writing V167 = 2
195	Too low a value on the reference channel with multiplier 1
131	Too low a value on the reference channel with multiplier 5
67	Too low a value on the reference channel with multiplier 25
203	Too high a value on the reference channel with multiplier 1
139	Too high a value on the reference channel with multiplier 5
75	Too high a value on the reference channel with multiplier 25
252	Filter of I0 channel faulty
253	No interruption from the A/D converter

General characteristics of D-type relay modules

User´s manual and Technical description



ABB

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Data subject to change without notice

General characteristics of D type relay modules

Contents

Control push-buttons

The front panel of the relay module contains two push buttons. The RESET / STEP push button is used for resetting operation indicators and for stepping forward or backward in the display main menu or submenus. The PROGRAM push button is used for moving from a certain position in the main menu to the corresponding submenu, for entering the setting mode of a certain parameter and together with the STEP push button for storing the set values. The different operations are described in the subsequent paragraphs in this manual.

Display

The measured and set values and the recorded data are shown on the display of the protection relay module. The display consists of four digits. The three green digits to the right show the measured, set or recorded value and the leftmost red digit shows the code number of the register. The measured or set value displayed is indicated by the adjacent yellow LED indicator on the front panel. When a recorded fault value is being displayed the red digit shows the number of the corresponding register. When the display functions as an operation indicator the red digit alone is shown.

When the auxiliary voltage of a protection relay module is switched on the module initially tests the display by stepping through all the segments of the display for about 15 seconds. At first the corresponding segments of all digits are lit one by one clockwise, including the decimal points. Then the center segment of each digit is lit one by one. The complete sequence is carried out twice. When the test is finished the display turns dark. The testing can be interrupted by pressing the STEP push button. The protection functions of the relay module are alerted throughout the testing.

Display main menu

Any data required during normal operation are accessible in the main menu i.e. present measured values, present setting values and recorded parameter values.

The data to be shown in the main menu are sequentially called up for display by means of the STEP push button. When the STEP push button is pressed for about one second, the display moves forward in the display sequence. When the push button is pressed for about 0.5 seconds, the display moves backward in the display sequence.

From a dark display only forward movement is possible. When the STEP push button is pushed constantly, the display continuously moves forward stopping for a while in the dark position.

Unless the display is switched off by stepping to the dark point, it remains lit for about 5 minutes from the moment the STEP push button was last pushed. After the 5 minutes' time-out the dispaly is switched off.

Display submenus

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 protection relay module.

A submenu is entered from the main menu by pressing the PROGRAM push button for about one second. When the push button is released, the red digit of the display starts flashing, indicating that a submenu has been entered. 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 the STEP push button is pushed for one second and backward when it is pushed for 0.5 seconds. The main menu has been re-entered when the red display turns dark.

When a submenu is entered from a main menu of a measured or set value indicated by a LED indicator, the indicator remains lit and the address window of the display starts flashing. A submenu position is indicated by a flashing red address number alone on the dispaly without any lit set value LED indicator on the front panel.

Selector switchgroups SGF, SGB and SGR

Part of the settings and the selections of the operation characteristic of the relay modules in various applications are made with the selector switchgroups SG_ . The switchgroups are software based and thus not physically to be found in the hardware of the relay module. The indicator of the switchgroup is lit when the checksum of the switchgroup is shown on the display. Starting from the displayed checksum and by entering the setting mode, the switches can be set one by one as if they were real physical switches. At the end of the setting procedure, a checksum for the whole switchgroup is shown. The checksum can be used for verifying that the switches have been properly set. Fig. 2 shows an example of a manual checksum calculation.

When the checksum calculated according to the example equals the checksum indicated on the display of the relay module, the switches in the concerned switchgroup are properly set.

Switch No	Pos.		Weigth		Value
1	1	x	1	=	1
2	0	x	2	=	0
3	1	x	4	=	4
4	1	x	8	=	8
5	1	x	16	=	16
6	0	x	32	=	0
7	1	x	64	=	64
8	0	x	128	=	0
	Checksum		Σ	=	93

Fig. 2. Example of calculating the checksum of a selector switchgroup SG_.

The functions of the selector switches of the different protection relay modules are described in detail in the manuals of the different relay modules.

Settings

Most of the start values and operate times are set by means of the display and the push buttons on the front panel of the relay modules. Each setting has its related indicator which is lit when the concerned setting value is shown on the display.

In addition to the main stack of setting values most D type relay modules allow a second stack of settings. Switching between the main settings and the second settings can be done in three different ways:

1) By command V150 over the serial communication bus
2) By an external control signal BS1, BS2 or RRES (BS3)
3) Via the push-buttons of the relay module, see submenu 4 of register A.

Setting mode

Generally, when a large number of settings is to be altered, e.g. during commissioning of relay systems, it is recommended that the relay settings are entered with the keyboard of a personal computer provided with the necessary software. When no computer nor software is available or when only a few setting values need to be altered the procedure described below is used.

The registers of the main menu and the submenus contain all parameters that can 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 PROGRAM push button, until the whole display starts flashing. This position indicates the value of the parameter before it has been altered. By pressing the PROGRAM push button the programming sequence moves forward one step. First the rightmost digit starts flashing while the rest of the display is steady. The flashing digit is set by means of the STEP push button. The flashing cursor is moved on from digit to digit by pressing the PROGRAM push button and in each stop the setting is performed with the STEP push button. After the parameter values have been set, the decimal point is put in place. At the end the position with the whole display flashing is reached again and the data is ready to be stored.

A set value is recorded in the memory by pressing the push buttons STEP and PROGRAM simultaneously. Until the new value has been recorded a return from the setting mode will have no effect on the setting and the former value will still be valid. Furthermore *any attempt to make a setting outside the permitted limits for a particular parameter will cause the new value to be disqualified and the former value will be maintained.* Return from the setting mode to the main menu or a submenu is possible by pressing the PROGRAM push button until the green digits on the display stop flashing.

NOTE! During any local man-machine communication over the push buttons and the display on the front panel a five minute time-out function is active. Thus, if no push button has been pressed during the last five minutes, the relay returns to its normal state automatically. This means that the display turns dark, the relay escapes from a display mode, a programming routine or any routine going on, when the relay is left untouched. This is a convenient way out of any situation when the user does not know what to do.

Before a relay module is inserted into the relay case, one must assure that the module has been given the correct settings. If there however is any doubt about the settings of the module to be inserted, the setting values should be read using a spare relay unit or with the relay trip circuits disconnected. If this cannot be done the relay can be sett into a non-tripping mode by pressing the PROGRAM push button and powering up the relay module simultaneously. The display will show three dashes "- - -" to indicate the non-tripping mode. The serial communication is operative and all main and submenues are accessible. In the non-tripping mode unnecessary trippings are avoided and the settings can be checked. *The normal protection relay mode is entered automatically after a timeout of five minutes or ten seconds after the dark display position of the main menu has been entered.*

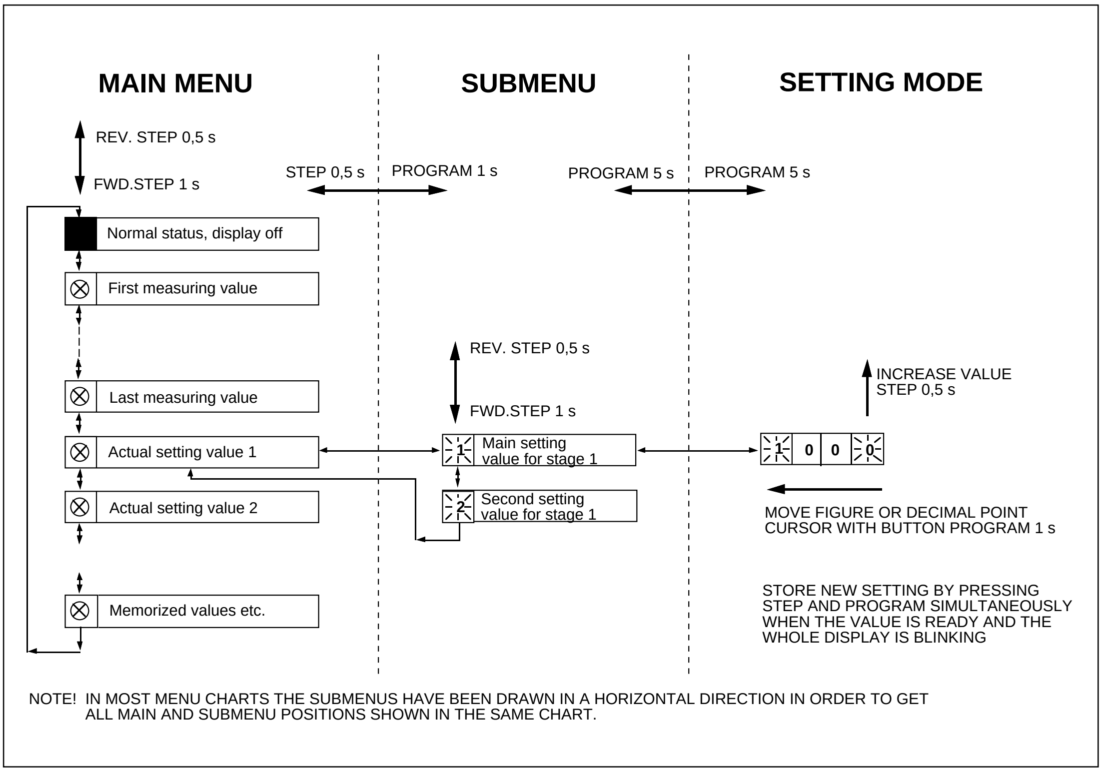


Fig.3. Basic principles of entering the main menus and submenus of a relay module.

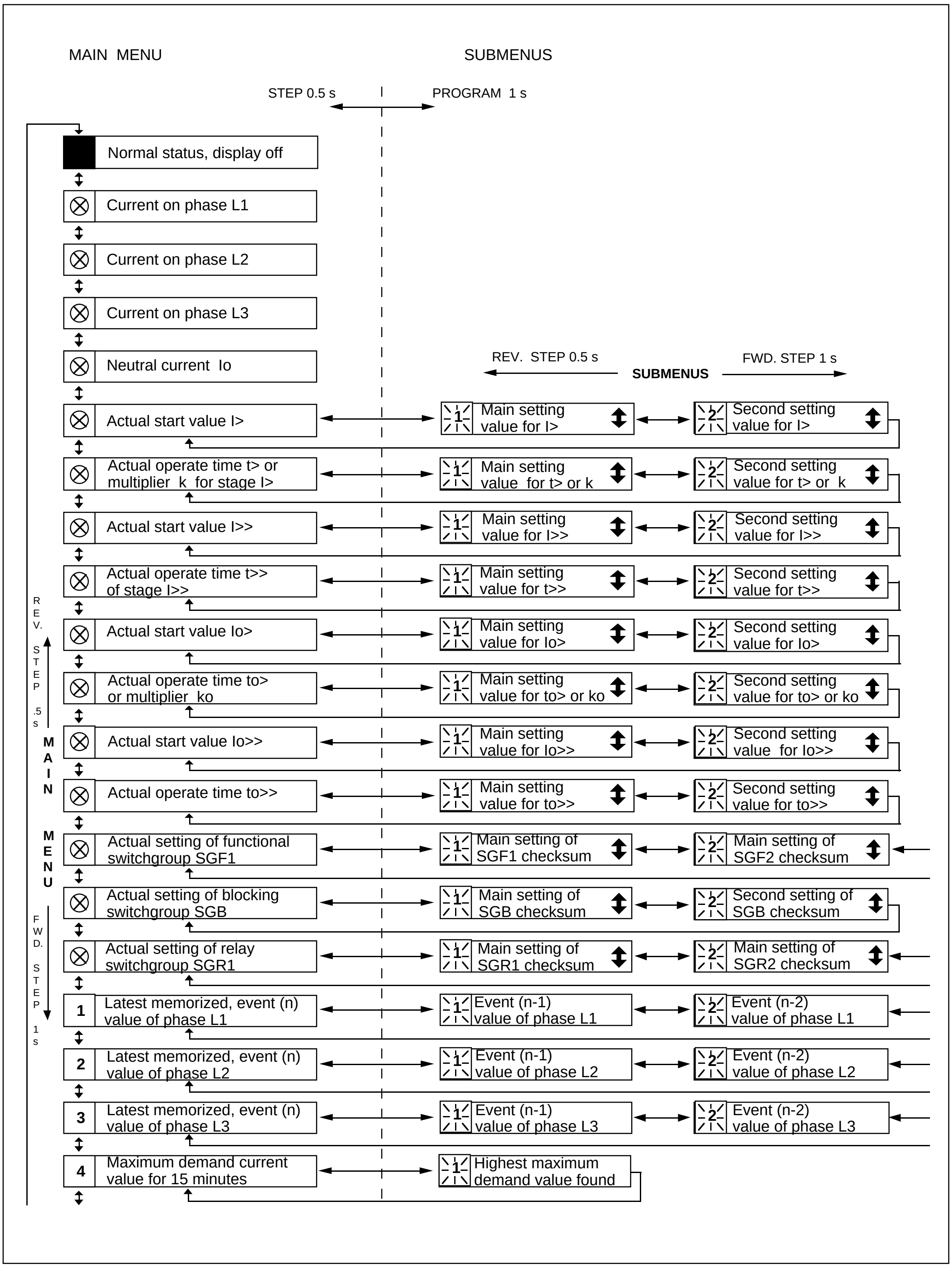
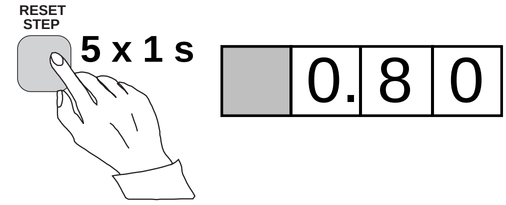


Fig. 4. Example of part of the main and submenus for the settings of the overcurrent and earth-fault relay module SPCJ 4D29. The settings currently in use are in the main manu and they are displayed by pressing the STEP push button. The main menu also includes the measured current values, the registers 1...9, 0 and A. The main and second setting values are located in the submenus and are called up on the display with the PROGRAM push button.

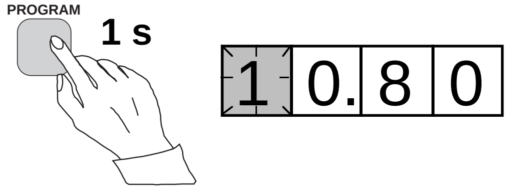
Example 1

Operation in the setting mode. Manual setting of the main setting of the start current value I> of an overcurrent relay module. The initial value for the main setting is 0.80 x I_n and for the second setting 1.00 x I_n. The desired main start value is 1.05 x I_n.

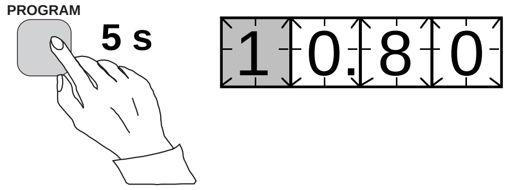
a)
Press push button STEP repeatedly until the LED close to the I> symbol is lit and the current start value appears on the display.



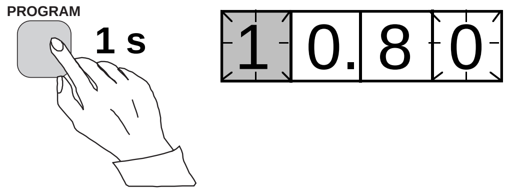
b)
Enter the submenu to get the main setting value by pressing the PROGRAM push button more than one second and then releasing it. The red display digit now shows a flashing number 1, indicating the first submenu position and the green digits show the set value.



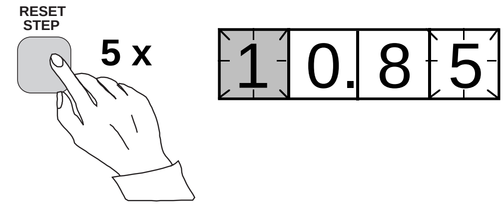
c)
Enter the setting mode by pressing the PROGRAM push button for five seconds until the display starts flashing.



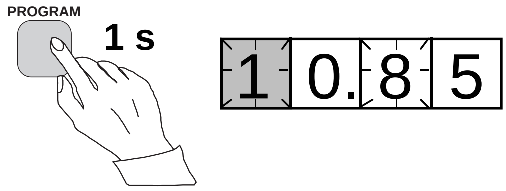
d)
Press the PROGRAM push button once again for one second to get the rightmost digit flashing.



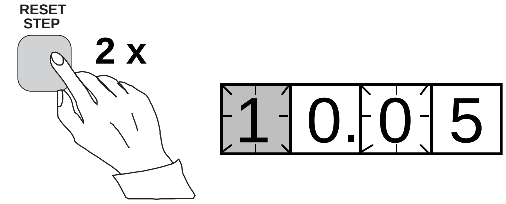
e)
Now the flashing digit can be altered. Use the STEP push button to set the digit to the desired value.



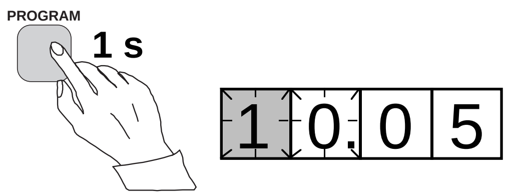
f)
Press the PROGRAM push button to make the middle one of the green digits flash.



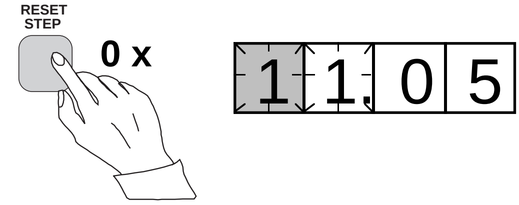
g)
Set the middle digit with of the STEP push button.



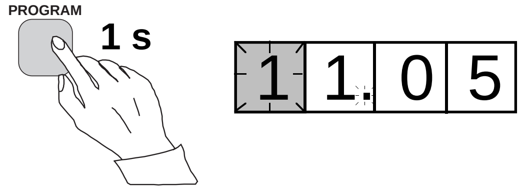
h)
Press the PROGRAM push button to make the leftmost green digit flash.



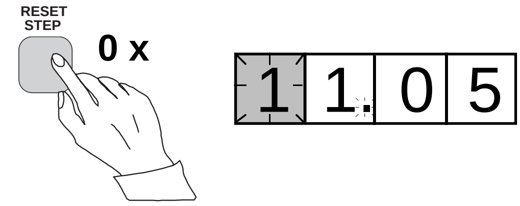
i)
Set the digit with the STEP push button.



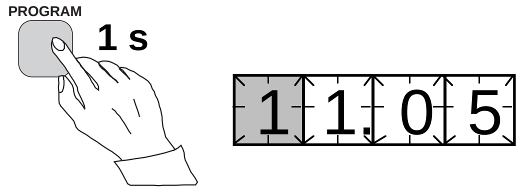
j)
Press the PROGRAM push button to make the decimal point flash.



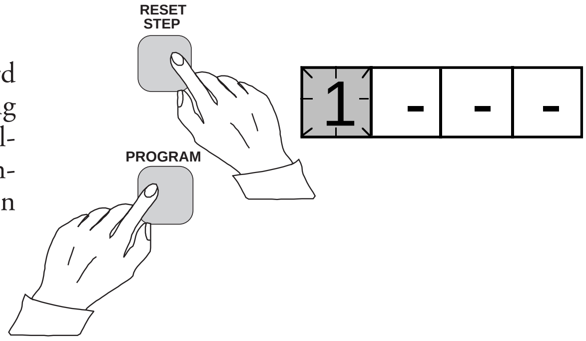
k)
If needed, move the decimal point with the STEP push button.



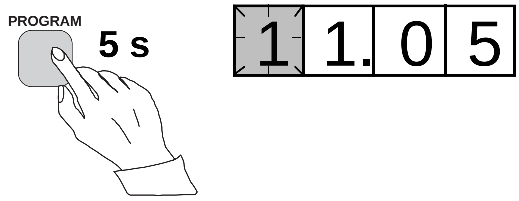
l)
Press the PROGRAM push button to make the whole display flash. In this position, corresponding to position c) above, one can see the new value before it is recorded. If the value needs changing, use the PROGRAM push button to alter the value.



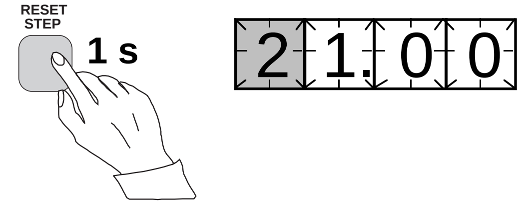
m)
When the new value has been corrected, record it in the memory of the relay module by pressing the PROGRAM and STEP push buttons simultaneously. At the moment the information enters the memory, the green dashes flash once in the display, i.e. 1 - - -.



n)
Recording of the new value automatically initiates a return from the setting mode to the normal submenu. Without recording one can leave the setting mode any time by pressing the PROGRAM push button for about five seconds, until the green display digits stop flashing.



o)
If the second setting is to be altered, enter submenu position 2 of the setting I> by pressing the STEP push button for approx. one second. The flashing position indicator 1 will then be replaced by a flashing number 2 which indicates that the setting shown on the display is the second setting for I>.

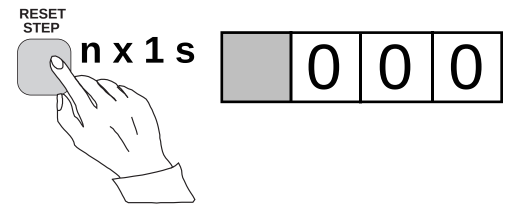


Enter the setting mode as in step c) and proceed in the same way. After recording of the requested values return to the main menu is obtained by pressing the STEP push button until the first digit is switched off. The LED still shows that one is in the I> position and the display shows the new setting value currently in use by the relay module.

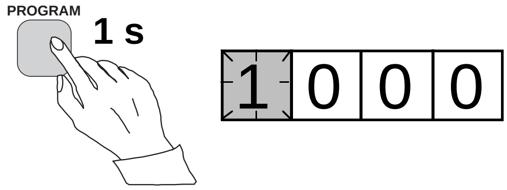
Example 2

Operation in the setting mode. Manual setting of the main setting of the checksum for the switchgroup SGF1 of a relay module. The initial value for the checksum is 000 and the switches SGF1/1and SGF1/3 are to be set in position 1. This means that a checksum of 005 should be the final result.

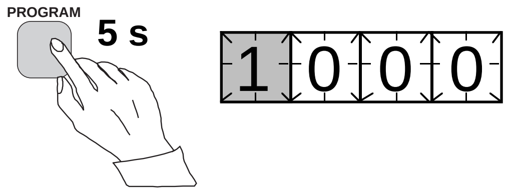
a)
Press push button STEP until the LED close to the SGF symbol is lit and the checksum appears on the display.



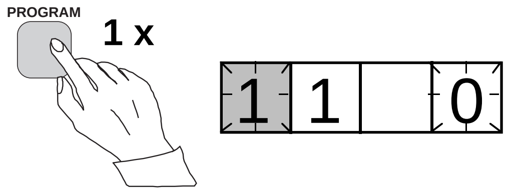
b)
Enter the submenu to get the main checksum of SGF1 by pressing the PROGRAM push button for more than one second and then releasing it. The red display now shows a flashing number 1 indicating the first submenu position and the green digits show the checksum.



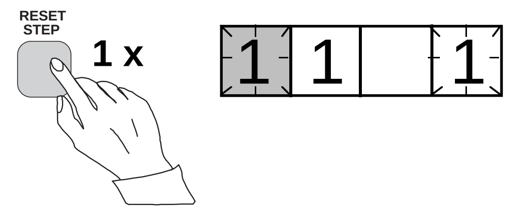
c)
Enter the setting mode by pressing the PROGRAM push button for five seconds until the display starts flashing.



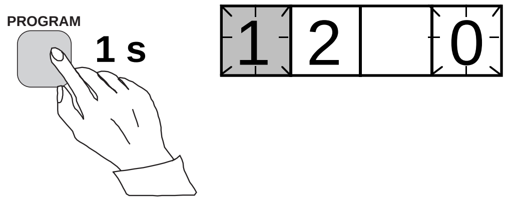
d)
Press the PROGRAM push button once again to get the first switch position. The first digit of the display now shows the switch number. The position of the switch is shown by the rightmost digit.



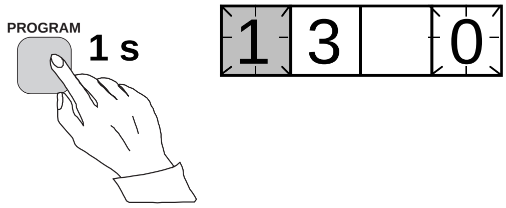
e)
The switch position can now be toggled between 1 and 0 by means of the STEP push button and it is left in the requested position 1.



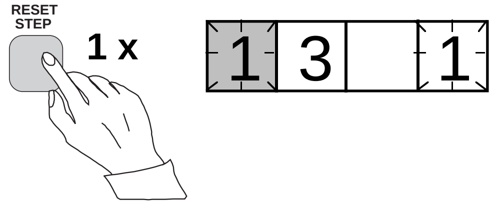
f)
When switch number 1 is in the requested position, switch number 2 is called up by pressing the PROGRAM push button for one second. As in step e), the switch position can be altered by using the STEP push button. As the desired setting for SGF1/2 is 0 the switch is left in the 0 position.



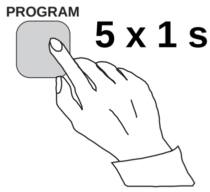
g)
Switch SGF1/3 is called up as in step f) by pressing the PROGRAM push button for about one second.



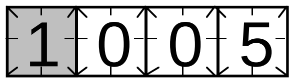
h)
The switch position is altered to the desired position 1 by pressing the STEP push button once.



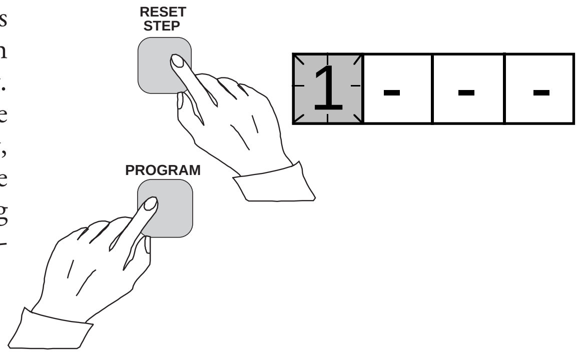
i)
Using the same procedure the switches SGF 1/ 4...8 are called up and, according to the example, left in position 0.



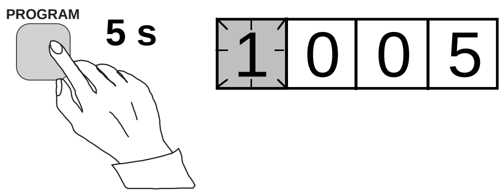
j)
In the final setting mode position, corresponding to step c), the checksum based on the set switch positions is shown.



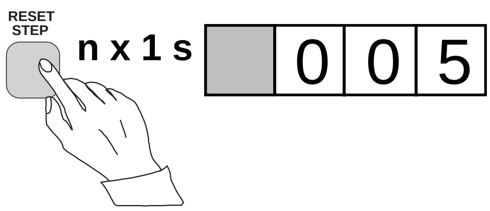
k)
If the correct checksum has been obtained, it is recorded in the memory by pressing the push buttons PROGRAM and STEP simultaneously. At the moment the information enters the memory, the green dashes flash in the display, i.e.1 - - -. If the checksum is incorrect, the setting of the separate switches is repeated using the PROGRAM and STEP push buttons starting from step d).



l)
Recording the new value automatically initiates a return from the setting mode to the normal menu. Without recording one can leave the setting mode any time by pressing the PROGRAM push button for about five seconds, until the green display digits stop flashing.



m)
After recording the desired values return to the main menu is obtained by pressing the STEP push button until the first digit is turned off. The LED indicator SGF still shows that one is in the SGF position and that the display shows the new checksum for SGF1 currently in use by the relay module.



Recorded information

The parameter values measured at the moment when a fault occurs or at the trip instant are recorded in the registers. The recorded data, except for some parameters, are set to zero by pressing the push buttons STEP and PROGRAM simultaneously. The data in normal registers are erased if the auxiliary voltage supply to the relay is interrupted, only the set values and certain other essential parameters are maintained in non-volatile registers during a voltage failure.

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

All D 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, status information and other signals. The codes are explained in the manuals of the different relay modules.

Register A contains the address code of the relay modul which is reqiured by the serial communication system.

Submenu 1 of register A contains the data transfer rate value, expressed in kilobaud, of the serial communication.

Submenu 2 of register A contains a bus communication monitor for the SPAbus. If the protection relay, which contains the relay module, is linked to a system including a contol data communicatoe, for instance SRIO 1000M and the data communication system is operating, the counter reading of the monitor will be zero. Otherwise the digits 1...255 are continuously scrolling in the monitor.

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

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

In order to secure the setting values, all settings are recorded in two separate memory banks within the non-volatile memory. Each bank is complete with its own checksum test to verify the condition of the memory contents. If, for some reason, the contents of one bank is disturbed, all settings are taken from the other bank and the contents from here is transferred to the faulty memory region, all while the relay is in full operation condition. If both memory banks are simultaneously damaged the relay will be be set out of operation, and an alarm signal will be given over the serial port and the IRF output relay

Trip test function

Register 0 also provides access to a 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 then will operate one by one during the testing.

When pressing the PROGRAM push button for about five seconds, the green digits to the right start flashing indicating that the relay module is in the test position. The indicators of the settings indicate by flashing which output signal can be activated. The required output function is selected by pressing the PROGRAM push button for about one second.

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

Setting I>	Starting of stage I>
Setting t>	Tripping of stage I>
Setting I>>	Starting of stage I>>
Setting t>>	Tripping of stage I>>
etc.	
No indication	Self-supervision IRF

The selected starting or tripping is activated by simultaneous pressing of the push buttons STEP and PROGRAM. The signal remains activated as long as the two push butttons are pressed. The effect on the output relays depends on the configuration of the output relay matrix switches.

The self-supervision output is activated by pressing the STEP push button 1 second when no setting indicator is flashing. The IRF output is activated in about 1 second after pressing of the STEP push button.

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

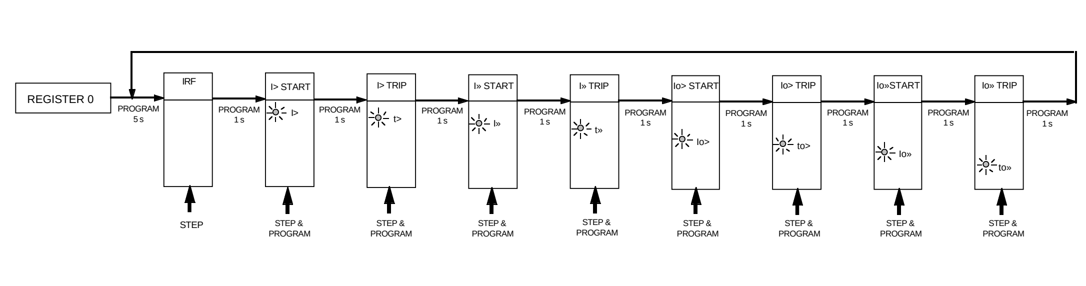


Fig. 5. Sequence order for the selection of output signals in the Trip test mode

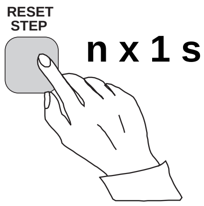
If, for instance, the indicator of the setting t> is flashing, and the push buttons STEP and PROGRAM are being pressed, the trip signal from the low-set overcurrent stage is activated. Return to the main menu is possible at any stage of the trip test sequence scheme, by pressing the PROGRAM push button for about five seconds.

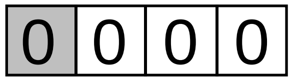
Note!
The effect on the output relays then depends on the configuration of the output relay matrix switchgroups SGR 1...3.

Example 3

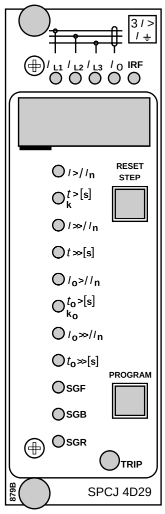
Trip test function. Forced activation of the outputs.

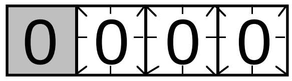
a)
Step forward on the display to register 0.

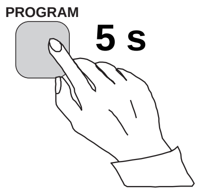




b)
Press the PROGRAM push button for about five seconds until the three green digits to the right.

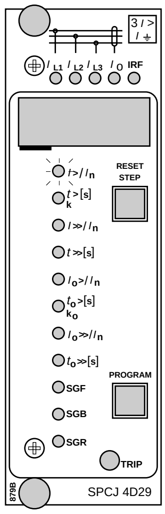


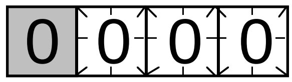




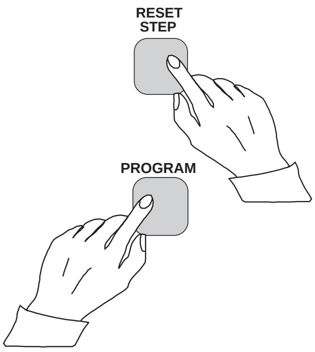
c)
Hold down the STEP push button. After one second the red IRF indicator is lit and the IRF output is activated. When the step push button is released the IRF indicator is switched off and the IRF output resets.

d)
Press the PROGRAM push button for one second and the indicator of the topmost setting start flashing.

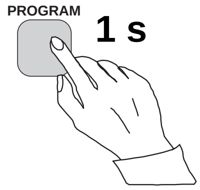


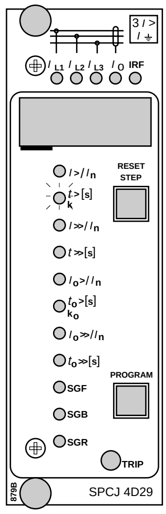


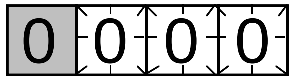
e)
If a start of the first stage is required, now press the push-buttons PROGRAM and STEP simultaneously. The stage output will be activated and the output relays will operate according to the actual programming of the relay output switchgroups SGR.



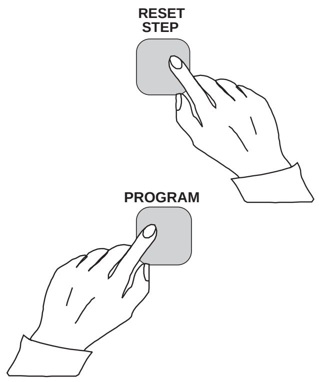
f)
To proceed to the next position press the PROGRAM push button for about 1 second until the indicator of the second setting starts flashing.

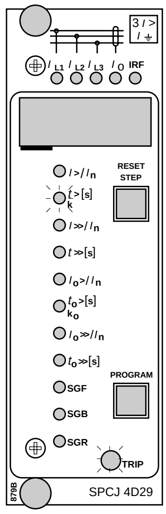


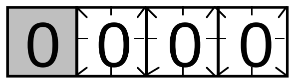




g)
Press the push buttons PROGRAM and STEP simultaneously to activate tripping of stage 1 (e.g. the I> stage of the overcurrent module SPCJ 4D29). The output relays will operate according to the actual programming of the relay switchgroups SGR. If the main trip relay is operated the trip indicator of the measuring module is lit.







h)
The starting and tripping of the remaining stages are activated in the same way as the first stage above. The indicator of the corresponding setting starts flashing to indicate that the concerned stage can be activated by pressing the STEP and PROGRAM buttons simultaneously. For any forced stage operation, the output relays will respond according to the setting of the relay output switchgroups SGR. Any time a certain stage is selected that is not wanted to operate, pressing the PROGRAM button once more will pass by this position and move to the next one without carrying out any operation of the selected stage.

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

Operation indication

A relay module is provided with a multiple of separate operation stages, each with its own operation indicator shown on the display and a common trip indicator on the lower part of the front plate of the relay module.

The starting of a relay stage is indicated with one number which changes to another number when the stage operates. The indicator remains glowing although the operation stage resets. The indicator is reset by means of the RESET push button of the relay module. An unreset operation indicator does not affect the function of the protection relay module.

In certain cases the function of the operation indicators may deviate from the above principles. This is described in detail in the descriptions of the separate modules.

Fault codes

In addition to the protection 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.

Shortly after the self-supervision system detects a permanent fault in the relay module, the red IRF indicator on the front panel is lit . At the same time the module puts forward a control signal to the output relay of the self-supervision system of the protection relay.

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 figure "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. When in a fault mode, the normal relay menus are operative, i.e. all setting values and measured values can be accessed although the relay operation is inhibited. The serial communication is also operative making it possible to access the relay information also from a remote site. The internal relay fault code shown on the display remains active until the internal fault possibly disappears and can also be remotely read out as variable V 169.

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