SIEMENS

Numerical Distance Protection for High Voltage Systems

SIPROTEC 7SA510 V3.2

Instruction Manual Order No. C53000−G1176−C115−3

Figure 1 Illustration of the numerical distance protection relay for high voltage systems SIPROTEC 7SA510 (in housing for surface mounting)

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Conformity

This product is in conformity with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Council Directive 89/336/EEC) and concerning electrical equipment for application within specified voltage limits (Low-voltage directive 73/23 EEC).

Conformity is proved by tests that had been performed according to article 10 of the Council Directive in accordance with the generic standards EN 50081 – 2 and EN 50082 – 2 (for EMC directive) and the standards EN 60255 – 6 (for low-voltage directive) by Siemens AG.

The device is designed and manufactured for application in industrial environment.

The device is designed in accordance with the international standards of IEC 60255 and the German standards DIN 57435 part 303 (corresponding to VDE 0435 part 303).

Contents

NOTE:

This instruction manual does not purport to cover all details in equipment, nor to provide for every possible contingency to be met in connection with installation, operation or maintenance.

Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to the local Siemens sales office.

The contents of this instruction manual shall not become part nor modify any prior or existing agreement, commitment or relationship. The sales contract contains the entire obligations of Siemens. The warranty contained in the contract between the parties is the sole warranty of Siemens. Any statements contained herein do not create new warranties nor modify the existing warranty.

1 Introduction

1.1 Application

Numerical distance protection relay SIPROTEC 7SA510 provides fast, reliable and selective clearance of all kinds of ground and phase faults in single and/or multiple fed overhead lines and cables in radial, ring or any type of meshed networks. The system starpoint may be isolated, compensated (arc suppressed by Petersen coil), solidly earthed or low resistance earthed. The scope of functions is optimized for use on high voltage lines. Principally, however, it can be used for any system voltage.

It contains all the vital functions for the protection of a high voltage feeder circuit and is thus universally applicable. It can also be used as a time-graded back-up protection for differential protection systems of all kinds for lines, transformers, generators, motors and busbars.

Its fundamental function is determination of the distance of the short circuit by impedance measurement. This can be supplemented by a series of optional function modules which provide power swing supplement, teleprotection interface (for 100 % rapid clearance), thermal overload protection (for cables), earth fault detection (for isolated or compensated networks), highly sensitive earth fault protection (for high-resistance earth fault in earthed networks), automatic reclosure (for overhead lines), fault location (for speedy location of the damaged area). External accessories are therefore normally not required.

Throughout a fault in the network the magnitudes of the instantaneous values are stored for a period of at most 5 seconds and are available for subsequent fault analysis.

Continuous monitoring of the measured values permits rapid annunciation of any fault in the measuring transformer circuits. Continuous plausibility monitoring of the internal measured value processing circuits and monitoring of the auxiliary voltages to ensure that they remain within tolerance are obviously inherent features.

Serial interfaces allow comprehensive communication with other digital control and storage devices. For data transmission a standardized protocol in accordance with VDEW/ZVEI and IEC 60870 – 5 – 103 is used. The device can therefore be incorporated in Localized Substation Automation networks (LSA). The system interface is suited to communication via a modem link.

1.2 Features

- Processor system with powerful 16-bit microprocessor;
- complete digital measured value processing and control from data acquisition and digitizing of the measured values up to the trip and close decisions for the circuit breaker;
- complete galvanic and reliable separation of the internal processing circuits from the measurement, control and supply circuits of the system, with analog input transducers, binary input and output modules and d.c./d.c. converter;
- scope of functions required for the protection of a high voltage feeder circuit;
- overcurrent fault detection – optionally voltage controlled (U/I) or phase-angle dependent impedance fault detection;
- polygonal tripping characteristic with independent setting of reach along the R – and X – axis with separate R – setting for earth faults;
- directional determination using sound phase polarization and voltage memory, giving unlimited directional sensitivity;
- supplementary functions can be ordered as an option;
- continuous calculation of operational measured values and indication on the front display;
- simple setting and operation using the integrated operation panel or a connected personal computer with menu-guided software;
- storage of fault data, storage of instantaneous values during a fault for fault recording;
- communication with central control and storage devices via serial interfaces is possible with connection of optical fibre (optional);
- continuous monitoring of the measured values and the hardware and software of the relay.

1.3 Implemented functions

7SA510 contains the following functions:

Distance protection with

- phase selective overcurrent fault detection;
- optional voltage controlled (U/I) fault detection or impedance fault detection with polygonally shaped angle-dependent characteristic;
- five distance zones can be set to operate either in the forward direction or in the reverse direction or non-directional, one of them can be used as graded overreach zones;
- seven time stages;
- polygonal tripping characteristic with independent setting of reach along the R– and X–axis, separate R–setting for phase and earth faults;
- directional determination using sound phase polarization and voltage memory, thus suitable for use with capacitive voltage transformers and giving unlimited directional sensitivity.

Power swing supplement (optional with impedance fault detection)

- power swing detection by dR/dt measurement;
- avoids unwanted trip occurrences during power swings in the system;
- for use of power swing blocking or out-of-step tripping.

Universal teleprotection interface

programmable for different schemes of

- permissive underreach transfer tripping (PUTT);
- permissive overreach transfer tripping (POTT).

Dead-fault protection

- provides high speed operation at either line end when switching manually onto a bolted fault.

Emergency overcurrent function

with two-stage definite time overcurrent characteristic and separate earth current stage,

- for ”emergency operation” if voltage transformer miniature circuit bbreaker trips or
- for ”emergency operation” in case of voltage transformer secondary fuse failure.

Thermal overload protection

- provides thermal replica of the current heat losses;
- true r.m.s. measurement of all three conductor currents;
- adjustable warning stages.

Earth fault detection (optional)

for compensated or isolated networks with

- phase selective fault detection;
- sensitive directional determination.

Highly sensitive earth fault protection (optional)

- for high-resistive earth faults in networks with earthed starpoint;
- with two-stage earth current pick-up;
- directional determination using zero sequence components of currents and voltages;
- optionally with directional comparison via communication link (e.g. PLC or optical fibre);
- back-up function in case of voltage failure using definite time earth current protection;
- alternatively non-directional inverse time earth current protection with three selectable characteristics (not in conjunction with directional earth fault protection).

Automatic reclose function (optional)

– single- or multi-shot (e.g. RAR and DAR);

– with separately allocated action times and dead times for RAR (rapid AR for first shot) and DAR (delayed AR for further shots).

Distance-to-fault location

– can be started by fault detection or trip command or by external command;

– calculation of the fault distance;

– output of fault distance in ohms (primary and secondary), kilometers and % line length.

The standard functions also include:

– two logical functions with time stages which can be defined by the user in order to combine, delay or process external signals;

– continuous self-monitoring right from the d.c. circuits, through the current and voltage transformer inputs to the tripping relays, thus achieving maximum availability and a more corrective than preventive maintenance strategy;

– measurement and test routines under normal load conditions:
measurement of load currents and operating voltages,
measurement of power and frequency,
output of measured impedances, directional and phase sequence check;

– annunciation storage and transmission of the last four network faults, with real time clock;

– storage of data of the last three earth faults in isolated or arc compensated systems;

– data storage and transmission for fault records giving
rapid fault analysis,
detailed fault records;

– counting of tripping commands as well as recording of fault data and accumulative addition of the interrupted fault currents;

– commissioning aids such as directional verification and circuit breaker live test.

2 Design

2.1 Arrangements

All protection functions including d.c./d.c. converter are accommodated on one plug-in module of Double Europa Format. This module is installed in a housing 7XP20. Two different types of housings can be delivered:

– **7SA510⋆–⋆B⋆⋆⋆–** in housing 7XP2030–1 for **panel surface mounting**

  The housing has full sheet-metal covers, as well as a removable front cover with transparent plastic window.

  Plastic guide rails are built in for the support of plug-in modules. Next to the guide rail at the bottom on the left-hand side of the module, a contact area which is electrically connected to the housing is installed to mate with the earthing spring of the module. Connection to earth is made before the plugs make contact. Earthing screws have been provided on the left hand side of the housing. Additionally, terminal 16 is connected to the case.

  All external signals are connected to 60 screwed terminals which are arranged over cut-outs on the top and bottom covers. The terminals are numbered consecutively from left to right at the bottom and top.

  The heavy duty current plug connectors provide automatic shorting of the c.t. circuits whenever the modules are withdrawn. This does not release from the care to be taken when c.t. secondary circuits are concerned.

  For the optional interface to a central control and storage unit, an additional coupling facility has been provided. For optical fibre connection (model 7SA510⋆–⋆⋆⋆⋆⋆–⋆**C**), two F–SMA connectors have been provided.

  The degree of protection for the housing is IP51, for the terminals IP21. For dimensions please refer to Figure 2.2.

– **7SA510⋆–⋆C⋆⋆⋆–** in housing 7XP2030–2 for **panel flush mounting** or **7SA510⋆–⋆E⋆⋆⋆–** for **cubicle installation**

  The housing has full sheet-metal covers as well as a removable front cover with transparent plastic window for panel mounting.

  Plastic guide rails are built in for the support of plug-in modules. Next to the guide rail at the bottom on the left-hand side of the module, a contact area which is electrically connected to the housing is installed to mate with the earthing spring of the module. Connection to earth is made before the plugs make contact. Earthing screws have been provided on the rear wall of the housing.

  All external signals are connected to connector modules which are mounted on the rear cover over cut-outs. For each electrical connection, one screwed terminal and one parallel snap-in terminal are provided. For field wiring, the use of the screwed terminals is recommended; snap-in connection requires special tools.

  The heavy duty current plug connectors provide automatic shorting of the c.t. circuits whenever the modules are withdrawn. This does not release from the care to be taken when c.t. secondary circuits are concerned.

  For the optional interface to a central control and storage unit (7SA510⋆–⋆⋆⋆⋆⋆–⋆**C**) a module with 2 F–SMA connectors is provided.

  The plug modules are labelled according to their mounting position by means of a grid system (e.g. **1A**2). The individual connections within a module are numbered consecutively from left to right (when viewed from the rear), (e.g. 1A**2**); refer to Figure 2.1.

  Degree of protection for the housing is IP51 (for cubicle installation IP 30), for the terminals IP21. For dimensions please refer to Figure 2.3.

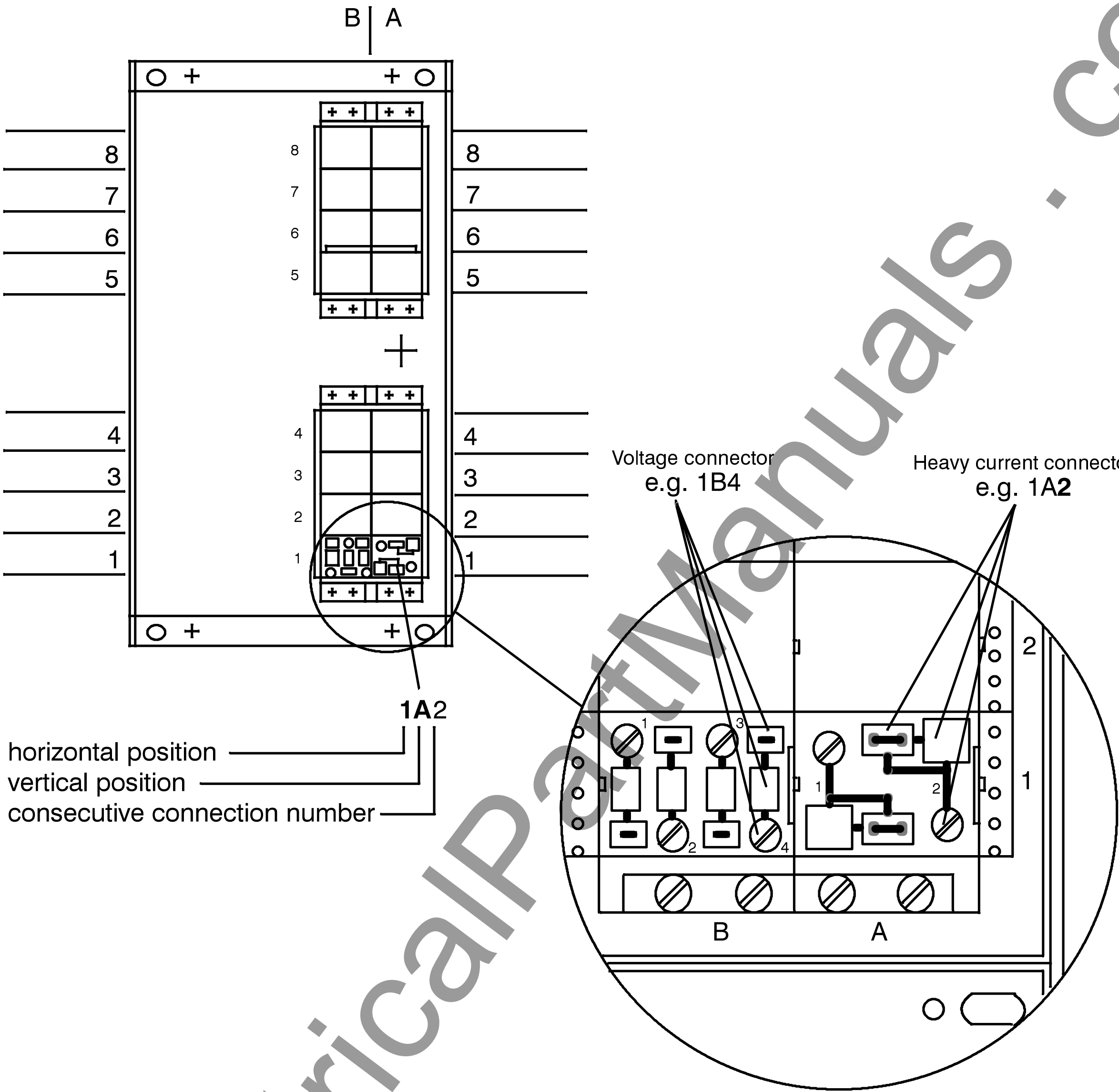
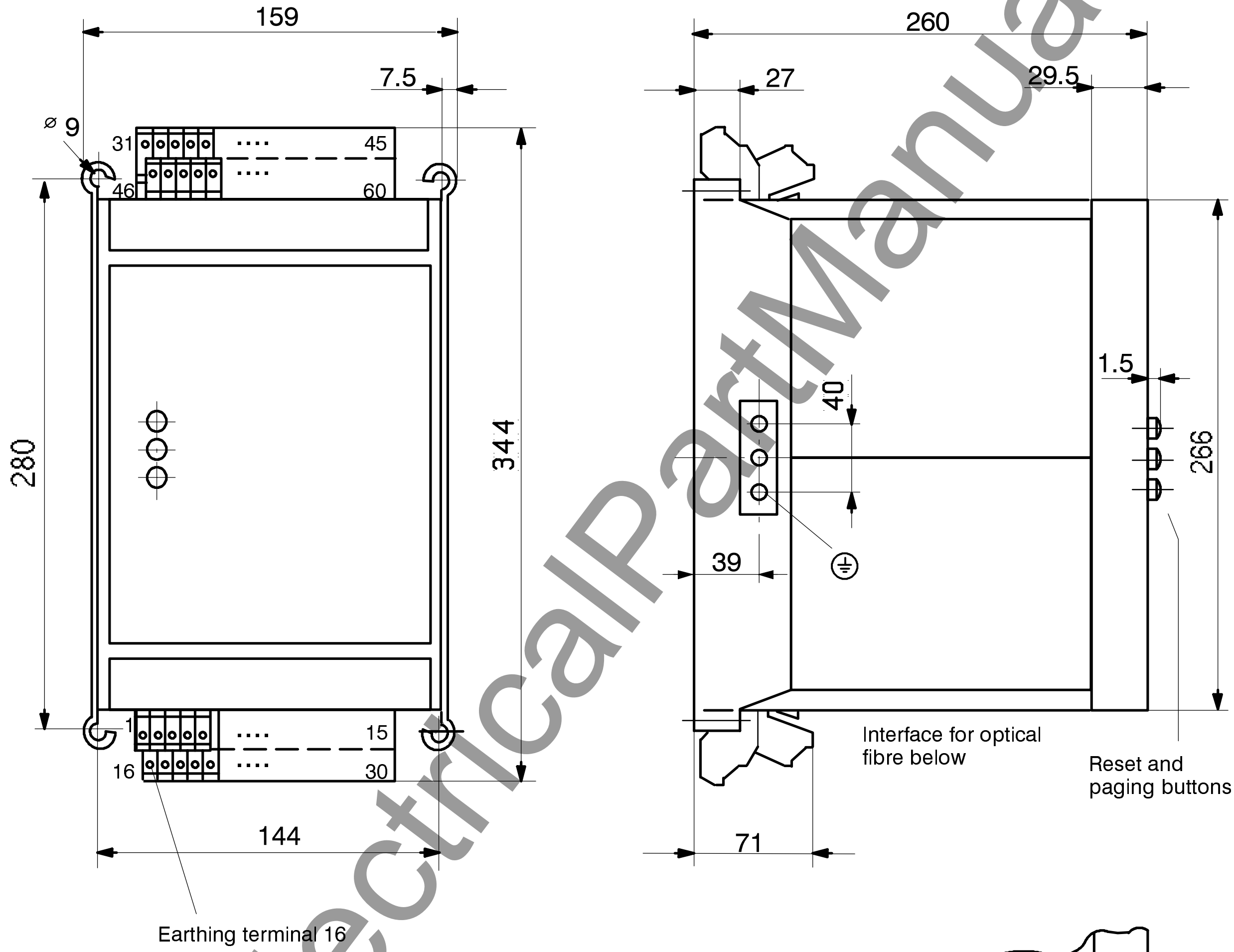


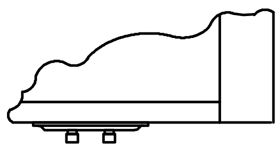
Figure 2.1 Connection plugs (rear view) – housing for flush mounting – example

2.2 Dimensions

Figures 2.2 and 2.3 show the dimensions of the various types of housings available.

7SA510 Housing for **panel surface mounting** 7XP2030 – 1





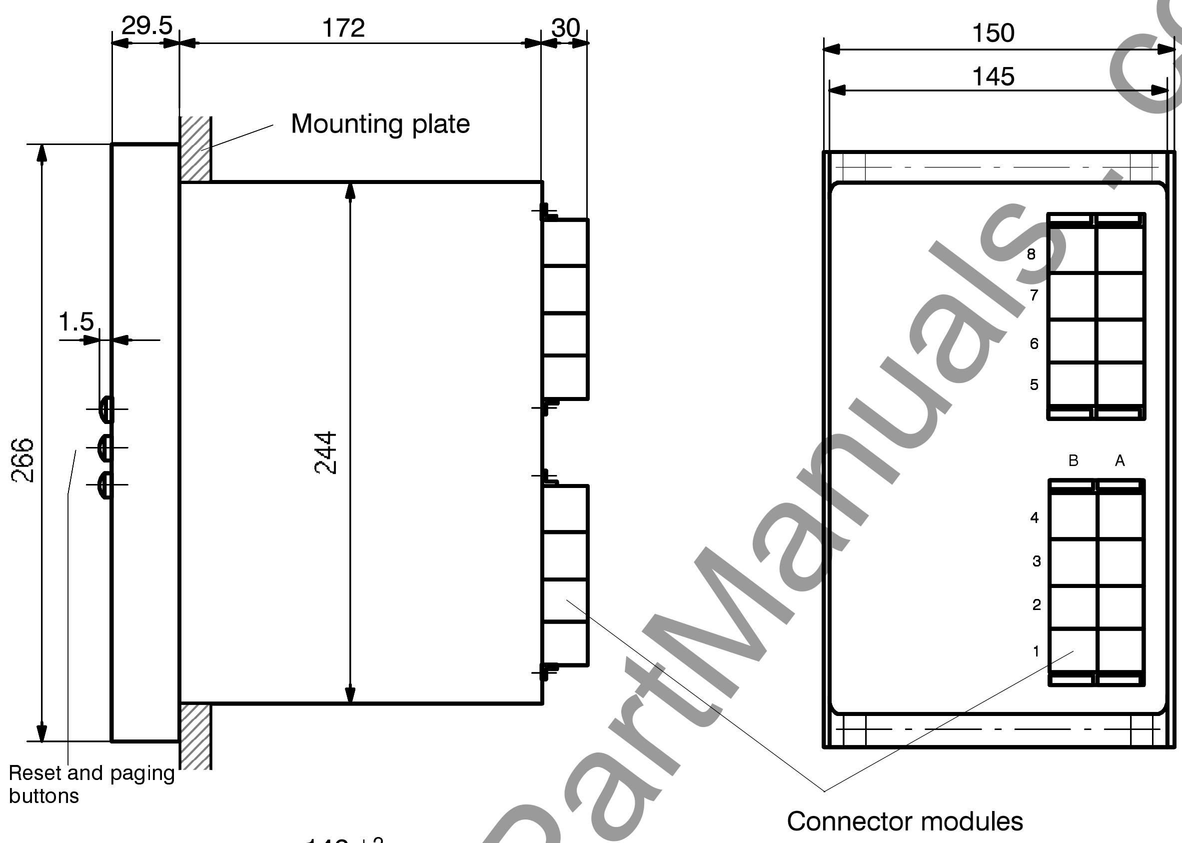
optical fibre connectors
integrated F – SMA connector, with ceramic post, e.g for glass fibre 62.5/125 µm

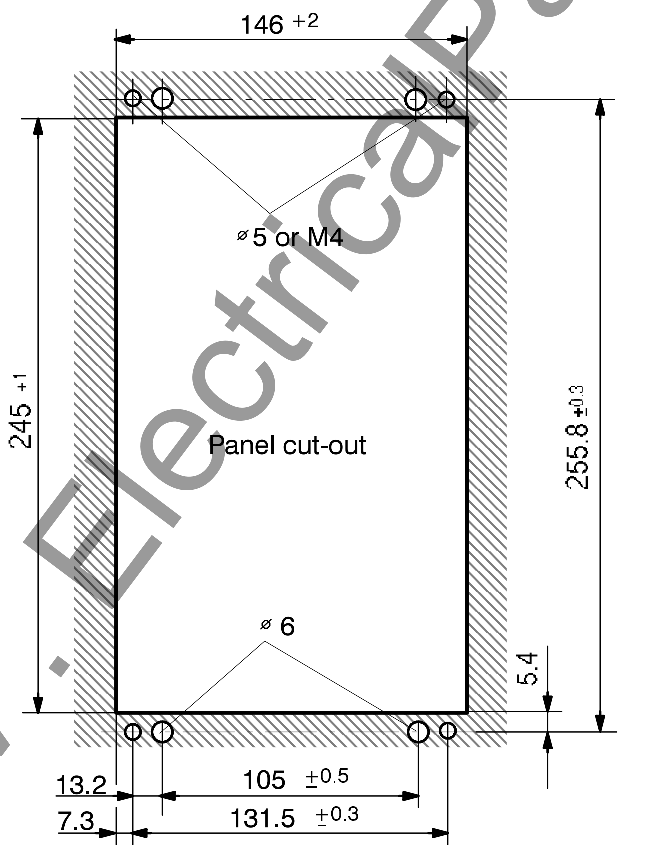
Max. 60 terminals for cross – section max. 7 mm²

Dimensions in mm

Figure 2.2 Dimensions for housing 7XP2030 – 1 for panel surface mounting

7SA510 Housing for **panel flush mounting** or **cubicle installation** 7XP2030−2





Heavy current connectors:
Screwed terminal for max. 4 mm^2.
Twin spring crimp connector in parallel for max. 2.5 mm^2.

Further connectors:
Screwed terminal for max. 1.5 mm^2.
Twin spring crimp connector in parallel for max. 1.5 mm^2.

Optical fibre connectors:
integrated F−SMA connector,
with ceramic post,
e.g for glass fibre 62.5/125 μm

Dimensions in mm

Figure 2.3 Dimensions for housing 7XP2030−2 for panel flush mounting or cubicle installation

2.3 Ordering data

Numerical distance protection relay **7 S A 5 1 0** [7.] – [8.] [9.] [10. A] [11. 7] [12.] – [13. 1] [14.] [15.] [16.]

Rated current; rated frequency (7.)

1 A; 50/60 Hz 1

5 A; 50/60 Hz 5

Auxiliary voltage (8.)

24/48 V dc 2

60/110/125 V dc 4

220/250 V dc 5

Construction (9.)

in housing 7XP2030 – 1 for panel surface mounting . . . . B

in housing 7XP2030 – 2 for panel flush mounting C

in housing 7XP2030 – 2 for cubicle installation
(without glass front) . . . . E

Fault detection systems (12.)

Overcurrent fault detectors 1

Overcurrent and voltage controlled underimpedance (U/I)
and polygonal impedance fault detectors 2

Overcurrent and underimpedance (U/I) fault detectors 3

Serial interface for coupling to a control centre (14.)

without serial interface . . . . A

with serial interface for optical fibre connection (820 nm) C

Supplements 1 (15.)

without . . . . D

with automatic reclosure (three-pole) . . . . F

Supplements 2 (16.)

without 0

with power swing option [1]) 1

with highly sensitive earth fault detection for isolated or compensated systems
and high-resistance earth fault protection for earthed systems (selectable) 2

with power swing option and [1])
with highly sensitive earth fault detection for isolated or compensated systems
and high-resistance earth fault protection for earthed systems (selectable) 3

[1]) only with polygonal impedance fault detectors (12th figure of ordering code = 2)

3 Technical data

3.1 General data

3.1.1 Inputs/outputs

Measuring circuits

Rated current I_N	1 A or 5 A
Rated voltage U_N	80 V to 125 V (settable)
Rated frequency f_N	50 Hz or 60 Hz (settable)
Burden c.t. circuits per phase	
– at I_N = 1 A	approx 0.05 VA
– at I_N = 5 A	approx 0.2 VA
Burden in residual current path at 1 A	approx 0.05 VA
Burden: v.t. circuits	
– at 100 V	< 0.1 VA
Overload capability c.t. circuits, phases	
– thermal (r.m.s.)	100 × I_N for 1 second 30 × I_N for 10 seconds 4 × I_N continuous
– dynamic (impulse)	250 × I_N (half cycle)
Overload capability c.t. circuit residual current	
– thermal (rms)	300 A for 1 second 100 A for 10 seconds 15 A continuous
Overload capability v.t. circuits	
– thermal (r.m.s.)	170 V continuous

Auxiliary DC supply

Auxiliary dc voltage supply via integrated dc/dc converter

Auxiliary voltage U_H	24/48 V dc	60/110/125 V dc	220/250 V dc
Operating ranges	19 to 56 V dc	48 to 144 V dc	176 to 288 V dc

Superimposed ac voltage, peak-to-peak		≤ 12 %
Power consumption	quiescent	approx 10 W
	picked up	approx 13 W
Bridging time during failure/short-circuit of auxiliary dc voltage		≥ 50 ms at U ≥ 110 V dc

Heavy duty (trip) contacts

Trip relays, number	2	
Contacts per relay	2 NO	
Switching capacity MAKE	1000	W/VA
BREAK	30	W/VA
Switching voltage	250	V
Permissible current	5	A continuous
	30	A for 0.5 s

Signal contacts

Signal relays	5	
Contacts per relay	1 CO	
Switching capacity MAKE/BREAK	20	W/VA
Switching voltage	250	V
Permissible current	1	A

Binary inputs, number 4

Voltage range: reconnectable 24 to 250 V dc in 4 ranges:

for rated control voltage	24/48 Vdc	60 Vdc	110/125 Vdc	220/250 Vdc
pick-up value, approx.	16 Vdc	44 Vdc	80 Vdc	160 Vdc

Max. control voltage	288 Vdc
Current consumption	approx 1.7 mA independent of operating voltage

Serial interfaces

Operator terminal interface	non-isolated
– Connection	at the front, 25-pole subminiature connector according ISO 2110 for connection of a personal computer or similar
– Transmission speed	as delivered 9600 Baud; min. 1200 Baud; max. 19200 Baud

Interface for data transfer to a control centre (optional)

– Standards	Protocol according to IEC 60870–5–103 and VDEW/ZVEI
– Transmission speed	as delivered 9600 Baud; min. 1200 Baud; max. 19200 Baud
– Transmission security	Hamming distance d = 4
– Connection optical fibre	integrated F–SMA connector for direct optical fibre connection, with ceramic post, e.g. glass fibre 62.5/125 μm for flush mounted housing: at the rear for surface mounted housing: on the bottom cover
Optical wave length	820 nm
Permissible line attenuation	max. 8 dB
Transmission distance	max. 1.5 km
Normal signal position	reconnectable; factory setting: "light off"

3.1.2 Electrical tests

Insulation tests

Standards:	IEC 60255–5
– High voltage test (routine test) except d.c. voltage supply input	2 kV (rms); 50 Hz
– High voltage test (routine test) only d.c. voltage supply input	2.8 kV dc
– Impulse voltage test (type test) all circuits, class III	5 kV (peak); 1.2/50 µs; 0.5 J; 3 positive and 3 negative shots at intervals of 5 s

EMC tests; immunity (type tests)

Standards:	IEC 60255–6, IEC 60255–22 (product standards) EN 50082–2 (generic standard) VDE 0435/part 303
– High frequency IEC 60255–22–1, class III	2.5 kV (peak); 1 MHz; τ =15 µs; 400 shots/s; duration 2 s
– Electrostatic discharge IEC 60255–22–2 class III and IEC 61000–4–2, class III	4 kV/6 kV contact discharge; 8 kV air discharge; both polarities; 150 pF; R_i = 330 Ω
– Radio-frequency electromagnetic field, non-modulated; IEC 60255–22–3 (report) class III	10 V/m; 27 MHz to 500 MHz
– Radio-frequency electromagnetic field, amplitude modulated; IEC 61000–4–3, class III	10 V/m; 80 MHz to 1000 MHz; 80 % AM; 1 kHz
– Radio-frequency electromagnetic field, pulse modulated; IEC 61000–4–3/ENV 50204, class III	10 V/m; 900 MHz; repetition frequency 200 Hz; duty cycle 50 %
– Fast transients IEC 60255–22–4 and IEC 61000–4–4, class III	2 kV; 5/50 ns; 5 kHz; burst length 15 ms; repetition rate 300 ms; both polarities; R_i = 50 Ω; duration 1 min
– Conducted disturbances induced by radio-frequency fields, amplitude modulated IEC 61000–4–6, class III	10 V; 150 kHz to 80 MHz; 80 % AM; 1 kHz
– Power frequency magnetic field IEC 61000–4–8, class IV IEC 60255–6	30 A/m continuous; 300 A/m for 3 s; 50 Hz 0.5 mT; 50 Hz

EMC tests; emission (type tests)

Standard:	EN 50081–★ (generic standard)
– Conducted interference voltage, aux. voltage CISPR 22, EN 55022, class B	150 kHz to 30 MHz
– Interference field strength CISPR 11, EN 55011, class A	30 MHz to 1000 MHz

3.1.3 Mechanical stress tests

Vibration and shock during operation

Standards:	IEC 60255−21 and IEC 60068−2
− Vibration IEC 60255−21−1, class 1 IEC 60068−2−6	sinusoidal 10 Hz to 60 Hz: ± 0.035 mm amplitude; 60 Hz to 150 Hz: 0.5 g acceleration sweep rate 1 octave/min 20 cycles in 3 orthogonal axes
− Shock IEC 60255−21−2, class 1	half sine acceleration 5 g, duration 11 ms, 3 shocks in each direction of 3 orthogonal axes
− Seismic vibration IEC 60255−21−3, class 1 IEC 60068−3−3	sinusoidal 1 Hz to 8 Hz: ± 3.5 mm amplitude (hor. axis) 1 Hz to 8 Hz: ± 1.5 mm amplitude (vert. axis) 8 Hz to 35 Hz: 1 g acceleration (hor. axis) 8 Hz to 35 Hz: 0.5 g acceleration (vert. axis) sweep rate 1 octave/min 1 cycle in 3 orthogonal axes

Vibration and shock during transport

Standards:	IEC 60255−21 and IEC 60068−2
− Vibration IEC 60255−21−1, class 2 IEC 60068−2−6	sinusoidal 5 Hz to 8 Hz: ± 7.5 mm amplitude; 8 Hz to 150 Hz: 2 g acceleration sweep rate 1 octave/min 20 cycles in 3 orthogonal axes
− Shock IEC 60255−21−2, class 1 IEC 60068−2−27	half sine acceleration 15 g, duration 11 ms, 3 shocks in each direction of 3 orthogonal axes
− Continuous shock IEC 60255−21−2, class 1 IEC 60068−2−29	half sine acceleration 10 g, duration 16 ms, 1000 shocks each direction of 3 orthogonal axes

3.1.4 Climatic stress tests

− recommended temperature during service	−5 °C	to +55 °C	(> 55 °C decreased display contrast)
− permissible temperature during service	−20 °C	to +70 °C	
permissible temperature during storage	−25 °C	to +55 °C	
permissible temperature during transport	−25 °C	to +70 °C	

Storage and transport with standard works packaging!

– Permissible humidity	mean value per year ≤ 75 % relative humidity; on 30 days per year 95 % relative humidity; Condensation not permissible!

We recommend that all units are installed such that they are not subjected to direct sunlight, nor to large temperature fluctuations which may give rise to condensation.

3.1.5 Service conditions

The relay is designed for use in industrial environment, for installation in standard relay rooms and compartments so that with proper installation **electro-magnetic compatibility (EMC)** is ensured. The following should also be heeded:

– All contactors and relays which operate in the same cubicle or on the same relay panel as the digital protection equipment should, as a rule, be fitted with suitable spike quenching elements.

– All external connection leads in sub-stations from 100 kV upwards should be screened with a screen capable of carrying power currents and earthed at both sides. No special measures are normally necessary for sub-stations of lower voltages.

– It is not permissible to withdraw or insert individual modules under voltage. In the withdrawn condition, some components are electrostatically endangered; during handling the standards for electrostatically endangered components must be observed. The modules are not endangered when plugged in.

WARNING! The relay is not designed for use in residential, commercial or light-industrial environment as defined in EN 50081.

3.1.6 Design

Housing	7XP20; refer to Section 2.1
Dimensions	refer to Section 2.2
Weight	
– in housing for surface mounting	approx. 8.8 kg
– in housing for flush mounting	approx. 5.5 kg
Degree of protection acc. to EN 60529	
– Housing	IP 51 *)
– Terminals	IP 21

*) IP30 for cubicle installation; the degree of protection required for the point of installation must be ensured by the cubicle.

3.2 Distance protection

Earth impedance matching

R_E/R_L	−7.00 to +7.00 (steps 0.01)
X_E/X_L	−7.00 to +7.00 (steps 0.01)

Phase preferences

for double earth faults in solidly earthed systems	phase to phase or leading phase to earth or lagging phase to earth
for double earth faults in isolated or arc compensated systems	L3 (L1) or L1 (L3) acyclic or L2 (L1) or L1 (L2) acyclic or L3 (L2) or L2 (L3) acyclic or L3 (L1) or L1 (L3) cyclic
Displacement voltage pick-up $U_e>$ (= $\sqrt{3} \cdot U_0$) in isolated or arc compensated systems	10 V to 100 V (steps 1 V)

Fault detection

Overcurrent fault detection, general fault detection parameters

Phase currents $I_{ph}>>/I_N$	0.25 to 4.00	(steps 0.01)
Earth current $I_e>/I_N$	0.10 to 1.00	(steps 0.01)
Displacement voltage pick-up $U_e>$ (= $\sqrt{3} \cdot U_0$) in solidly earthed systems	2 V to 100 V	(steps 1 V); ∞
Drop-off ratios	approx. 0.95	
Measuring tolerances according VDE 0435 part 303	± 5%	

Voltage controlled current fault detection (under-impedance fault detection) (optional)

Characteristic	two-stage with settable inclination	
Voltage control	by U_{ph-e} or U_{ph-ph} (selectable)	
Setting ranges:		
− minimum current pick-up $I_{ph}>$	0.10 to 1.00 · I_N	(steps 0.01 · I_N)
− Undervoltage pick-up $U_{ph-e}<$	20 V to 70 V	(steps 1 V)
$U_{ph-ph}<$	40 V to 130 V	(steps 1 V)
Drop-off ratios:		
− $I_{ph}>$	approx. 0.95	
− $U_{ph-e}<$, $U_{ph-ph}<$	approx. 1.05	
Measuring tolerances according VDE 0435 part 303	± 5%	

Impedance fault detection (fix-impedance) (optional)

Characteristic	polygonal, phase angle dependent R−section	
Setting values (based on I_N = 1A*):		
X+A = forwards reach (for all faults)	0.10 Ω to 200.00 Ω	(steps 0.01 Ω)
X−A = reverse reach (for all faults)	0.10 Ω to 200.00 Ω	(steps 0.01 Ω)
RA_2 = resistance tolerance (phase-phase, $\varphi_{SC} > \varphi_A$)	0.10 Ω to 200.00 Ω	(steps 0.01 Ω)
RA_1 = resistance tolerance (phase-phase, $\varphi_{SC} < \varphi_A$)	0.10 Ω to 100.00 Ω	(steps 0.01 Ω)
φ_A = limit angle between RA_1 and RA_2	30.0° to 80.0°	(steps 0.1°)
RA_{2E} = resistance tolerance (phase-earth, $\varphi_{SC} > \varphi_{AE}$)	0.10 Ω to 200.00 Ω	(steps 0.01 Ω)
RA_{1E} = resistance tolerance (phase-earth, $\varphi_{SC} < \varphi_{AE}$)	0.10 Ω to 200.00 Ω	(steps 0.01 Ω)
φ_{AE} = limit angle between RA_{1E} and RA_{2E}	30.0° to 80.0°	(steps 0.1°)
$I_{ph}>$ = minimum operating phase current	0.10 to 4.00 · I_N	(steps 0.01 · I_N)
Drop-off ratios:		
− for R, X	approx. 1.06	
− for $I_{ph}>$	approx. 0.95 (for I ≥ I_N)	

*) Secondary values are related on I_N = 1 A; for I_N = 5 A the values are to be divided by 5.

Measuring tolerances according VDE0435 part 303 with sinusoidal quantities	$\left\|\frac{\Delta x}{x}\right\| \leq 5\%$ for $30^\circ \leq \varphi_{sc} \leq 90^\circ$ $\left\|\frac{\Delta R}{R}\right\| \leq 5\%$ for $0^\circ \leq \varphi_{sc} \leq 60^\circ$

Distance measurement

Characteristic	polygonal, 3 independent + 1 controlled stages
Setting values (based on I_N = 1A*)	
X = forwards reach (for all faults)	0.05 Ω to 130.00 Ω (steps 0.01 Ω)
R = resistance tolerance (phase-phase)	0.05 Ω to 65.00 Ω (steps 0.01 Ω)
R_E = resistance tolerance (phase-earth)	0.05 Ω to 130.00 Ω (steps 0.01 Ω)
Measuring tolerances according VDE0435 part 303 with sinusoidal quantities	$\left\|\frac{\Delta x}{x}\right\| \leq 5\%$ for $30^\circ \leq \varphi_{sc} \leq 90^\circ$ $\left\|\frac{\Delta R}{R}\right\| \leq 5\%$ for $0^\circ \leq \varphi_{sc} \leq 60^\circ$

*) Secondary values are related on I_N = 1 A; for I_N = 5 A the values are to be divided by 5.

Directional determination

For all types of faults	with quadrature voltages and voltage memory
Sensitivity	dynamically unlimited

Times

Shortest tripping time	approx. 22 ms
Drop-off time	approx. 40 ms
Time stages:	
Setting ranges for all stages	0.00 s to 32.00 s (steps 0.01 s) or ∞ (i.e. stage ineffective)
Time expiry tolerances	≤1% of set value or 10 ms

All stages can be set to operate in forward or reverse direction or non-directional. The set times are pure delay times.

Overcurrent emergency protection

with measured voltage failure, e.g. VT secondary mcb trip or detected fuse failure

High-set phase overcurrent $I>>/I_N$	0.50 to 9.99	(steps 0.01)
Definite time delay $T_{I>>}$	0.00 s to 32.00 s	(steps 0.01 s)
	or ∞ (i.e. stage ineffective)	
Phase overcurrent $I_{ph}>/I_N$	0.10 to 4.00	(steps 0.01)
Definite time delay $T_{Iph>}$	0.00 s to 32.00 s	(steps 0.01 s);
	or ∞ (i.e. stage ineffective)	
Earth overcurrent $I_E>/I_N$	0.10 to 4.00	(steps 0.01)
Definite time delay $T_{IE>}$	0.00 s to 32.00 s	(steps 0.01 s)
	or ∞ (i.e. stage ineffective)	
Drop-off ratios		
– for $I \geq I_N$	approx. 0.95	
– for $I \geq 0.25 \times I_N$	approx. 0.90	
Measuring tolerances according VDE 0435 part 303	± 5%	

3.3 Power swing supplement (optional – only with impedance fault detection)

Power swing detection	rate of change of the impedance vector between ”power swing polygon” and ”fault detection polygon”
Setting the difference ΔR between the polygons (secondary based on I_N = 1A *)	0.10 Ω to 50.00 Ω (steps 0.01 Ω)
Setting rate of change dR/dT	0 Ω/s to 200 Ω/s (steps 1 Ω/s)
Programs	block first distance zone only, block all zones but first zone, block all distance zones, out-of-step tripping
Action time	0.01 s to 32.00 s (steps 0.01 s) or ∞ (i.e. until drop-off of the power swing polygon)

*) Secondary values are related on I_N = 1 A; for I_N = 5 A the values are to be divided by 5.

3.4 Teleprotection interface

Teleprotection modes (selectable)

– Permissive underreach transfer trip	zone acceleration (special zone Z1B) fault detection acceleration
Transmit signal prolongation	0.01 s to 32.00 s (steps 0.01 s)
Transmit signal delay	0.00 s to 32.00 s (steps 0.01 s)
Received signal prolongation	0.00 s to 32.00 s (steps 0.01 s)
– Permissive overreach transfer trip	release overreaching zone Z1B release fault detection zone directional unblocking zone Z1B unblocking fault detection zone directional blocking zone Z1B
Transmit signal prolongation	0.01 s to 32.00 s (steps 0.01 s)
Transmit signal delay	0.00 s to 32.00 s (steps 0.01 s)
Echo delay time	0.01 s to 32.00 s (steps 0.01 s); ∞
Echo pulse duration	0.02 s to 32.00 s (steps 0.01 s)
Echo block duration	0.01 s to 32.00 s (steps 0.01 s)
Transient blocking time	0.01 s to 32.00 s (steps 0.01 s)
Waiting time for transient blocking	0.01 s to 32.00 s (steps 0.01 s); ∞
– Overreaching transfer via pilot wires	NC link with DC control cable and supplementary auxiliary relay
– Reverse interlocking	with NO or NC interlock loop

3.5 User definable logic functions

Number	2
logical inputs via binary input logical outputs for binary outputs	Start and Stop time expired
operating time	approx. 30 ms
delay	0.00 s to 32.00 s (steps 0.01 s)
time tolerance	1 % of set value or 10 ms

3.6 Thermal overload protection

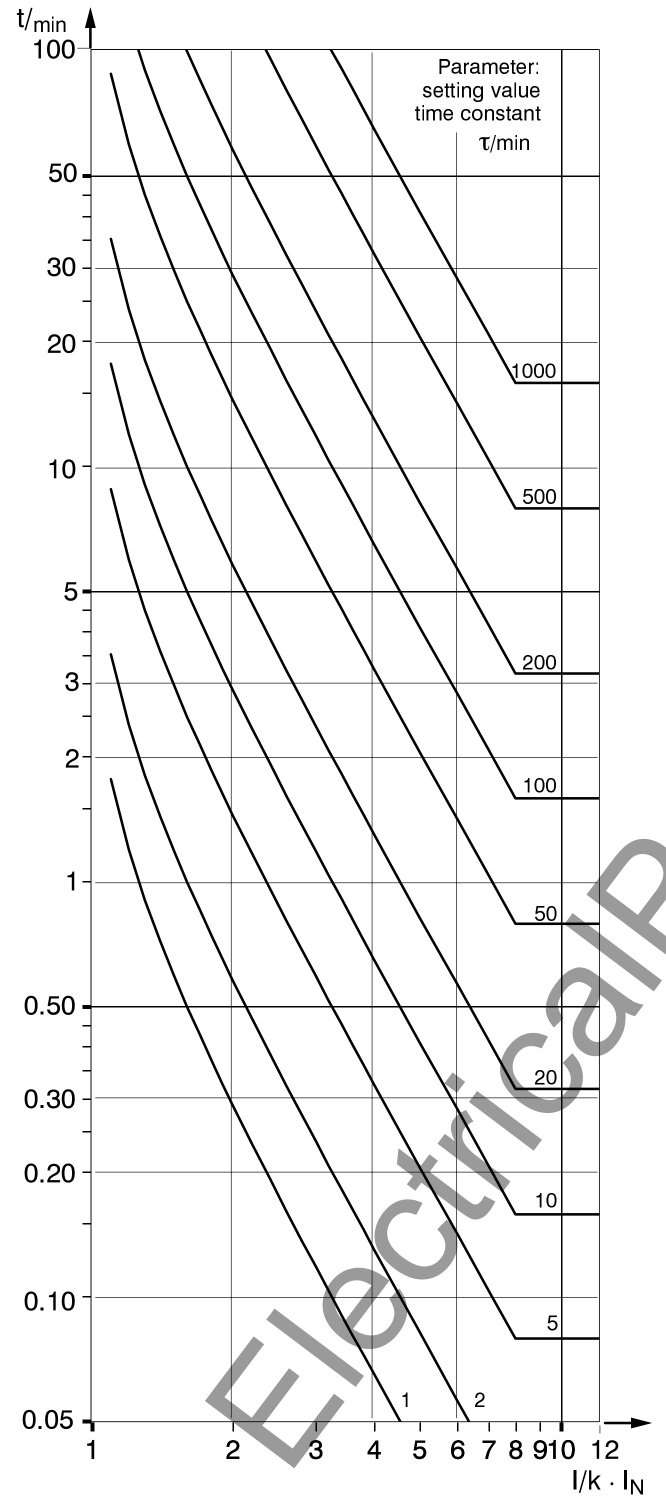
Setting ranges/steps			
Factor k according to IEC 60255−8		0.10 to 4.00	(steps 0.01)
Time constant τ		1.0 to 999.9 min	(steps 0.1 min)
Thermal warning stage	$\Theta_{warn} / \Theta_{trip}$	50 % to 100 % referred to trip temperature rise	(steps 1 %)
Current warning stage	I_{warn}/I_N	0.10 to 4.00	(steps 0.01)

Trip time characteristic

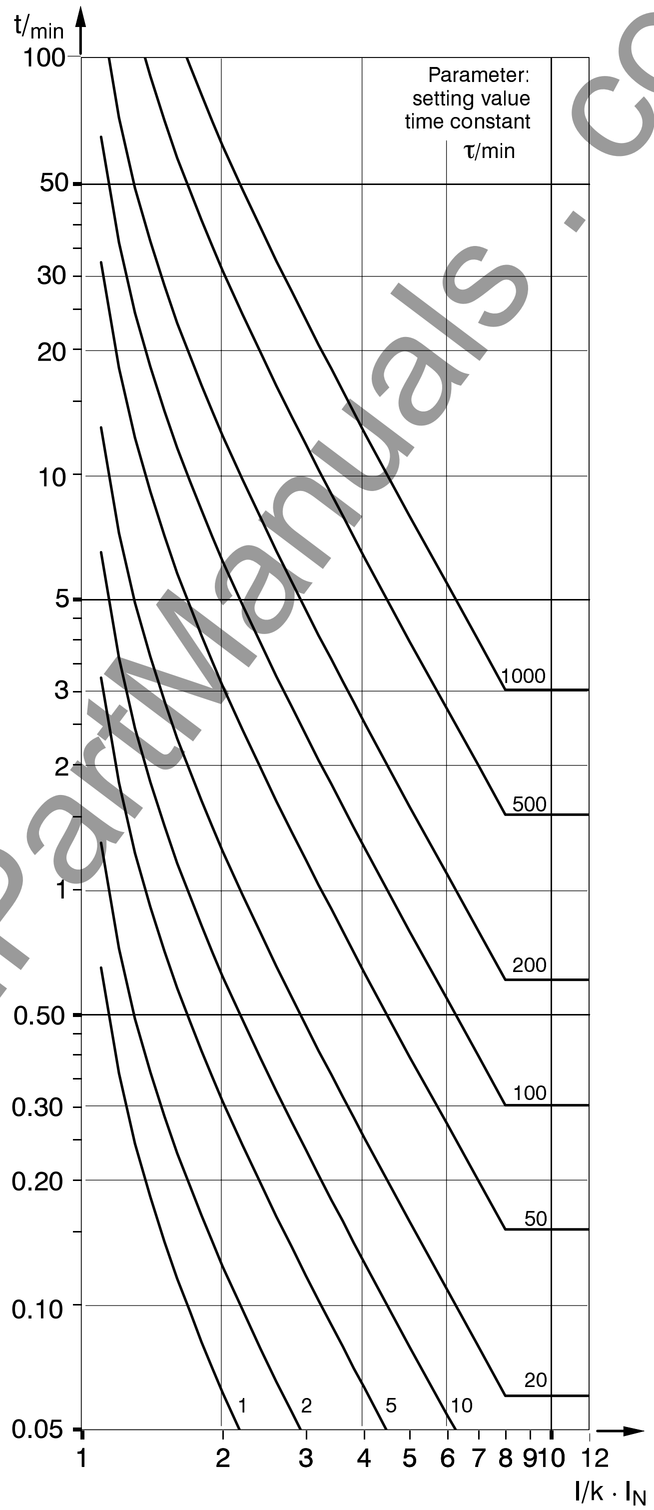
$$t = \tau \cdot \ln \frac{\left(I/(k \cdot I_N)\right)^2 - \left(I_{pre}/(k \cdot I_N)\right)^2}{\left(I/(k \cdot I_N)\right)^2 - 1}$$

t	trip time
τ	thermal time constant
I	load current
I_{pre}	preload current
k	factor according to IEC 60255−8 refer also to Figures 3.1 and 3.2

Drop-off ratios	
Θ / Θ_{trip}	approx. 0.99
Θ / Θ_{warn}	approx. 0.99
I/I_{warn}	approx. 0.99
Tolerances	
– referring to $k \cdot I_N$	± 10 %
– referring to trip time	± 10 % ± 2 s
Influence variables referred to $k \cdot I_N$	
– Auxiliary dc voltage in range $0.8 \leq U_H/U_{HN} \leq 1.15$	$\leq$ 1 %
– Temperature in range $-5\ ^\circ C \leq \vartheta_{amb} \leq +40\ ^\circ C$	$\leq$ 0.5 %/10 K
– Frequency in range $0.95 \leq f/f_N \leq 1.05$	$\leq$ 1 %



$$t = \tau \cdot \ln \frac{\left(I/(k \cdot I_N)\right)^2}{\left(I/(k \cdot I_N)\right)^2 - 1}$$



$$t = \tau \cdot \ln \frac{\left(I/(k \cdot I_N)\right)^2 - \left(I_{pre}/(k \cdot I_N)\right)^2}{\left(I/(k \cdot I_N)\right)^2 - 1}$$

for 90 % preload

Figure 3.1 Trip time characteristic of overload protection – without preload –

Figure 3.2 Trip time characteristic of overload protection – with 90 % preload –

3.7 Earth fault detection in non-earthed systems (optional)

Detection	
Displacement voltage U_e>	10 V to 100 V (steps 1 V)
Delay (optional trip)	approx. 1 s (settable up to 320 s)
Measuring tolerance according VDE 0435 part 303	$\leq$ 5 % of set value
Faulted phase determination	
Measuring principle	voltage measurement phase to earth
U< (faulted phase) U> (unfaulted phases)	10 V to 100 V (steps 1 V) 10 V to 100 V (steps 1 V)
Measuring tolerance according VDE 0435 part 303	$\leq$ 5 % of set value
Directional determination	
Measuring principle	measurement of active and reactive power
Pick-up value I_e> (active or reactive component) CT angle error correction	3 mA to 1000 mA (steps 1 mA) 0.0° to 5.0° (steps 0.1°) for 2 operating points of the CT characteristic
Measuring tolerance according VDE 0435 part 303	$\leq$ 10 % of set value for tan $\varphi \leq$ 20 (with active component)

3.8 High-resistance earth fault protection in solidly earthed systems (optional)

Fault detection

Earth current pick-up $I_E>/I_N$ (for trip)	0.10 to 4.00 (steps 0.01)
Lower pick-up value (for measurement release)	$0.75 \cdot I_E>/I_N$
Displacement voltage $U_E>$	1.0 V to 10.0 V (steps 0.1 V)
Drop-off ratio	approx. 0.95
Measuring tolerance according VDE 0435 part 303	$\leq$ 5 % of set value

Directional determination

Measuring principle	with I_E (= $3 \cdot I_0$) and U_E (= $\sqrt{3} \cdot U_0$)
Forwards angle	approx. −14° to +166°
Measuring tolerances at U_N and I_N with sinusoidal quantities	$\leq$ 5°
Directional comparison	release mode

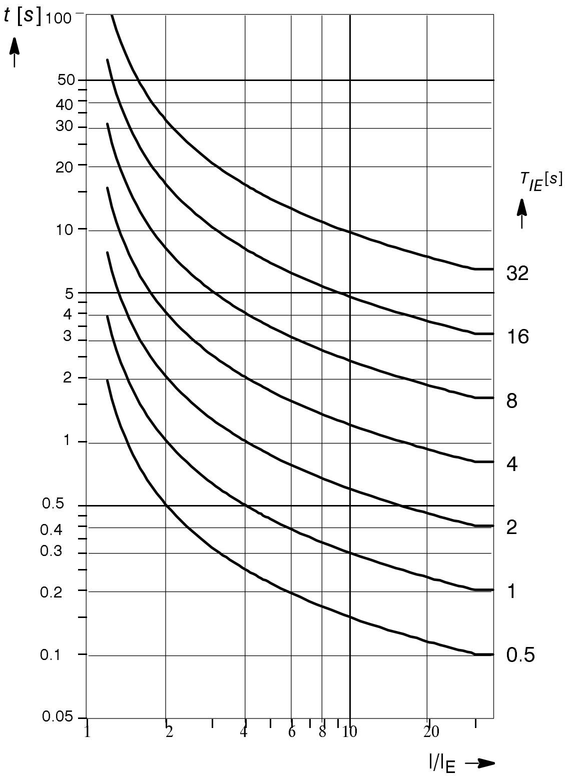
Times

Shortest tripping time	approx. 50 ms
Re-orientation time after change of direction	approx. 50 ms
Trip delay time	0.00 s to 32.00 s (steps 0.01 s); ∞
Back-up time T directional	0.00 s to 32.00 s (steps 0.01 s); ∞
Back-up time T non-directional	0.00 s to 32.00 s (steps 0.01 s); ∞
Echo delay time	0.01 s to 32.00 s (steps 0.01 s); ∞
Echo pulse duration	0.02 s to 32.00 s (steps 0.01 s)
Echo block duration	0.01 s to 32.00 s (steps 0.01 s)
Transient blocking time	0.01 s to 32.00 s (steps 0.01 s)
Waiting time for transient blocking	0.01 s to 32.00 s (steps 0.01 s); ∞
Time expiry tolerances	$\leq$ 1% or 10 ms

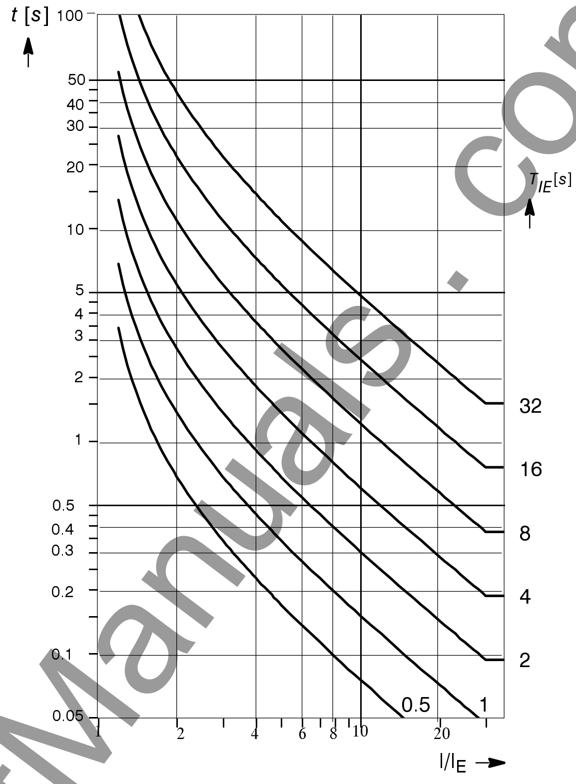
Inverse time earth fault back-up protection

can be used **instead** of the earth fault protection as described before

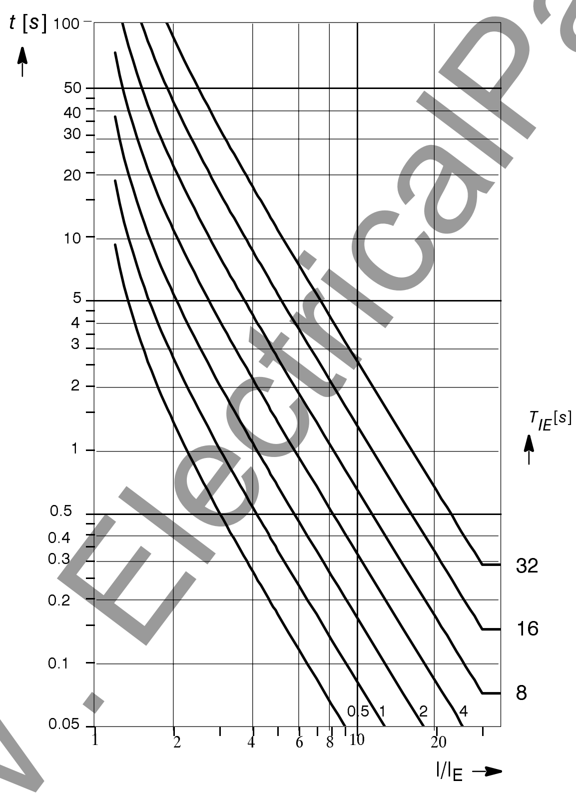
Characteristics	normal inverse or very inverse or extremely inverse (type A or B or C) according IEC 60255−3 or BS142; refer to Figure 3.3
Pick-up value $I_E>/I_N$	0.10 to 4.00 (steps 0.01)
Time setting $T_{IE>}$	0.00 s to 32.00 s (steps 0.01 s); ∞
corresponds to TM factor	0.000 to 3.200 (steps 0.001); ∞
Measuring tolerances	
− earth current pick-up value	+ 5 % to +15 %
− time expiry	$\leq$ 5 % $\pm$ 15 ms for $2 \leq I/I_E \leq 20$ and $1 \leq T_{IE}/s \leq 20$



Normal inverse: $t = \frac{0.14}{(I/I_E)^{0.02} - 1} \cdot \frac{T_{IE}}{10}$ [s]



Very inverse: $t = \frac{13.5}{(I/I_E) - 1} \cdot \frac{T_{IE}}{10}$ [s]



Extremely inverse: $t = \frac{80}{(I/I_E)^2 - 1} \cdot \frac{T_{IE}}{10}$ [s]

T_{IE}/10 corresponds to the usual time multiplier TM

t	tripping time
T_{IE}	set time delay (parameter TIe>)
I	earth fault current
I_E	set earth fault pick-up value (parameter Ie>)

Figure 3.3 Tripping time characteristics of inverse time earth fault protection

3.9 Automatic reclosure (optional)

Max. number of possible shots	1 RAR (first shot) up to 9 DAR (further shots)	
Auto-reclose mode	three-pole	
Action times	0.01 s to 320.00 s	(steps 0.01 s)
RAR dead time	0.01 s to 320.00 s	(steps 0.01 s)
DAR dead times	0.01 s to 1800.00 s	(steps 0.01 s)
Reclaim time	0.50 s to 320.00 s	(steps 0.01 s)
Lock-out time	0.50 s to 320.00 s	(steps 0.01 s); ∞
Reclaim time after manual close	0.50 s to 320.00 s	(steps 0.01 s)
Duration of RECLOSE command	0.01 s to 32.00 s	(steps 0.01 s)

3.10 Distance-to-fault location

Output of fault distance	in Ω primary in Ω secondary in km line length [1]) in percent line length [1])
Start-to-measure command	by trip signal or by drop-off of fault detection or by external command via binary input
Setting reactance per unit line length (secondary*))	0.010 Ω/km to 5.000 Ω/km (steps 0.001 Ω/km)
Measuring tolerances according VDE 0435 part 303 sinusoidal quantities	$\leq$ 2.5 % of line length (without intermediate infeed) for $30° \leq \varphi_{sc} \leq 90°$ and $U_{sc}/U_N \leq 0.1$

*) Secondary values are related on I_N = 1 A; for I_N = 5 A the values are to be divided by 5.

[1]) Output of fault distance in km or miles or percents only for homogeneous lines! When setting related reactance in Ω/mile, the output is to be read in miles.

3.11 Ancillary functions

Output of measured values

Operational values of currents	I_{L1}, I_{L2}, I_{L3} in A primary and in % I_N
– range	0 % to 240 % I_N
– tolerance	2 % of I_N for $I \leq I_N$ 2 % of meas. value for $I > I_N$
Operational values of voltages	U_{L1-E}, U_{L2-E}, U_{L3-E} in kV primary and in % $U_N/\sqrt{3}$
– range	0 % to 120 % $U_N/\sqrt{3}$
– tolerance	2 % of U_N
Operational values of voltages	U_{L1-L2}, U_{L2-L3}, U_{L3-L1} in kV primary and in % U_N
– range	0 % to 120 % U_N
– tolerance	2 % of U_N
Operational values of powers	P_a, P_r (active and reactive power) in MW or MVAr primary and in % S_N ($= \sqrt{3} \cdot U_N \cdot I_N$)
– range	0 % to 120 % S_N
– tolerance	5 % of S_N
Operational value of frequency	f in % f_N
– range	96 % to 104 % f_N
– tolerance	0.5 % of f_N
Operational values of overload protection	calculated temperature rise related on trip temperature rise
Earth fault measured values in non-earthed systems (models with sensitive residual current input)	I_{Ea}, I_{Er} (active and reactive earth current) in A primary and mA at relay input

All indications ±1 digit display tolerance

Measured values plausibility checks

– Sum of currents	phases and earth

Steady-state measured value supervision

Current unbalance	I_{max}/I_{min} > symmetry factor as long as $I > I_{limit}$
Voltage unbalance (phase-to-phase and phase-to-earth)	U_{max}/U_{min} > symmetry factor as long as $U > U_{limit}$
Voltage failure (three-phase)	$\|U\| <$ limit voltage as long as $\|Imax\| >$ limit current
Voltage failure (single-phase)	$U_E>$ and $I_E<$
Phase sequence	clockwise phase rotation

Fault event data storage

Storage of annunciations of the last four fault events; the three last can be read out locally

Real time clock

Resolution for operational annunciations	1 min (1ms with personal computer)
Resolution for fault event annunciations	1 ms
Resolution fo earth fault annunciations	1 ms
Max time deviation	0.01 %
Buffer battery	Lithium – Battery 3 V/1 Ah, Type CR 1/2 AA Self-discharge time > 10 years

Data storage for fault recording

Storage period (fault detection or trip command = 0 ms), max.	5 s, selectable pre-trigger and post-fault time
Sampling rate	1 instantaneous value per ms at 50 Hz 1 instantaneous value per 0.83 ms at 60 Hz

Circuit breaker operation log

Number of stored trip events caused by 7SA510	up to 9 decimal digits
Number of stored reclose events	up to 9 decimal digits; separate for RAR and DAR
Total of tripped currents	up to 7 decimal digits plus 1 after decimal point pole segregated

Trip command and annunciations via binary input

– 1 user definable trip command	for annunciation processing and direct local trip
– 4 user definable annunciations	for annunciation processing

Commissioning aids

Phase sequence and directional check	
Circuit breaker test	with or without auto-reclosure
Storage of a test record	

4 Method of operation

4.1 Operation of complete unit

The numerical distance protection SIPROTEC 7SA510 is equipped with a powerful and proven 16-bit microprocessor. This provides fully digital processing of all functions from data acquisition of measured values to the trip command for the circuit breaker.

Figure 4.1 shows the base structure of the unit.

The transducers of the measured value input section ME transform the currents and voltages from the measurement transformers of the switch-gear and match them to the internal processing level of the unit. Apart from the galvanic and low-capacitive isolation provided by the input transformers, filters are provided for the suppression of interference. The filters have been optimized with regard to bandwidth

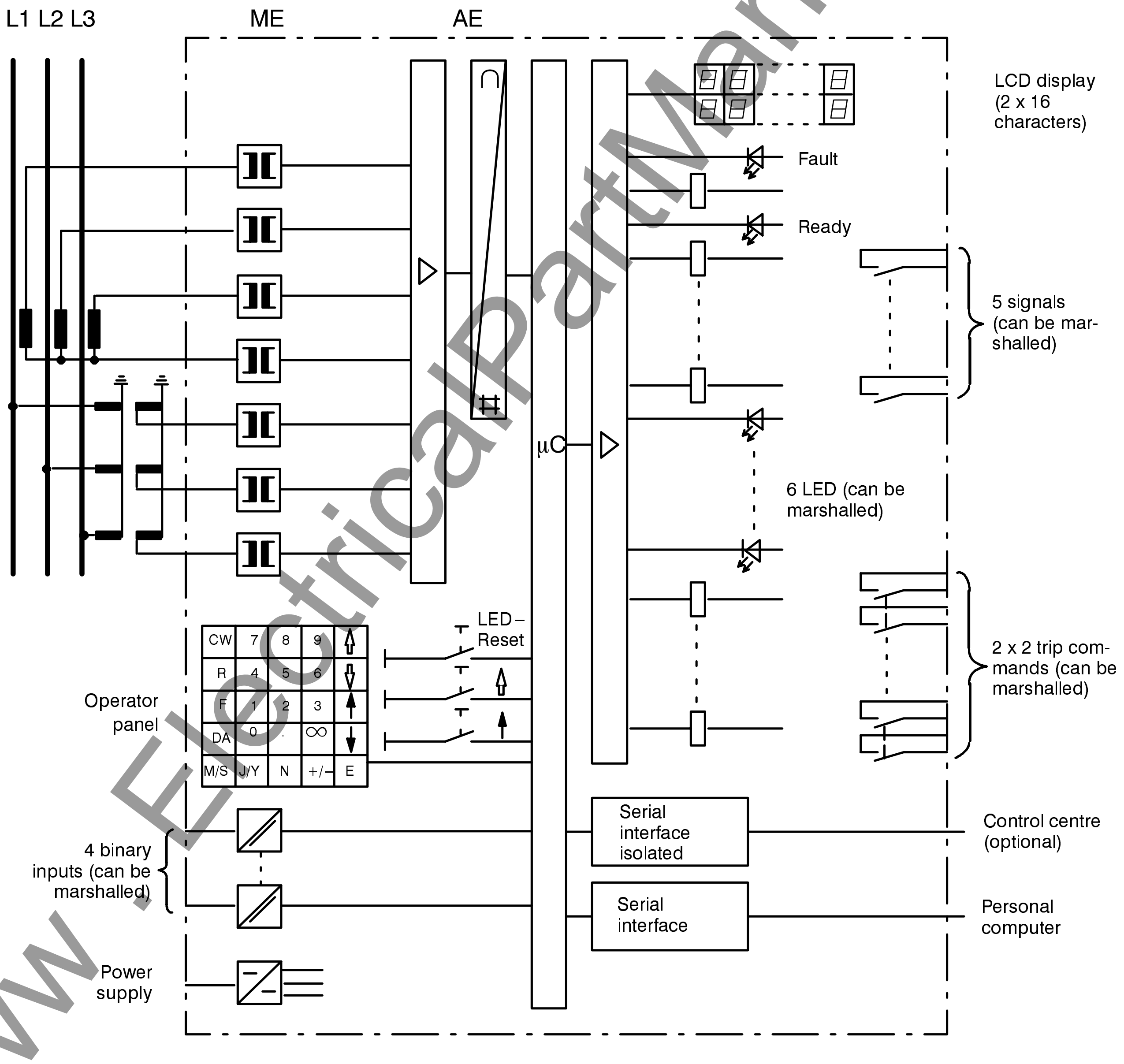


Figure 4.1 Hardware structure of distance protection relay 7SA510

and processing speed to suit the measured value processing. The matched analog values are then passed to the analog input section AE.

The analog input section AE contains input amplifiers, sample and hold elements for each input, analog-to-digital converters and memory circuits for the data transfer to the microprocessor.

Apart from control and supervision of the measured values, the microprocessor processes the actual protective functions. These include in particular:

– filtering and formation of the measured quantities,
– continuous calculation of the values which are relevant for fault detection,
– determination of the faulted phases in case of a fault,
– scanning of limit values and time sequences,
– controlling of signals and sequences for teleprotection etc.,
– decision about trip commands,
– storage of instantaneous current and voltage values during a fault for analysis.

Binary inputs and outputs to and from the processor are channelled via the input/output elements. From these the processor receives information from the switch-gear (e.g. remote resetting) or from other equipment (e.g. blocking signals). Outputs include, in particular, trip commands to the circuit breaker, signals for remote signalling of important events and conditions as well as visual indicators (LEDs) and an alphanumerical display on the front.

An integrated membrane keyboard in connection with a built-in alphanumerical LCD display enables communication with the unit. All operational data such as setting values, plant data, etc. are entered into the protection from this panel (refer to Section 6.3). Using this panel the parameters can be recalled and the relevant data for the evaluation of a fault can be read out after a fault has occurred (refer to Section 6.4). The dialog with the relay can be carried out alternatively via the serial interface in the front plate by means of a personal computer.

Via a second serial interface (option), fault data can be transmitted to a central evaluation unit. During healthy operation, measured values can also be transmitted, e.g. load currents. This second interface is suited to the transmission by means of optical fibre links.

A power supply unit provides the auxiliary supply on the various voltage levels to the described functional units. +24 V is used for the relay outputs. The analog input requires ±15 V whereas the processor and its immediate peripherals are supplied with +5 V. Transient failures in the supply voltage, up to 50 ms, which may occur during short-circuits in the d.c. supply system of the plant are bridged by a dc voltage storage element (rated auxiliary voltage $\geq$ 110 Vdc).

4.2 Distance protection

Distance protection is the main function of the relay. It is characterized by high measuring accuracy and flexible adaptation possibilities for the given network characteristics. It can be extended by a range of auxiliary functions.

4.2.1 Fault detection

Fault detection has the duty to detect a faulty condition in the network and to initiate all the necessary procedures for selective clearance of the fault:

- Start the delay times,
- Selection of the measured values,
- Release of impedance calculation and directional identification,
- Release of tripping command,
- Initiation of auxiliary functions,
- Indication/output of the faulty conductor(s).

The distance protection relay has a variety of fault detection functions from which the optimum can be chosen for the system under consideration (refer to Section 2.3 Ordering data).

The overcurrent fault detection operates with high short circuit currents. If there is no significant difference between normal operation (including overload) and short-circuit, in terms of the current which will flow – e.g. in networks with highly fluctuating system impedance or, where short circuit current limiting devices are installed – then under-impedance fault detection (voltage controlled current) or impedance fault detection must be used. With these options comprehensive facilities are possible to match to the network conditions and the user's philosophy.

4.2.1.1 Earth fault detection and processing

An important element for all fault detection methods is the detection of an earth fault since the determination of the faulty line loops (Section 4.2.2) essentially depends on whether it is an earth fault or not. The model 7SA510 is equipped with stabilized measurement of the earth current (with delay facility) as well as detection of the displacement voltage. Measures have also been provided to suppress fault detection in the case of single-phase earth faults in isolated or compensated systems.

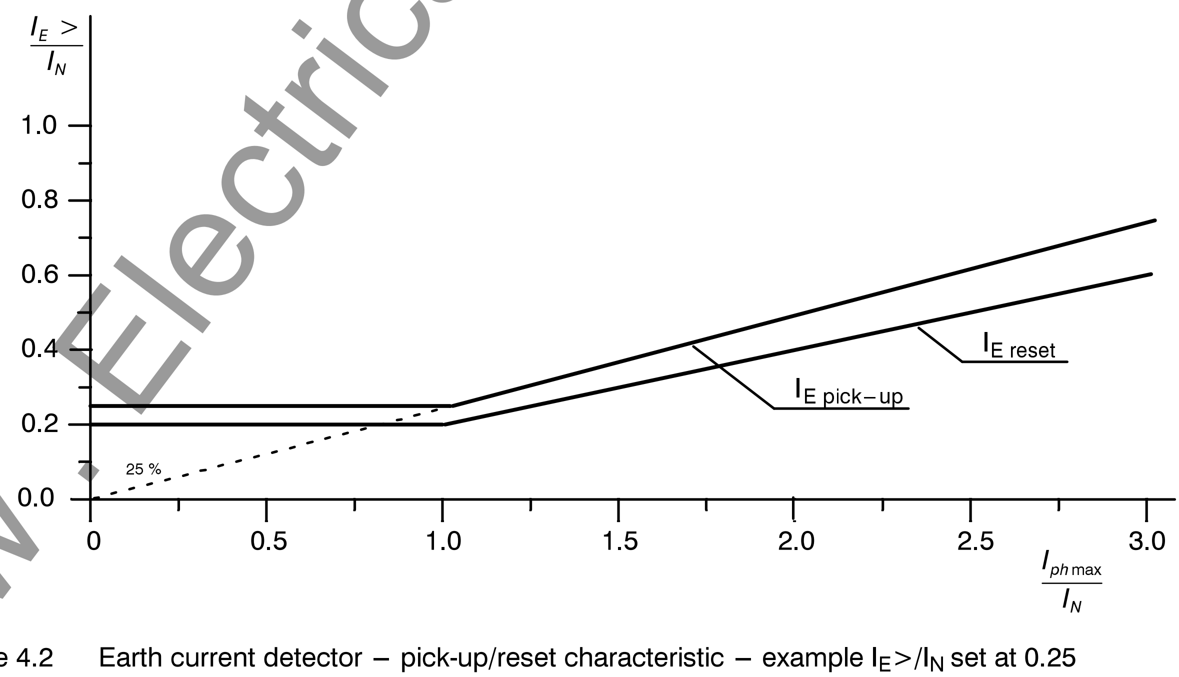


Figure 4.2 Earth current detector – pick-up/reset characteristic – example $I_E>/I_N$ set at 0.25

The earth current detector monitors the fundamental wave of the total of the phase currents ($I_E = 3 \cdot I_0$) in comparison with the threshold value. It is stabilized against faulty pick-up caused by asymmetric operating currents or distorted currents in the secondary circuit of the current transformers resulting from different current transformer saturation with earth-free short-circuits: the actual pick-up value is automatically increased as the phase currents increase (Figure 4.2: Example for setting 0.25; the horizontal branch is shifted according different settings). The drop-off value is approx. 95 % of the pick-up value.

The displacement voltage detector monitors the fundamental wave of the displacement voltage ($U_E = \sqrt{3} \cdot U_0$) in comparison with the set threshold value. The drop-off value is approx. 95 % of the pick-up value.

In systems with an earthed starpoint (solidly earthed or low-resistance earthed), the pick-up of the earth current monitor as well as that of the displacement voltage monitor lead to pick-up of the earth fault detector. Detection of an earth fault *on its own* does not lead to general fault detection signal of the distance protection but only controls the other fault detection modules. It is not annunciated *on its own* either.

In non-earthed systems (isolated starpoint or with arc compensation by means of Petersen coil), the displacement voltage monitor is not used for earth fault detection. A single-phase earth fault is also initially assumed in these systems in the event of a single-phase fault detection and the detection is suppressed to prevent faulty pick-up by the oscillation transients on the occurrence of a simple earth fault. Pick-up is enabled again following an adjustable delay time TIe 1PHASE (address 1801); this is necessary so that the distance protection is still able to recognize a cross country double earth fault with one base point on a spur feeder. If, however, an earth fault is already present in the system, this is detected by the displacement voltage monitor; the delay is then not effective: an earth fault which now occurs in another phase can only be a double-phase earth fault.

4.2.1.2 Overcurrent fault detection

The overcurrent fault detection is a phase-dedicated fault detection procedure. Following numeric filtering, the currents in each phase are monitored in comparison with a set threshold value. A pick-up signal is output for that (those) phase(s) in which the set threshold has been exceeded.

To enable measured value selection (see Section 4.2.2), the phase-dedicated fault detection signals are converted into phase-loop information. This is carried out depending on the earth fault detection according Section 4.2.1.1 and – in earthed systems – on the parameter 1PH FAULTS (address 1705) according to Table 4.1. In non-earthed system, the phase-phase loop is always selected in the case of a single-phase fault detection without earth fault detection.

The faulty phases are annunciated. An earth fault is also annunciated if detected according to Section 4.2.1.1.

The overcurrent fault detector is reset when 95 % of the pick-up value is fallen below.

Fault detection module	Earth fault detection	Parameter 1PH FAULTS	Resultant loop	Annunciation
L1 L2 L3	no no no	*PHASE – PHASE*	L3 – L1 L1 – L2 L2 – L3	L1 L2 L3
L1 L2 L3	no no no	*PHASE – EARTH* [1)]	L1 – E L2 – E L3 – E	L1 L2 L3
L1 L2 L3	yes yes yes	irrelevant	L1 – E L2 – E L3 – E	L1, E L2, E L3, E

1) only for earthed system starpoint

Table 4.1 Line loops and phase annunciations with single phase overcurrent fault detection

4.2.1.3 **Impedance fault detection (fix-impedance)** (optional)

Impedance fault detection is a loop-dedicated fault detection procedure. Either the three phase-phase loops (without earth fault) or the three phase-earth loops (with earth fault) are monitored depending on the result of the earth fault detection (Section 4.2.1.1). A prerequisite for measurement of a loop impedance is that at least one of the assigned phase currents as well as the difference current decisive for the loop have exceeded an adjustable minimum value $I_{ph}>$.

Pick-up caused by single-phase earth faults in systems with a non-earthed starpoint is effectively suppressed by the measures described in Section 4.2.1.1.

The impedances are calculated separately for R and X in cyclic time intervals and compared with the set values. A measured value step change monitor is used to synchronize the measurement window on occurrence of a fault. Calculation procedure is the same as that described for distance measurement in Section 4.2.3.

An example of the fault detection characteristic in the complex R/X plane is shown in Figure 4.3. The bold dots identify the setting parameters which determine the geometry of the fault detection polygon. The X intersections X+A and X−A are decisive for the fault reach in the forward (line) direction and in the reverse (bus-bar) direction. The R intersections can be set differently for phase-phase loops (RA1) and phase-earth loops (RA1E). It is thus possible e.g. to permit a larger fault resistance tolerance for earth faults (bold dotted line in Figure 4.3).

In order to guarantee unequivocal criteria for discrimination between load operation and a short-circuit – especially in the case of long, high-loaded lines – the characteristics can be set dependent on the phase angle: the R section RA2 then applies to phase angles above a settable value φ_A, the R section RA1 below φ_A.

To avoid intermittent pick-up signals near the border lines of the characteristic, a hysteresis of 6 % is provided.

Phase angle dependence can separately be achieved for earth fault with RA2E and φ_{AE} but for reasons of simplification this is not illustrated in Figure 4.3.

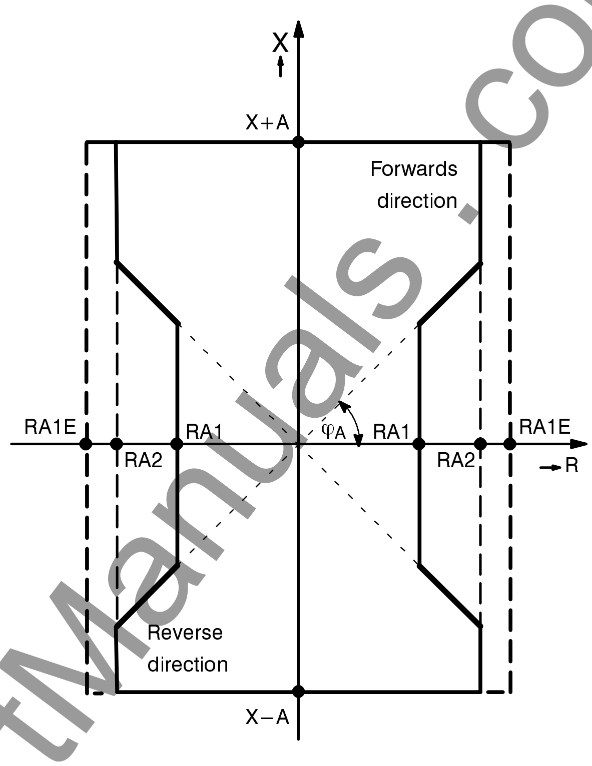


Figure 4.3 Impedance fault detection characteristics

Pick-up results for the measurement loop in which the impedance vector lies within the fault detection polygon. If detection occurs in more than one loop the relay regards as valid all those loops whose impedance is not greater than 150 % of that smallest impedance. This avoids wrong pick-up signals which could be caused by the influence of the fault currents and voltages on the unfaulted line loops – especially in cases of small source impedances.

The impedance fault detection for phase-earth is supplemented by an overcurrent stage $I_{ph}>>$ where pick-up of the overcurrent stage only leads to detection if the associated impedance loop has been eliminated as described in the previous paragraph. In this manner double faults with high current are also correctly detected even if a fault loop has been eliminated by the procedure described above. Since the overcurrent stage can only re-establish eliminated loops for pick-up, erroneous fault detection as a result of an overcurrent is prevented at the same time if the short-circuit currents in the fault-free phases can exceed the set overcurrent value on non-earthed feeding transformers or earthed consumer transformers.

It is additionally possible to use the impedance fault detection just only for earth faults. In this case, the phase-earth measurement is enabled by means of the earth fault detection, it is not effective for phase-phase faults. Overcurrent detection is effective instead in this case. This detection program is of advantage in systems with limiters for earth currents (earthed at low impedance, so-called resistance earthing) where a short-circuit current sufficient for the overcurrent stage flows for phase-phase faults but not for phase-earth faults. Earth-free faults are thus detected by the overcurrent stage I_{ph}>>.

4.2.1.4 Voltage controlled fault detection (Under-impedance fault detection) (optional)

The voltage controlled fault detection is a phase-dedicated fault detection procedure which also takes into consideration loop information. Decisive is the exceeding of phase currents, where the pick-up value depends on the magnitude of the loop voltages.

The basic characteristic can be gathered from the current/voltage characteristic shown in Figure 4.4. The exceeding of a minimum current I_{ph}> is the first prerequisite for each phase pick-up. Above this current, voltage-controlled overcurrent detection is effective whose slope is defined by the parameters U(I>) and U(I>>). A high-set overcurrent stage I_{ph}>> is superimposed in the case of short-circuits of high current. The bold dots in Figure 4.4 identify the setting parameters which determine the geometry of the current/voltage characteristic.

Fault detection of a phase is reset when 95 % of the respective current is fallen below or 105 % of the respective voltage is exceeded.

The device has three such fault detection modules, each of which is controlled by the phase-earth voltages or the phase-phase voltages. Parameters are used to define whether the voltages U_{ph-E} or the voltages U_{ph-ph} are decisive, or whether this depends on the earth fault detection as described in Section 4.2.1.1. This enables highly flexible adaptation to the system conditions. Optimum control largely depends on whether the system starpoint is not earthed (isolated or compensated), earthed with a low impedance (resistance earthed) or solidly earthed. The position of the starpoint earthing is also significant in the latter case. Information on the setting is contained in Section 6.3.4.5.

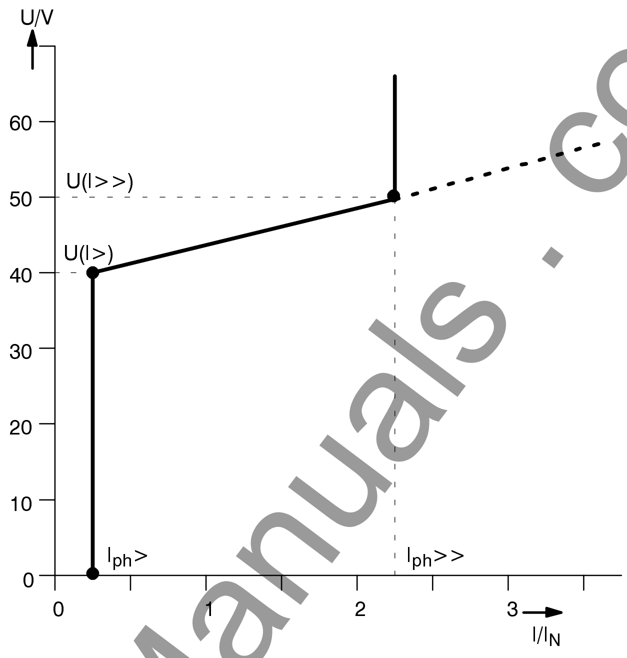


Figure 4.4 Voltage controlled fault detectors, U/I characteristic

Control with U_{ph-E} is characterized by a high sensitivity to earth short-circuits and is therefore particularly advantageous in systems with an earthed starpoint. It is automatically adapted to the existing load conditions, i.e. it becomes more current-sensitive during low-load operation, the pick-up threshold is higher in the case of high load currents. Table 4.2 shows the assignment of the phase currents, loop voltages and output results with single-phase pick-up if control with phase-earth voltages is selected.

The measured line loop depends on the earth fault detection according to Section 4.2.1.1 and – in earthed systems – on the parameter 1PH FAULTS (address 1705) according to Table 4.2. In non-earthed systems, the phase-phase loop is always selected in the case of single-phase pick-up without earth fault detection.

The detected phase(s) are annunciated. An earth fault is also annunciated if detected according to 4.2.1.1.

Fault detection module	Measured current	Measured voltage	Earth fault detection	Parameter 1PH FAULTS	Resultant line loop	Annunci-ation
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	no no no	*PHASE – PHASE*	L3 – L1 L1 – L2 L2 – L3	L1 L2 L3
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	no no no	*PHASE – EARTH* [1]	L1 – E L2 – E L3 – E	L1 L2 L3
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	yes yes yes	irrelevant	L1 – E L2 – E L3 – E	L1, E L2, E L3, E

[1] only for earthed system starpoint

Table 4.2 Line loops and phase annunciations with single-phase voltage controlled fault detection phase-earth

The sensitivity is particularly high in the case of phase-phase faults when controlling with U_{Ph-Ph}. This control is advantageous with extended compensated systems because its principle excludes pick-up by single earth faults. It is automatically adapted to the existing load conditions in the case of two-phase and three-phase faults; i.e. it becomes more current-sensitive during low-load operation, the pick-up threshold is higher in the case of high load currents. Table 4.3 shows the assignment of the phase currents, loop voltages and output results in the case of pick-up of only one fault detection module if control with phase-phase voltages is selected.

The measured line loop in this case is independent of the earth fault detection, and this method is therefore not suitable for earthed systems.

Fault detection module	Measured current	Measured voltage	Earth fault detection	Parameter 1PH FAULTS	Resultant line loop	Annunci-ation
L1 L2 L3	L1 L2 L3	L1 – L2 L2 – L3 L3 – L1	irrelevant	irrelevant	L1 – L2 L2 – L3 L3 – L1	L1 L2 L3

Table 4.3 Line loops and phase annunciations with single-phase voltage controlled fault detection phase-phase

If the possibility of making the voltage loops dependent on the earth fault detection is used, the high sensitivity for phase-earth faults then also applies to phase-phase faults. This possibility is, in principle, independent of the treatment of the system starpoint; it assumes, however, that the earth fault criteria according to Section 4.2.1.1 have been satisfied safely for all earth faults. Table 4.4 applies to the fault detection program phase-earth or phase-phase voltages with single-phase pick-up.

Fault detection module	Measured current	Measured voltage	Earth fault detection	Parameter 1PH FAULTS	Resultant line loop	Annunci-ation
L1 L2 L3	L1 L2 L3	L1 – L2 L2 – L3 L3 – L1	no no no	irrelevant	L1 – L2 L2 – L3 L3 – L1	L1 L2 L3
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	yes yes yes	irrelevant	L1 – E L2 – E L3 – E	L1, E L2, E L3, E

Table 4.4 Line loops and phase annunciations with single-phase voltage controlled fault detection, voltages phase-earth with earth fault, voltages phase-phase without earth fault

It is finally also possible to only control with the voltage loops U_{Ph-E} when an earth fault has been detected. Detection for phase-phase faults then only takes place with high-set overcurrent I>>. This is advantageous in systems with a low-impedance earthed starpoint, i.e. with earth fault limiting aids (so-called resistance earthing). In these cases only earth faults are to be detected by the voltage controlled fault detection. It is usually even undesirable that phase-phase short-circuits lead to under-impedance fault detection.

The measured loop is independent of the parameter 1PH FAULTS. Table 4.5 shows the assignment of the phase currents, loop voltages and output results.

Fault detection module	Measured current	Measured voltage	Earth fault detection	Parameter 1PH FAULTS	Resultant line loop	Annunci-ation
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	yes yes yes	irrelevant	L1 – E L2 – E L3 – E	L1, E L2, E L3, E
L1 L2 L3	L1 L2 L3	L1 – E L2 – E L3 – E	no no no	irrelevant	no pick-up and no annunciation by U_{Ph-E}</I>	

Table 4.5 Line loops and phase annunciations with single-phase voltage controlled fault detection phase-earth; without earth fault detection only overcurrent pick-up

4.2.2 Determination of the faulted loop

For calculation of the distance to fault, the currents and voltages of the faulty loop are decisive. The phase selective fault detector determines the faulted loop and releases the corresponding measurement values for impedance calculation.

For calculation of a phase-phase loop, for example, for a two-phase short circuit L1 – L2 (Figure 4.5) the following identity applies:

$$\underline{I}_{L1} \cdot \underline{Z}_L - \underline{I}_{L2} \cdot \underline{Z}_L = \underline{U}_{L1-E} - \underline{U}_{L2-E}$$

where $\underline{U}$, $\underline{I}$ are (complex) measured values and
$\underline{Z} = R + jX$ is the (complex) line impedance.

The line impedance is thus

$$\underline{Z}_L = \frac{\underline{U}_{L1-E} - \underline{U}_{L2-E}}{\underline{I}_{L1} - \underline{I}_{L2}}$$

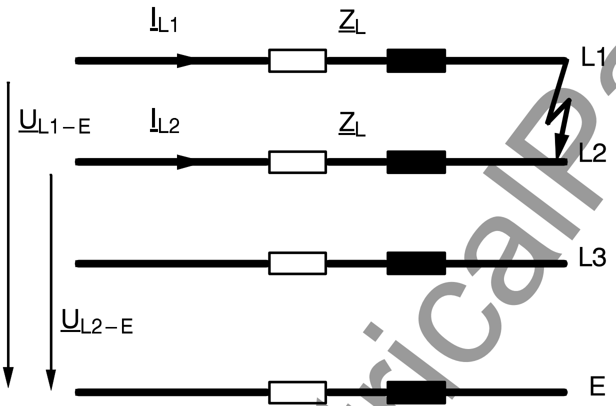


Figure 4.5 Phase-phase short circuit loop

For the calculation of a phase-earth loop, for example, for a short circuit L3 – E (Figure 4.6) it must be observed that the impedance of the earth return path is not normally equal with the impedance of the phase. In the loop equation

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_E = \underline{U}_{L3-E}$$

$\underline{Z}_E$ is replaced by $\frac{\underline{Z}_E}{\underline{Z}_L} \cdot \underline{Z}L$ which gives us

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_L \cdot \frac{\underline{Z}_E}{\underline{Z}_L} = \underline{U}_{L3-E}$$

from which one obtains the line impedance

$$\underline{Z}_L = \frac{\underline{U}_{L3-E}}{\underline{I}_{L3} - \underline{Z}_E/\underline{Z}_L \cdot \underline{I}_E}$$

whereby the factor $\underline{Z}_E/\underline{Z}_L$ is dependent only upon the line constants and not upon the distance to fault.

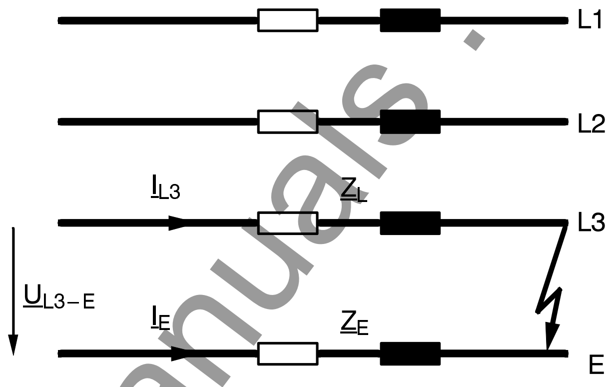


Figure 4.6 Phase-earth short circuit loop

Fault loop selection is such that for each type of fault the correct measured values are used for the calculation. For multiple faults (whereby more than two phases or earth are involved), one of the possible fault loops will be given preference.

The selection of valid short-circuit loops varies considerably, dependent upon whether the system starpoint is earthed, isolated or compensated (Petersen coil). Accordingly, the treatment of the system starpoint has to be known before the device is put into operation (see Section 6.3.3.1).

4.2.2.1 Loop determination for solidly earthed systems

In networks with earthed starpoint, each contact of a phase with earth is a short circuit which must be interrupted immediately by the nearest protective device. If all power transformers feeding towards the short circuit are earthed, then the earth fault element will respond (4.2.1.1). The earth fault element is therefore used as an additional criterion for earth faults.

With double earth faults, pick-up normally occurs in two phases and earth (with overcurrent detection) or for two phase-earth loops (impedance detection). In this case it is possible to set the relay so that only the phase-phase loop (parameter PHPHE FLTS = *PHASE – PHASE ONLY*) or the loop of the leading phase to earth (PHPHE FLTS = *LEADING PH – E*) or the loop of the lagging phase to earth (PHPHE FLTS = *LAGGING PH−E)* will be selected.

Tables 4.6 and 4.7 show the measurement quantities which will be selected for distance measurement in earthed networks.

Note: In systems with earthed star-point the relay must be connected to three star connected voltage transformers U_{L1-N}, U_{L2-N}, U_{L3-N} with earthed primary star-point and to three current transformers I_{L1}, I_{L2}, I_{L3}. The relay calculates the earth fault current from the sum of the three phase currents, and the displacement voltage from the sum of the three phase-to-earth voltages.

Fault detection phases	Selected loop	Selected setting parameter
L1, E L2, E L3, E	L1−E L2−E L3−E	irrelevant
L1, L2 L2, L3 L1, L3	L1−L2 L2−L3 L3−L1	irrelevant
L1, L2, E L2, L3, E L1, L3, E	L1−L2 L2−L3 L3−L1	PHPHE FLTS = *PHASE−PHASE ONLY*
L1, L2, E L2, L3, E L1, L3, E	L1−E L2−E L3−E	PHPHE FLTS = *LEADING PH−E*
L1, L2, E L2, L3, E L1, L3, E	L2−E L3−E L1−E	PHPHE FLTS = *LAGGING PH−E*
L1, L2, L3, L1, L2, L3, E	L3−L1 L3−E	3PH FAULTS = *E/F CONTROL*
L1, L2, L3, L1, L2, L3, E	L3−L1 L3−L1	3PH FAULTS = *PHASE−PHASE ONLY*
L1, L2, L3, L1, L2, L3, E	L3−E L3−E	3PH FAULTS = *PHASE−EARTH ONLY*

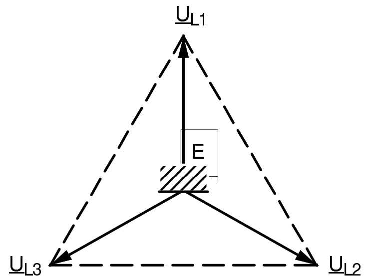
Table 4.6 Selected measurement quantities in **earthed** systems, with **overcurrent** or under-impedance fault detection

Fault detection phase loops	Selected loop	Selected setting parameter
L1 – E L2 – E L3 – E	L1 – E L2 – E L3 – E	irrelevant
L1 – L2 L2 – L3 L3 – L1	L1 – L2 L2 – L3 L3 – L1	irrelevant
L1 – E, L2 – E L2 – E, L3 – E L1 – E, L3 – E	L1 – L2 L2 – L3 L3 – L1	PHPHE FLTS = *PHASE – PHASE ONLY*
L1 – E, L2 – E L2 – E, L3 – E L1 – E, L3 – E	L1 – E L2 – E L3 – E	PHPHE FLTS = *LEADING PH – E*
L1 – E, L2 – E L2 – E, L3 – E L1 – E, L3 – E	L2 – E L3 – E L1 – E	PHPHE FLTS = *LAGGING PH – E*
L1 – L2, L2 – L3, L2 – L3, L3 – L1, L3 – L1, L1 – L2,	L1 – L2 L2 – L3 L3 – L1	irrelevant
L1 – E, L2 – E, L3 – E L1 – L2, L2 – L3, L3 – L1	L3 – E L3 – L1	3PH FAULTS = *E/F CONTROL*
L1 – E, L2 – E, L3 – E L1 – L2, L2 – L3, L3 – L1	L3 – L1 L3 – L1	3PH FAULTS = *PHASE – PHASE ONLY*
L1 – E, L2 – E, L3 – E L1 – L2, L2 – L3, L3 – L1	L3 – E L3 – E	3PH FAULTS = *PHASE – EARTH ONLY*

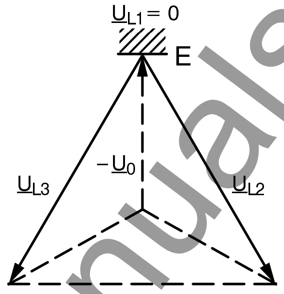
Table 4.7 Selected measurement quantities in **earthed** systems, with **impedance** fault detection

4.2.2.2 Loop determination for non-earthed systems

In isolated or compensated networks, no currents resembling a short circuit are present in the case of a single-phase earth fault. Only a displacement of the voltage triangle occurs (Figure 4.7). This condition does not represent any immediate danger for the operation of the network. In this case the distance protection must not respond since the phase-to-earth voltage of the faulty phase is zero throughout the whole galvanically interconnected network. This would lead to a measured impedance equal zero, for the faulty phase-earth loop, at each measuring point. For this reason pick-up of one single phase-to-earth fault detector is avoided in 7SA510 relay.



a) sound network, without earth fault



b) earth fault in phase L1

Fig. 4.7 Earth fault in a non-earthed network

On the occurrence of an earth fault – above all in extensive, compensated networks – a significant ignition current can flow which can cause the earth current detector to pick up or, for the overcurrent element, in certain circumstances, even a phase current pick-up. 7SA510 has special features to prevent such faulty reaction (see Section 4.2.1.1).

In the case of a double earth fault in isolated or compensated networks, it is sufficient to eliminate one fault. The second fault remains in the network as a simple earth fault. Which one of the faults will be interrupted, is dependent upon the double earth fault priority which is set to be the same throughout the whole galvanically connected network. With 7SA510 the following double earth fault priorities can be selected:

acyclic L3 before L1 before L2,
abbreviated L3(L1) acyclic;
acyclic L1 before L3 before L2,
abbreviated L1(L3) acyclic;
acyclic L2 before L1 before L3,
abbreviated L2(L1) acyclic;
acyclic L1 before L2 before L3,
abbreviated L1(L2) acyclic;
acyclic L3 before L2 before L1,
abbreviated L3(L2) acyclic;
acyclic L2 before L3 before L1,
abbreviated L2(L3) acyclic;
cyclic L3 before L1 before L2 before L3,
abbreviated L3(L1) cyclic;
cyclic L1 before L3 before L2 before L1,
abbreviated L1(L3) cyclic.

One earth fault will be cleared in accordance with the selected preference; a second (cross-country) fault would remain on the network and can be detected by the earth fault detection facility (see Section 4.8).

For unearthed networks, measuring quantities will be selected in accordance with Tables 4.8 and 4.9.

Note: Generally it is assumed that three current transformers I_{L1}, I_{L2}, I_{L3} and three star connected voltage transformers are provided. If only two current transformers and/or two voltage transformers (in V–connection) are available, reliable detection of double earth faults in non-earthed networks is not always possible. For the double earth fault preference, the preferred phases must always be equipped with the current transformers if only two current transformers are connected.

Fault detection phases	Selected loop	Selected setting parameter
L1, E L2, E L3, E	L1 – E L2 – E L3 – E	irrelevant
L1, L2 L2, L3 L1, L3	L1 – L2 L2 – L3 L3 – L1	irrelevant
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L1 – E L3 – E L3 – E L3 – L1 L3 – E	PHASE PREF = *L3(L1) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L1 – E L3 – E L1 – E L3 – L1 L1 – E	PHASE PREF = *L1(L3) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L2 – E L2 – E L1 – E L1 – L2 L2 – E	PHASE PREF = *L2(L1) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L1 – E L2 – E L1 – E L1 – L2 L1 – E	PHASE PREF = *L1(L2) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L2 – E L3 – E L3 – E L2 – L3 L3 – E	PHASE PREF = *L3(L2) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L2 – E L2 – E L3 – E L2 – L3 L2 – E	PHASE PREF = *L2(L3) ACYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L1 – E L2 – E L3 – E L3 – L1 L3 – E	PHASE PREF = *L3(L1) CYCLIC*
L1, L2, E L2, L3, E L1, L3, E L1, L2, L3 L1, L2, L3, E	L2 – E L3 – E L1 – E L3 – L1 L1 – E	PHASE PREF = *L1(L3) CYCLIC*

Table 4.8 Selected measurement quantities in **non-earthed** systems, with **overcurrent** fault detection or **under-impedance** fault detection

Fault detection phase loops	Selected loop	Selected setting parameter
L1−E L2−E L3−E	L1−E L2−E L3−E	irrelevant
L1−L2 L2−L3 L3−L1	L1−L2 L2−L3 L3−L1	irrelevant
L1−E, L2−E L2−E, L3−E L1−E, L3−E L1−E, L2−E, L3−E L1−L2, L2−L3 L2−L3, L3−L1 L3−L1, L1−L2 L1−L2, L2−L3, L3−L1	L1−E L3−E L3−E L3−E L2−L3 L3−L1 L3−L1 L3−L1	PHASE PREF = *L3(L1) ACYCLIC*
L1−E, L2−E L2−E, L3−E L1−E, L3−E L1−E, L2−E, L3−E L1−L2, L2−L3 L2−L3, L3−L1 L3−L1, L1−L2 L1−L2, L2−L3, L3−L1	L1−E L3−E L1−E L1−E L1−L2 L3−L1 L3−L1 L3−L1	PHASE PREF = *L1(L3) ACYCLIC*
L1−E, L2−E L2−E, L3−E L1−E, L3−E L1−E, L2−E, L3−E L1−L2, L2−L3 L2−L3, L3−L1 L3−L1, L1−L2 L1−L2, L2−L3, L3−L1	L2−E L2−E L1−E L2−E L1−L2 L2−L3 L1−L2 L1−L2	PHASE PREF = *L2(L1) ACYCLIC*
L1−E, L2−E L2−E, L3−E L1−E, L3−E L1−E, L2−E, L3−E L1−L2, L2−L3 L2−L3, L3−L1 L3−L1, L1−L2 L1−L2, L2−L3, L3−L1	L1−E L2−E L1−E L1−E L1−L2 L3−L1 L1−L2 L1−L2	PHASE PREF = *L1(L2) ACYCLIC*
L1−E, L2−E L2−E, L3−E L1−E, L3−E L1−E, L2−E, L3−E L1−L2, L2−L3 L2−L3, L3−L1 L3−L1, L1−L2 L1−L2, L2−L3, L3−L1	L2−E L3−E L3−E L3−E L2−L3 L2−L3 L3−L1 L2−L3	PHASE PREF = *L3(L2) ACYCLIC*

Table 4.9 Selected measurement quantities in **non-earthed** systems, with **impedance** fault detection (continued next page)

Fault detection phase loops	Selected loop	Selected setting parameter
L1–E, L2–E	L2–E	PHASE PREF = *L2(L3) ACYCLIC*
L2–E, L3–E	L2–E	
L1–E, L3–E	L3–E	
L1–E, L2–E, L3–E	L2–E	
L1–L2, L2–L3	L2–L3	
L2–L3, L3–L1	L2–L3	
L3–L1, L1–L2	L1–L2	
L1–L2, L2–L3, L3–L1	L2–L3	
L1–E, L2–E	L1–E	PHASE PREF = *L3(L1) CYCLIC*
L2–E, L3–E	L2–E	
L1–E, L3–E	L3–E	
L1–E, L2–E, L3–E	L3–E	
L1–L2, L2–L3	L2–L3	
L2–L3, L3–L1	L2–L3	
L3–L1, L1–L2	L3–L1	
L1–L2, L2–L3, L3–L1	L3–L1	
L1–E, L2–E	L2–E	PHASE PREF = *L1(L3) CYCLIC*
L2–E, L3–E	L3–E	
L1–E, L3–E	L1–E	
L1–E, L2–E, L3–E	L1–E	
L1–L2, L2–L3	L1–L2	
L2–L3, L3–L1	L3–L1	
L3–L1, L1–L2	L3–L1	
L1–L2, L2–L3, L3–L1	L3–L1	

Table 4.9 Selected measurement quantities in **non-earthed** systems, with **impedance** fault detection

4.2.3 Fault impedance calculation

The relay calculates the resistance R and the reactance X of the fault loop separately, using the measured values determined by the selection described in Section 4.2.2. As long as a fault detector has picked up, the calculation is effected continuously. The algorithm evaluates all the updated instantaneous values of current and voltage throughout at least the last half cycle. With difficult measurement conditions, e.g. very small measurement voltages or near the balanced point, the data window and thus the number of evaluated values is automatically increased.

The calculation is an integration of the line identity:

$$L \cdot \frac{di}{dt} + R \cdot i = u,$$

and allows, with its ideal filter characteristics, determination of the R and X (= ω·L) components for the short circuit loop, independent of the setting of the tripping characteristics.

For calculation of a phase-to-phase loop values conforming to the selection given in 4.2.2, for u the instantaneous values of phase-to-phase voltage, and for i the difference of the phase currents, are used, e.g. (Figure 4.5)

$$L \cdot \left(\frac{di_{L1}}{dt} + \frac{di_{L2}}{dt}\right) + R \cdot (i_{L1} - i_{L2}) = u_{L1-E} - u_{L2-E}$$

For calculation of a phase-to-earth loop (according to Figure 4.6)

$$L \cdot \left(\frac{di_{L3}}{dt} - \frac{X_E}{X_L} \cdot \frac{di_E}{dt}\right) + R \cdot \left(i_{L3} - \frac{R_E}{R_L} i_E\right) = u_{L3-E}$$

R and L are the required impedance components.

The calculated reactance is the line reactance X_L up to the point of fault. This determines the distance to fault. The resistance value on the other hand contains, in addition to the conductor resistance R_L, the fault resistance R_F (refer to Figures 4.8 and 4.9).

Note: The factors R_E/R_L and X_E/X_L are purely mathematical values and have no physical meaning. They can be relatively easily calculated from the line data – without using complex forms – from the formulae:

$$\frac{R_E}{R_L} = \frac{1}{3} \cdot \left(\frac{R_0}{R_1} - 1\right)$$

and

$$\frac{X_E}{X_L} = \frac{1}{3} \cdot \left(\frac{X_0}{X_1} - 1\right)$$

refer to Section 6.3.3.2.

The separate setting facilities for the factors allows the possible phase difference between earth and conductor impedance to be taken into account, in addition to the relationship Z_E/Z_L. This difference can be of significant value in cable networks.

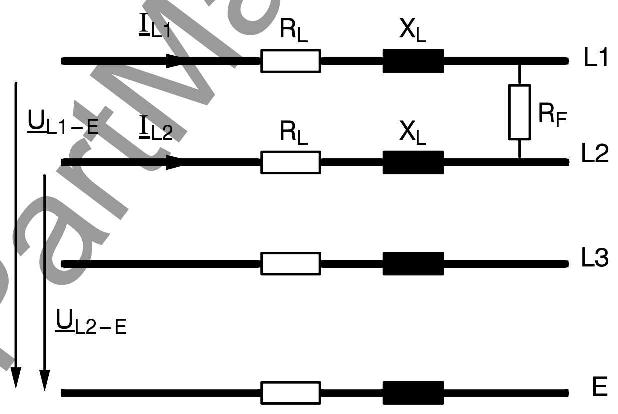


Figure 4.8 Phase-phase short circuit loop

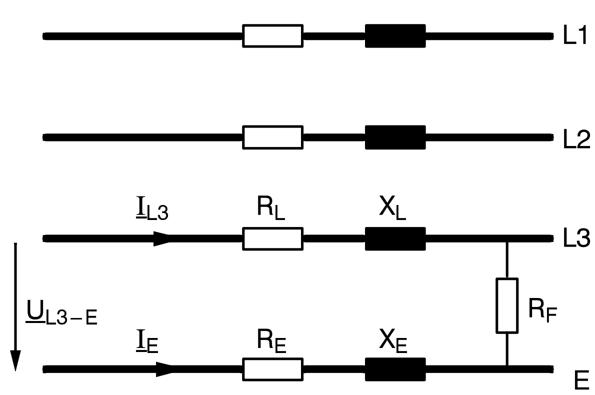


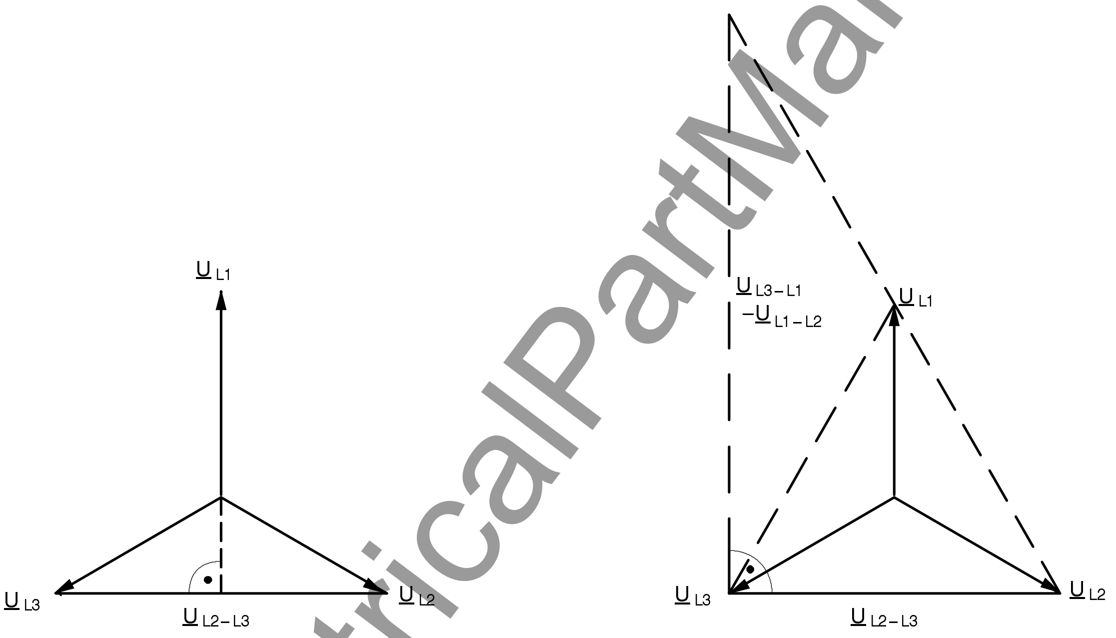
Figure 4.9 Phase-earth short circuit loop

4.2.4 Directional determination

The direction of the flow of fault energy is determined in a similar way to distance measurement (Section 4.2.3). For the directional determination, however, sound phase and stored reference voltages are used. It is thus ensured that the relay correctly determines the direction of all types of fault, even when the short-circuit voltage has collapsed. The stored voltage (2 a.c. cycles) is only of importance, if the measuring-circuit voltage is not sufficient for a precise directional determination.

The reference voltage for both a phase-earth loop and a phase-phase loop is always at right angles to the short circuit voltages (Figure 4.10). This is considered in the calculation of the directional vector. Table 4.10 shows the allocation of measured values for the calculation of distance and direction to the 6 possible fault loops.

The theoretical directional line is shown in Figure 4.11. In practice, the position of the directional characteristic is dependent upon the source impedance as well as the load current carried by the line immediately before fault inception.



a) Loop phase-earth (L1−E) b) Loop phase-phase (L2−L3)

Figure 4.10 Reference voltages for directional determination

Faulted loop	Measuring current (distance/direction)	Measuring voltage (distance)	Measuring voltage (direction)
L1−E	$\underline{I}_{L1} - \underline{k}_E \cdot \underline{I}_E$	$\underline{U}_{L1-E}$	$\underline{U}_{L2-L3}$
L2−E	$\underline{I}_{L2} - \underline{k}_E \cdot \underline{I}_E$	$\underline{U}_{L2-E}$	$\underline{U}_{L3-L1}$
L3−E	$\underline{I}_{L3} - \underline{k}_E \cdot \underline{I}_E$	$\underline{U}_{L3-E}$	$\underline{U}_{L1-L2}$
L1−L2	$\underline{I}_{L1} - \underline{I}_{L2}$	$\underline{U}_{L1-L2}$	$\underline{U}_{L2-L3} - \underline{U}_{L3-L1}$
L2−L3	$\underline{I}_{L2} - \underline{I}_{L3}$	$\underline{U}_{L2-L3}$	$\underline{U}_{L3-L1} - \underline{U}_{L1-L2}$
L3−L1	$\underline{I}_{L3} - \underline{I}_{L1}$	$\underline{U}_{L3-L1}$	$\underline{U}_{L1-L2} - \underline{U}_{L2-L3}$

Note: $\underline{k}_E = \underline{Z}_E / \underline{Z}_L$

Table 4.10 Measured values for distance calculation and directional determination

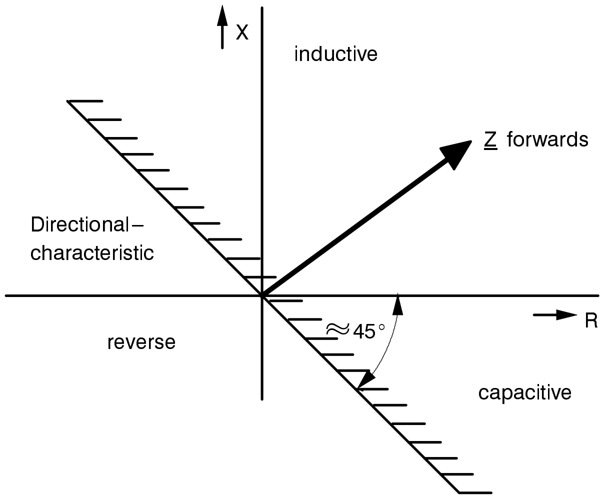


Figure 4.11 7SA510, directional characteristics

Figure 4.12 shows the directional characteristic, taking into consideration the source impedance, without load current. Since the unfaulted voltage equals the generator voltage and does not change after fault inception, the directional characteristic in the impedance diagram appears to be displaced by the source impedance. If the location of the fault is F1 (Figure 4.12a) the short circuit lies in the forward direction, the source impedance in the reverse direction. All fault locations right up to the relay location (c.t.s) are clearly recognized as "forwards" (Figure 4.12b). When the current flows in the opposite direction, the directional characteristic changes immediately (Figure 4.12c). Then the reversed current, which is determined by the source impedance $\underline{Z}_{S2}$ + $\underline{Z}_L$, flows through the measuring point (current transformer).

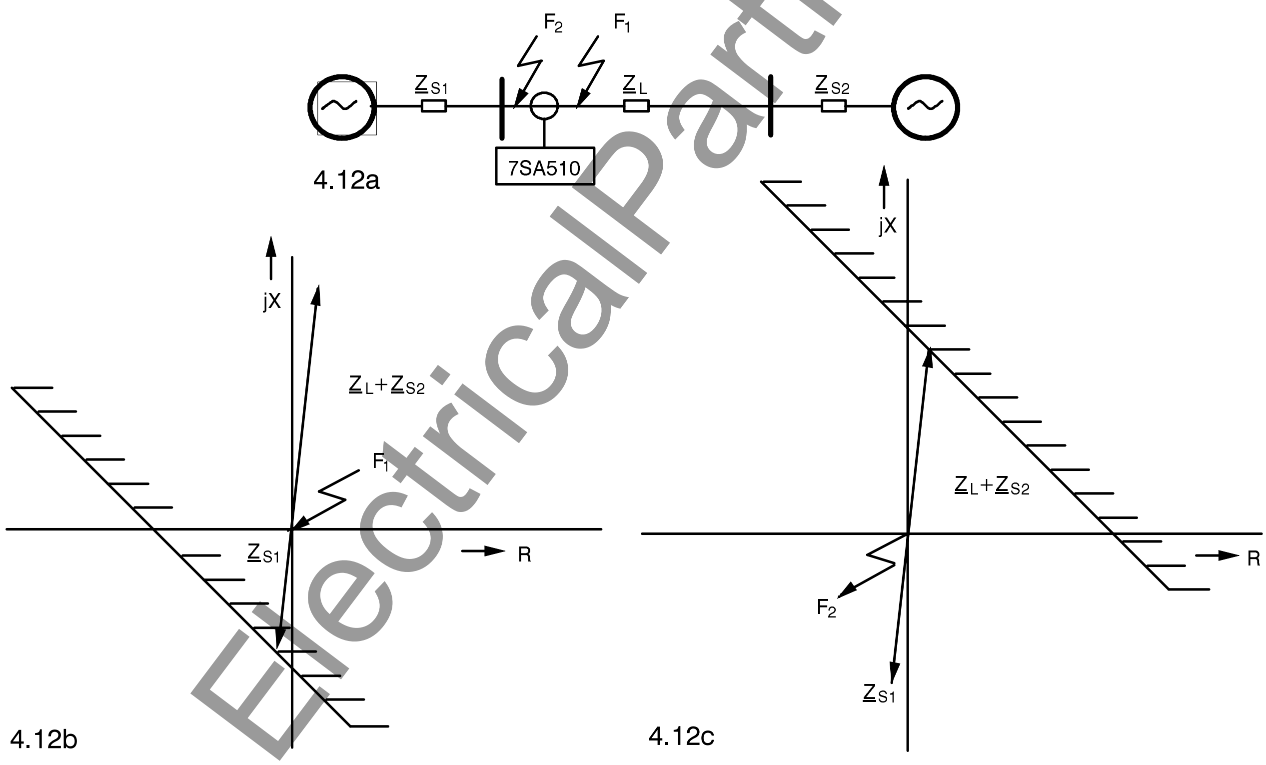
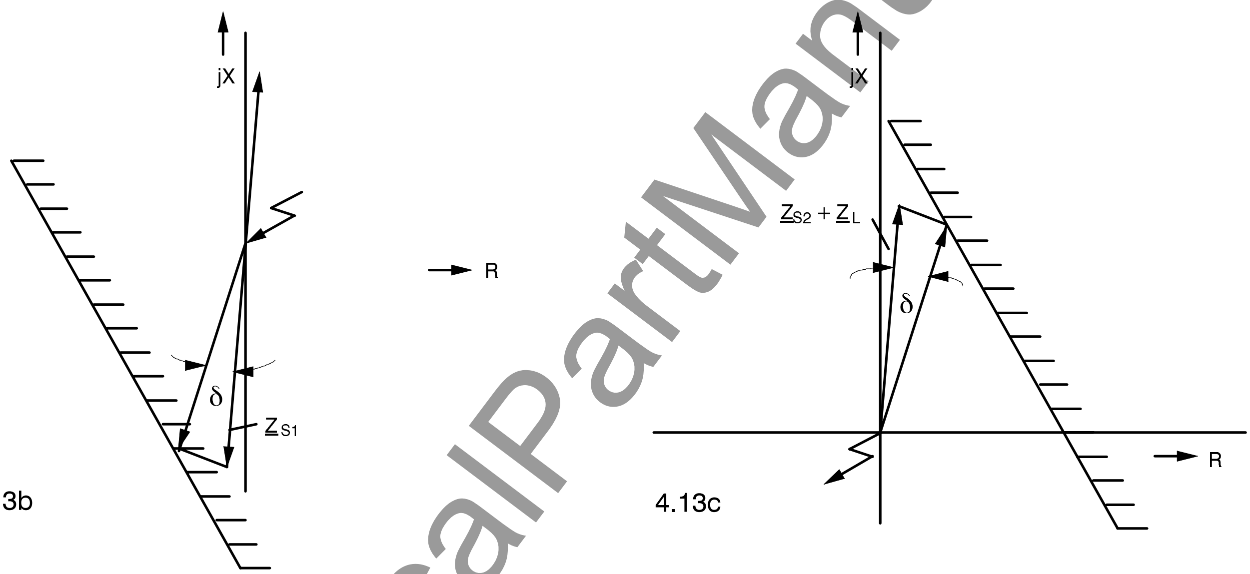


Figure 4.12 Directional characteristic with source impedance without load transport

If load is carried by the line, then this results in a voltage drop at the source impedance (Figure 4.13a). Since, at the measuring point, the voltage U is measured, not generator voltage E, the directional characteristic suffers a rotation by the load angle δ (Figures 4.13b and 4.13c). Therefore, the directional characteristic has a safety distance from the limits of the first quadrant in the R–X–diagram (Figure 4.11).

before fault inception after fault inception

4.13a Voltage vector diagram for earth fault on loaded line



4.13b 4.13c

Figure 4.13 Directional characteristic with source impedance and load transport

4.2.5 Tripping characteristics

The tripping zones of the distance protection relay 7SA510 have a polygonal characteristic. They consist of the directional lines in accordance with Section 4.2.4 and, in each case, a reactance and resistance limit. Reactance intersection X and resistance intersection R can be set separately and independently from each other. In addition, the R–intersections can be set separately for phase-phase faults and phase-earth faults (RE) so that a higher resistance margin can be obtained for earth faults, if required.

As shown in Figure 4.14 the relay possesses the following characteristics which can be set independently:

– 1st zone (instantaneous zone Z1), with the setting parameters:

  X1 Reactance = reach
  R1 Resistance phase-phase
  R1E Resistance phase-earth
  T1 T1 = 0 or delayed, if required, separate time settings for single-phase and multi-phase faults.

– 2nd zone (delayed back-up zone Z2) with the setting parameters:

  X2 Reactance = reach,
  R2 Resistance phase-phase,
  R2E Resistance phase-earth,
  T2 Delay(separate settings for single-phase and multi-phase faults).

– 3rd zone (delayed back-up zone Z3) with the setting parameters:

  X3 Reactance = reach,
  R3 Resistance phase-phase,
  R3E Resistance phase-earth,
  T3 Delay.

Besides these independent zones, two controlled zone is available which can be activated by logical conditions:

– Overreach zone Z1B for zone extension, e.g for teleprotection or controlled via binary input, with the setting parameters:

  X1B Reactance = reach,
  R1B Resistance phase-phase,
  R1BE Resistance phase-earth,
  T1B T1B = 0 or delayed, if required, separate time settings for single-phase and multi-phase faults.

– Overreach zone Z1L, activated by multi-shot AR (2nd and further cycles, so-called DAR)or controlled via binary input, with the setting parameters:

  X1L Reactance = reach,
  R1L Resistance phase–phase,
  R1LE Resistance phase–earth,
  T1L T1L = 0 or delayed, if required.

All zones can be set to operate either in forward direction, or in reverse direction or non-directional.

Figure 4.14 shows the tripping characteristics. For an easier clarification, separate R–setting for earth faults is shown for 1st zone only. Zone Z1L is omitted for the same reason.

Additionally, a directional and a non-directional final stage are available. Characteristic and reach of these are determined by the selected fault detection option (refer to Section 4.2.1). For models with impedance fault detection (4.2.1.3), fault detection zone ZA is provided, as shown in Figure 4.3. The reaches of the other types of fault detection are dependent on the infeed characteristics (e.g. system impedance ratio), so that they have no fixed shape in the R–X–plane.

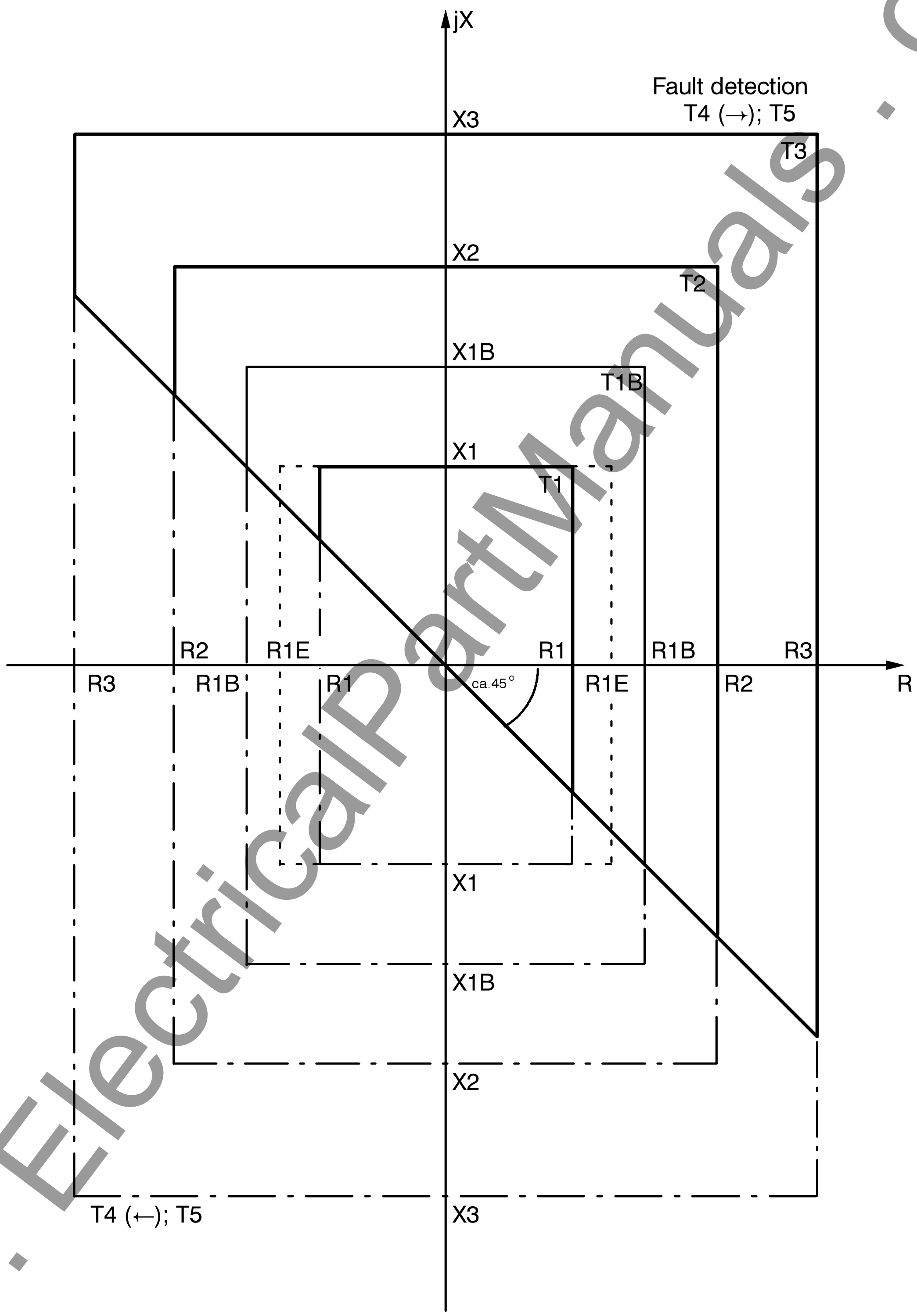


Figure 4.14 Tripping characteristics

4.2.6 Tripping logic

When the relay has detected a fault (see Section 4.2.1), the delay times are started. The impedance of the selected fault loop, according to Section 4.2.2, are compared with the threshold of the set zones. Tripping occurs when the impedance is within a zone whose corresponding time stage has expired and the fault direction complies with the direction as set for that zone. For zone Z1 (and Z1B) the delay time can equal zero, i.e. tripping occurs as soon as it has been confirmed that the fault lies within the zone. An automatic repetition of the measurement becomes effective near to the balanced point in order to prevent any transient overreach. This can lead to a slight increase in the reaction time.

External binary inputs can be used to release the overreach zones Z1B and/or Z1L.

Figure 4.15 illustrates the block diagram of the tripping logic.

The integrated switch-onto-fault logic (Section 4.2.7) can be set to activate either zone Z1B (directional or non-directional) or fault detection (non-directional and non-delayed). Figure 4.15 shows both possibilities.

For the issue of tripping command to the circuit breaker, appropriately powerful tripping relays are provided, each with two closing contacts. The tripping relays are automatically reset, when the fault detector resets and the fault current has been switched off (reset of minimum current monitor $0.1I_N$). Up to that point, the tripping circuit must be broken by an auxiliary contact on the circuit breaker.

4.2.7 Switch-onto-fault protection

If one switches a dead but short circuited line onto a live bus-bar it is essential, in general, that this line be immediately disconnected. Using distance protection alone, however, disconnection for faults close to either line end is not always possible: for a three-phase fault at the location of a relay an accurate measured voltage for correct directional determination will not necessarily be available; when the voltage transformers are connected on the line side, even stored voltage values are not available. If the fault is at the opposite line end, distance protection will operate only after a time delay.

For close-up faults the distance protection will decide on ”forwards” after connection of the line when the voltage signal is missing. Thus, instantaneous trip by the first zone is possible.

To be sure of an immediate disconnection under any condition and especially when switching onto bolted fault, the manual close command from the discrepancy switch can be repeated, via a binary input to cause an immediate trip signal when a fault is detected within an adjustable time (Figure 4.16). The fault is cleared either with pick-up of overreaching zone Z1B (directional), as illustrated in Figure 4.16, or pick-up of the fault detector (selectable) without delay.

The integrated switch-onto-fault logic of 7SA510 automatically distinguishes between an external control command and an automatic reclose command by means of the internal auto-reclose circuits, so that the binary input ”manual close” can be connected directly to the control circuit of the closing coil of the circuit breaker. If, however, external closing commands are possible, which the switch-onto-fault protection shall not operate (e.g. external auto-reclose devices), the binary input ”manual close” must be triggered by a separate auxiliary contact on the discrepancy switch.

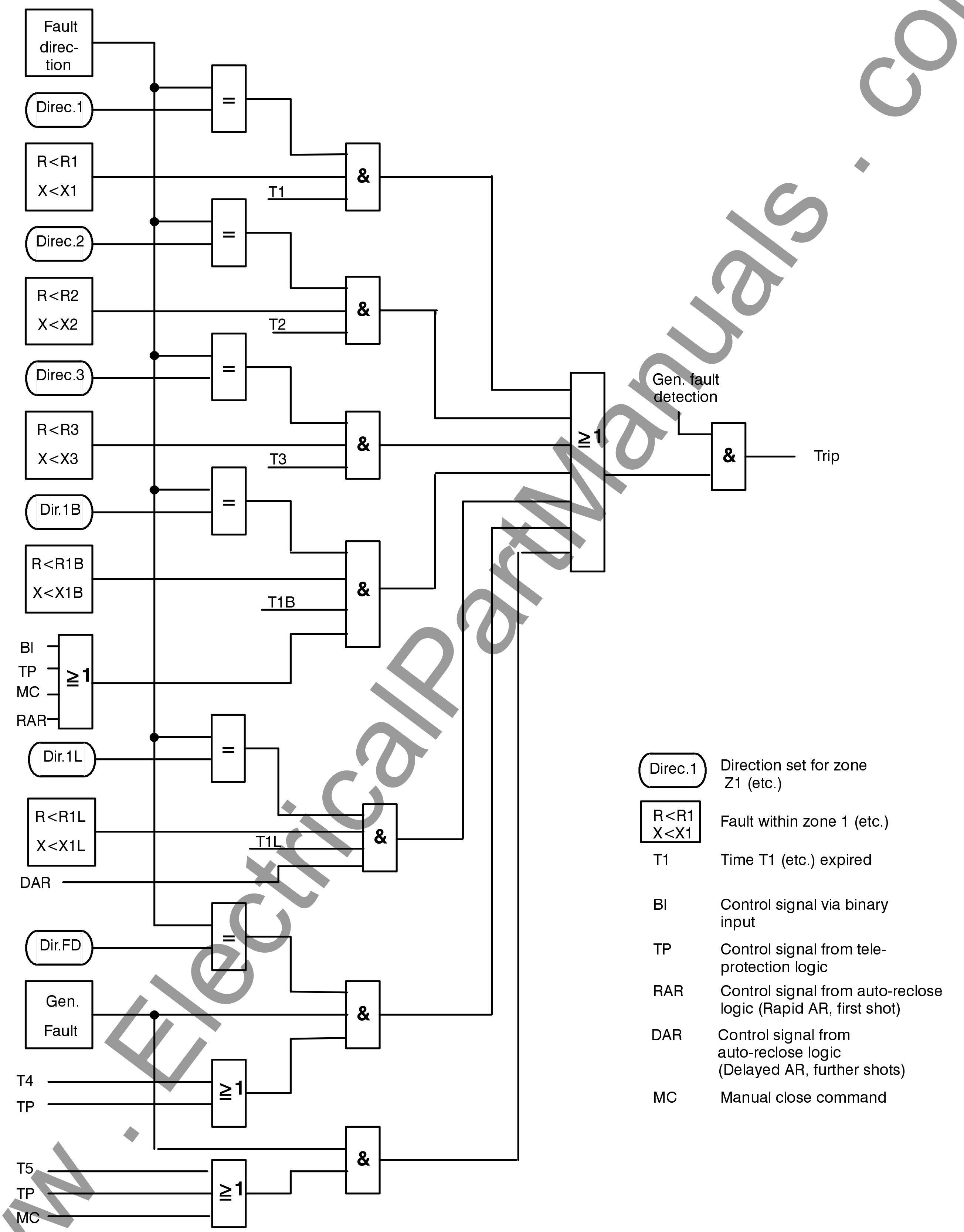


Figure 4.15 Schematic block diagram of the tripping logic of the distance protection

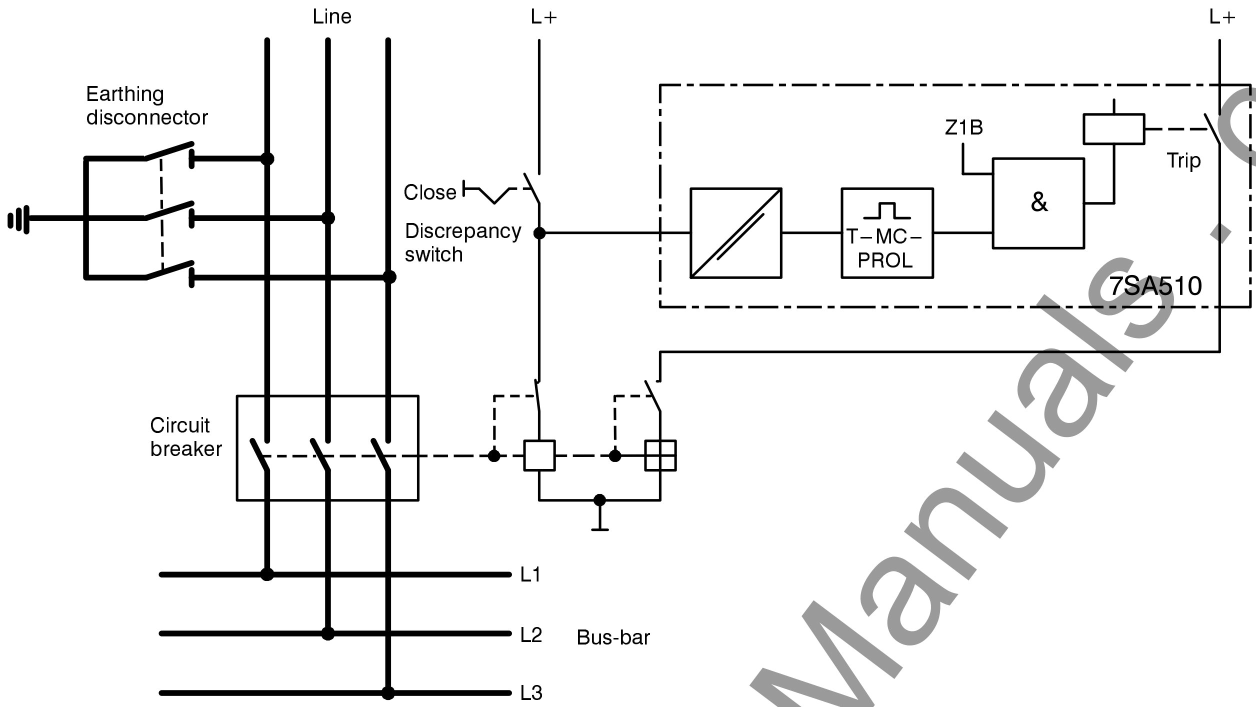


Figure 4.16 Functional diagram of the switch-onto-fault protection

4.2.8 Definite time overcurrent and emergency protection

7SA510 provides an overcurrent protection. This feature may, for example, be useful when, during first commissioning, voltage transformer output is not available.

The overcurrent function may also come automatically into operation when the measured voltage is not available, e.g. during short-circuit or an interruption in the VT circuits.

Overcurrent protection backs up the distance protection when failure of the measured voltages is detected by any one of the following conditions: operation of the fuse failure monitor (refer to Section 4.13.4.3) or the signal ”VT mcb tripped” is applied to an input relay.

If either of these factors occurs, distance protection is immediately blocked and emergency overcurrent protection may become operative (selectable).

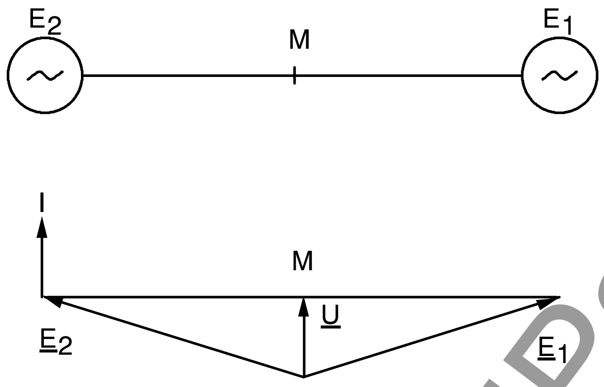
Under this condition, selectivity can only be achieved by time delay, just as for all types of overcurrent protection scheme.

As soon as the device recognizes that the measured voltages have reappeared, the system switches back to distance protection.

For further details refer to Section 4.6.

4.3 Measures to be taken in the case of power swings (optional with impedance fault detection)

After dynamic occurrences, such as load fluctuations, short circuits, auto-reclosures or switching operations, the generators may have to adjust to the new load conditions in the network. The distance protection registers the high equalizing currents and – in particular in the electrical centre – reduced voltages during power swings (Figure 4.17). Small voltages with simultaneously high currents simulate apparently small impedances, which can lead to tripping. In extensive networks which carry high loads, even the stability of the energy transfer can be endangered by such power swings.



$$\underline{I} = \frac{\underline{E}_1 - \underline{E}_2}{X}$$ at measuring point M

Figure 4.17 Power swing

In order to prevent uncontrolled tripping, the distance protection devices are provided with power swing blocking devices. In certain strategic locations within the network, out-of-step tripping devices are installed, so that the network can be split into part networks in the case of loss of synchronism due to strong (unstable) power swings.

In models with impedance fault detector, the distance protection relay 7SA510 can be equipped with a powerful power swing supplementary function (dependent of the ordered model), which prevents tripping by the distance protection during power swings (power swing blocking), but also allows tripping at predetermined locations in the case of unstable power swings (out-of-step tripping).

4.3.1 Detection of power swings

Power swings are three-phase symmetrical occurrences. The first prerequisite is therefore the absence of any earth fault and the symmetry of the measured impedances. As long as the earth fault detection has picked up (see Section 4.2.1.1) or the three impedances phase-phase differ from each other by more than 25 %, power swings are not detected. Asymmetrical short circuits (i.e. all one-phase and two-phase short circuits) can therefore not result in pick-up of the power swing blocking function. Even when a power swing has been recognized, the following asymmetrical short circuit currents lead to fast release of the power swing blocking function and render possible tripping by the distance protection.

In order to detect a power swing, the rate of change of the impedance vector is measured. Because of the symmetry conditions, it is sufficient to limit the power swing detection to one loop (L1 – L2). The measurement commences when the impedance vector moves into the power swing polygon PPOL (see Figure 4.18). In the case of a three-phase short circuit (1), the impedance vector immediately moves into the fault detection polygon APOL. However, in the case of a power swing, the apparent impedance vector first moves into the power swing polygon PPOL and later into the fault detection polygon APOL (2). It is also possible for the impedance vector to enter and leave the power swing polygon without moving into the fault detection polygon (3). If the impedance vector moves through the whole area represented by the power swing polygon, then parts of the network, seen from the protective device, have become asynchronous (4): the transfer of energy has become unstable.

If the rate of change of the impedance vector is smaller than a (selectable) value dR/dt, a power swing is recognized. The measuring time of the power swing detector is coordinated with the distance between power swing polygon PPOL and fault detection polygon APOL, so that the power swing is detected before the vector moves into the fault detection polygon.

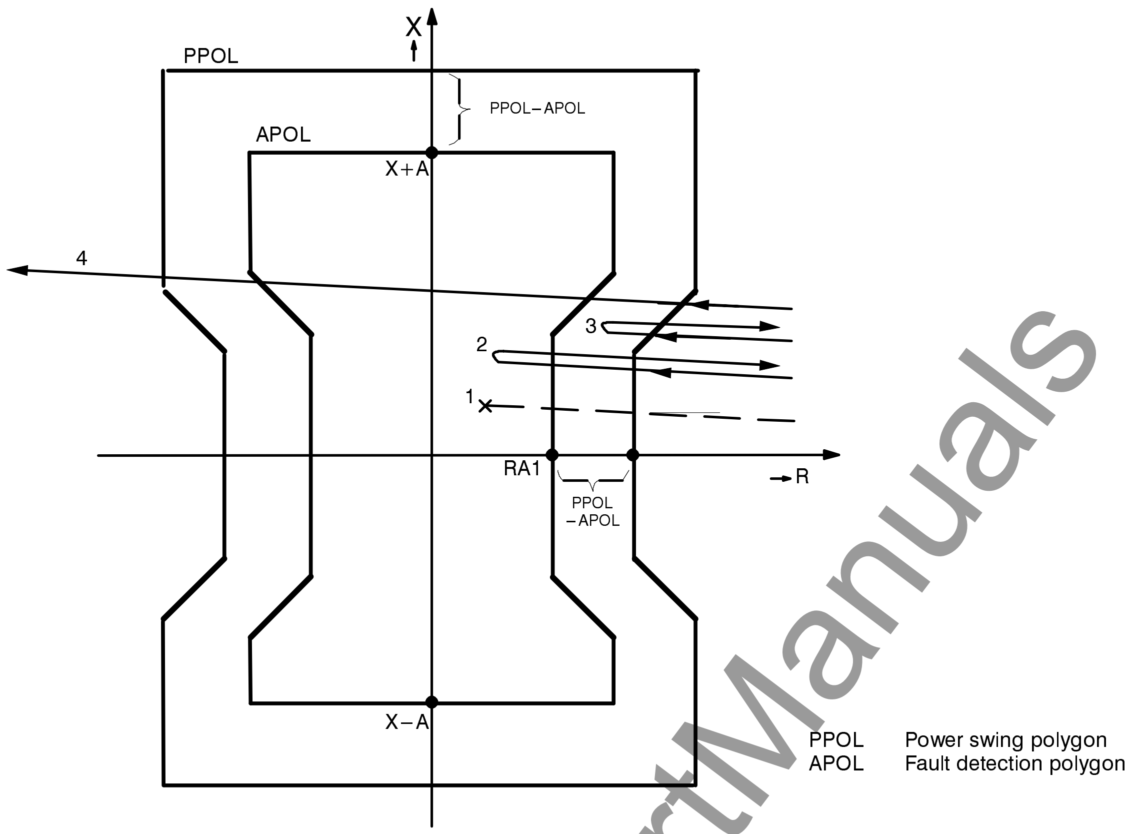


Figure 4.18 Pick-up characteristic for the detection of power swings

4.3.2 Power swing blocking

When the criteria for power swing detection have been met, then the following reactions are possible (settable) for power swing blocking:

– Blocking of the first stage only:
  The first stage of the distance protection (Z1 and Z1B) cannot trip. Faults from the second stage onwards (T2 expired) are tripped after their delay time.

– Blocking of all stages but the first:
  Only the first stage of the distance protection (Z1 or Z1B) is available. Higher stages are not available.

– Blocking of all stages:
  The distance protection is blocked with all of its stages.

The selected reaction remains effective until the measured impedance vector leaves the power swing polygon PPOL or when, due to earth fault pick-up or asymmetry, the power swing criteria are no longer met. The action time of the power swing blocking device can also be limited by a selectable time P/S T−ACT.

4.3.3 Out-of-step tripping

When the criteria for power swing detection are met, and when out-of-step tripping is selected, then the distance protection with all of its stages is blocked, in order to prevent tripping by the distance protection.

When the impedance vector leaves the power swing polygon, the vector is checked by its R−component. If the R−component still has the same sign as at the point of entry, then the power swing is in the process of stabilizing. Otherwise the vector has passed through the polygon (loss of synchronism, case (4) in Figure 4.18). The device issues a tripping command of adjustable duration. The out-of-step trip is announced. The impedance vector must have passed through the power swing polygon within an active time which is identical with P/S T−ACT.

4.4 Universal teleprotection interface

Short circuits on the protected line which lie beyond the first distance zone can be selectively cleared by distance protection only after a delay time. For line lengths which are shorter than the shortest reasonable distance setting, short circuits can equally not be selectively cleared instantaneously.

Thus, to achieve instantaneous clearance of all faults for 100 % of line length, 7SA510 can exchange and process information from the opposite end station by the use of an incorporated teleprotection interface. For this purpose, the relay has transmitter output and receiver input.

Distinction is made between permissive underreach transfer trip modes (PUTT) and permissive overreach (comparison) transfer modes (POTT).

For underreach transfer tripping, the relay is set with normal discrimination steps. If a tripping command is given in the first zone, this is transmitted to the other line end through a teleprotection system. There, the received signal will cause intertripping, as long as the relay at that end has picked up or has recognized a fault in its overreaching zone. 7SA510 permits:

- underreach transfer trip via fault detection zone (FD non-directional),

- underreach transfer trip via overreach zone Z1B acceleration (directional).

For the comparison (overreach) transfer modes the relay will already incorporate a fast overreach zone. This can, however, give a trip signal only when a fault is also detected at the other line end in an overreach zone. Either a release or a blocking signal can be transmitted.

Distinction is made between

Release modes:
- Permissive overreach transfer with overreach zone Z1B,
- Directional comparison transfer with fault detection,
- Zone Z1B comparison unblocking mode,
- Directional comparison unblocking mode (with fault detection).

Blocking mode:
- Blocking of the overreach zone Z1B.

Pilot wire modes:
- Zone Z1B overreach transfer trip via pilot,
- Reverse interlocking.

The comparison via pilot wire is particularly useful in cable networks with short distances. Here the information exchange between the line ends can be made via one pilot wire pair or control cores, using direct current. The reverse interlocking scheme works with d.c. control signals, too.

For the other teleprotection modes, a voice frequency channel is most frequently used (e.g. Siemens transmission device SWT 500 F6 with frequency shift modulation). The voice frequency is transmitted via telephone cable, power line carrier, or radio transmission. Alternatively, the signals can be transmitted via optical fibre connections.

If a fault occurs in the receiving device or on the transmission link, the receiver logic of the universal teleprotection interface can be blocked by the input of a binary signal without affecting the normal distance protection grading. Measurement range control (release of zone Z1B) can then be transferred to the auto-reclose function (see also Section 4.10.1), or the auto-reclose function can be blocked.

Since, in 7SA510, all zones operate independently, it is also possible to give rapid trip in Z1 without receipt of a release signal, or with a blocking signal present, in the comparison modes. If instantaneous trip is not desired, e.g. for extremely short lines for reasons of selectivity then zone Z1 must be delayed by time stage T1.

When emergency overcurrent protection is operating the universal teleprotection interface function is out of operation.

4.4.1 Permissive underreach transfer trip with fault detection

With a fault in zone Z1, an intertrip signal is transmitted to the opposite end of the line. This can be delayed by T_d. The signal received there will result in a trip, as long as the relevant protective device has picked up (fault detection FD). The duration of the transmit signal can be increased by T_s (programmable) in order to match with different pick-up times of the relays at the line ends. The duration of the receive signal can be increased by T_r.

Figure 4.19 shows a simplified block scheme of this function.

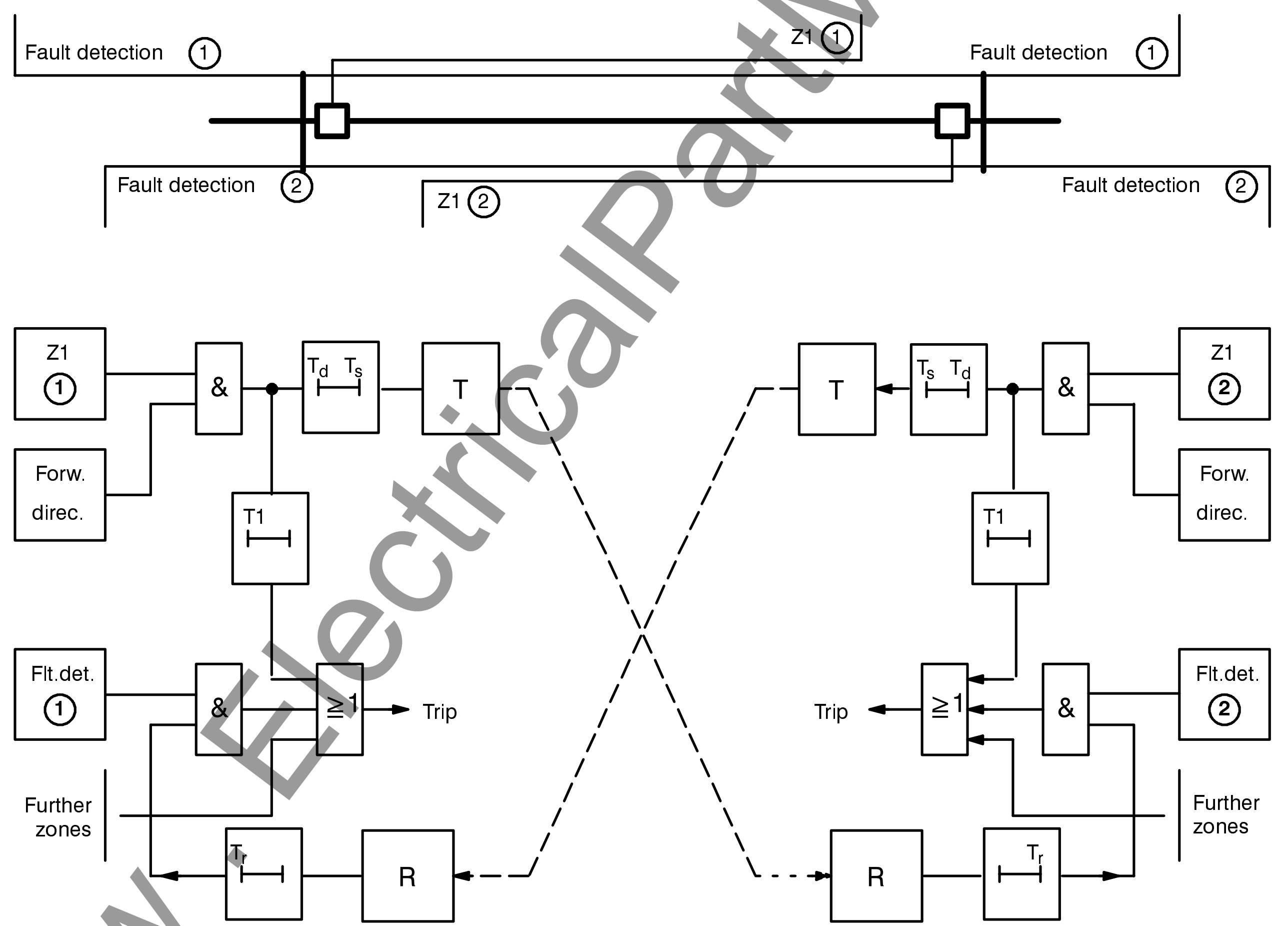
In this operating mode, the overreach zone Z1B is of no importance for the universal teleprotection interface, but it can be initiated by the auto-reclosure function (see Section 4.10.1).

4.4.2 Zone acceleration with Z1B

Just as for a permissive underreach transfer trip with fault detection, the tripping signal of distance zone Z1 will transmit an intertrip signal to the opposite line end (if desired, delayed by T_d). There, a trip command is given when the fault has been detected in zone Z1B in the set direction. The difference between permissive underreach trip with fault detection and zone Z1B acceleration is that at the receiving end the tripping area is defined by the extended zone Z1B directional. The duration of the transmit signal can be increased by T_s, the duration of the receive signal can be increased by T_r.

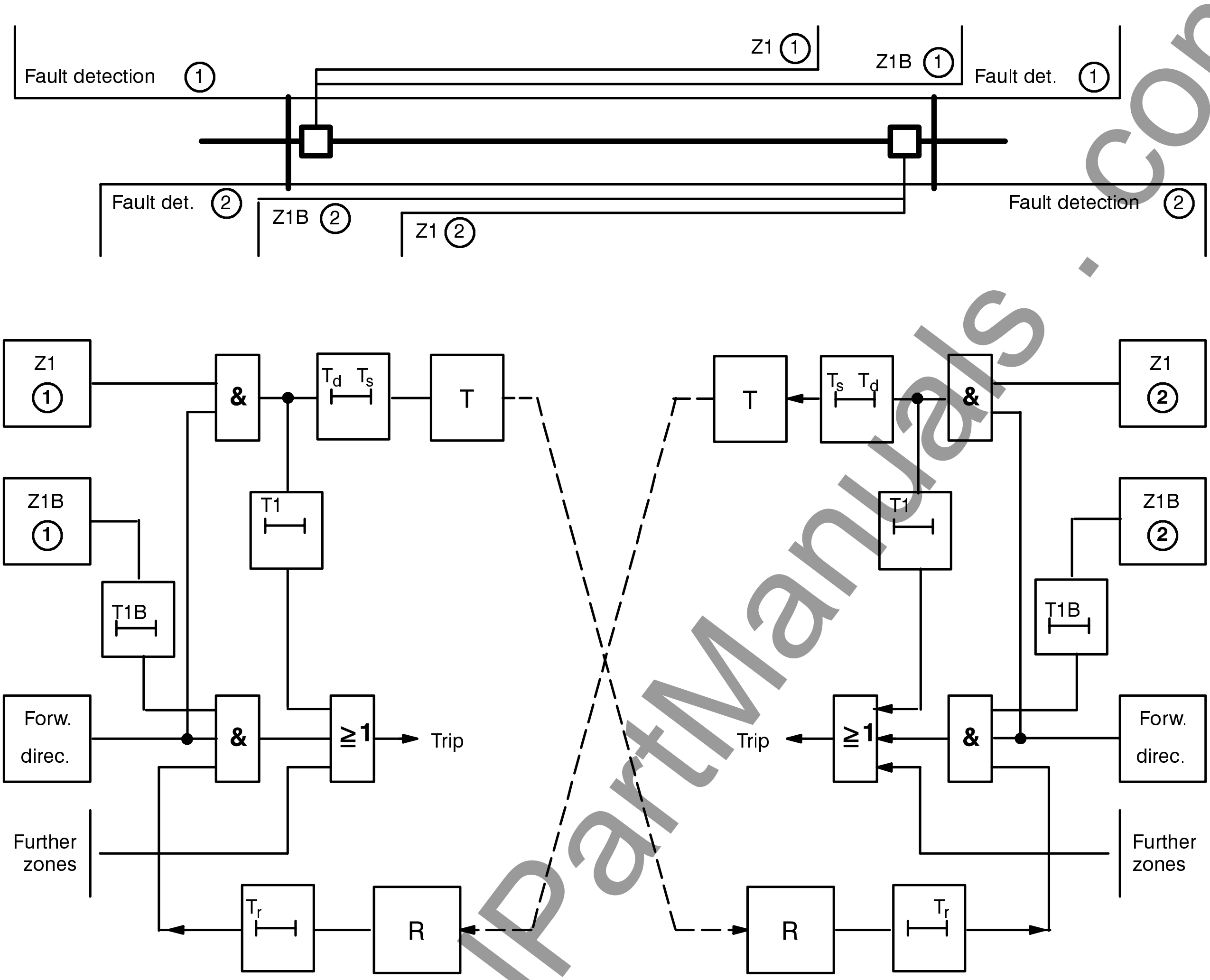
Figure 4.20 shows a simplified block scheme of this function.

If the transmission link is faulty, the overreach zone Z1B can be initiated by the auto-reclosure function (see Section 4.10.1).



Z1	Fault in first distance zone	T1	Delay of first zone (normally 0)
Forw.direc.	Fault in parameterized direction	T_d	Delay of transmission signal
T	Transmitter	T_s	Prolongation of transmission signal
R	Receiver	T_r	Prolongation of received signal

Figure 4.19 Permissive underreach transfer trip (FD acceleration) – block scheme



Z1	Fault in first distance zone	T1	Delay of first zone (normally 0)
Z1B	Fault in overreach zone Z1B	T1B	Delay of overreach zone Z1B (normally 0)
Forw.direc.	Fault in parameterized direction	T_d	Delay of transmission signal
T	Transmitter	T_s	Prolongation of transmission signal
R	Receiver	T_r	Prolongation of received signal

Figure 4.20 Zone acceleration Z1B – block scheme

4.4.3 Permissive overreach transfer trip with Z1B

The permissive overreach transfer trip function uses a permissive release principle. Zone Z1B is of significance as it is set to include the next station and beyond. This method of signal comparison can also be used for extremely short line lengths, when a setting to 85 % of the line length and therefore selective immediate disconnection is not possible. In the latter case, Zone Z1 has to be delayed by T1 because it will operate independent of receipt of a signal.

Figure 4.21 shows a simplified block scheme.

If the distance protection detects a fault within the overreach zone Z1B, a release signal is sent to the opposite line end (if desired, delayed by T_d). If a release signal is also received from the opposite end of the line, the tripping command is transmitted to the command relay. Prerequisite for immediate disconnection is therefore the detection of a fault within zone Z1B from both line ends in the parameterized direction.

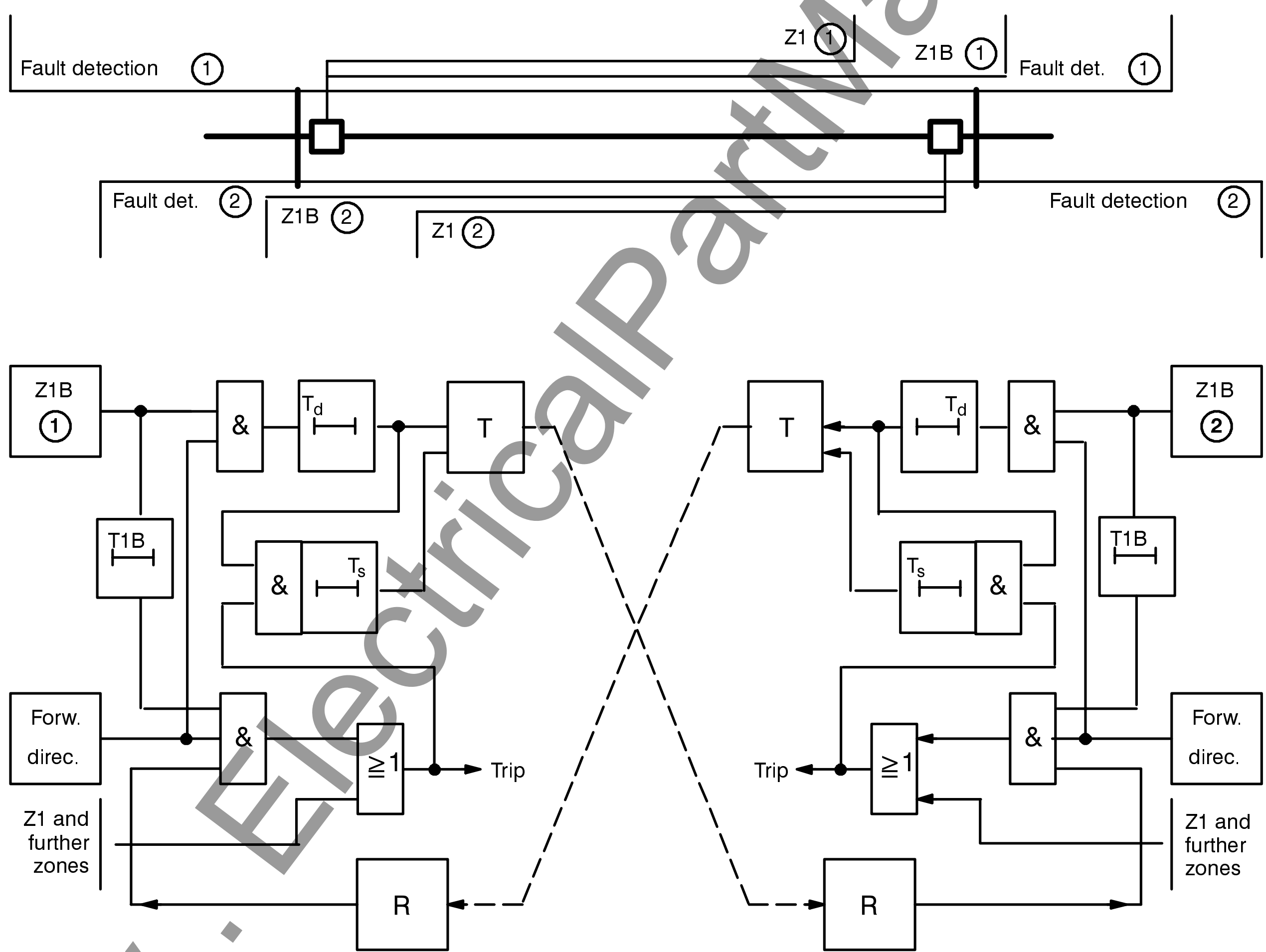
The duration of the transmit signal can be increased by T_s (programmable), but this prolongation is effective only after the protection has issued a trip command. This ensures the remote line end to be released also in case the local line end is tripped very quickly by the independent first distance zone.

For the other zones (Z1, Z2, Z3), tripping occurs without release from the opposite line end, so that the distance protection works normally even without transmission.

If the teleprotection channel is monitored and a transmission fault is detected, the receiving end logic can be made ineffective by the input of a binary signal. Distance protection then operates with normal grading (rapid trip in Z1). Overreach zone Z1B can then be initiated from the AR function (see Section 4.10.1).

False signals which may have been caused by transient oscillations after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel lines, are rendered harmless by a transient blocking function (refer to Section 4.4.11).

For lines which are fed from one line end only, no release signal can be formed at the unfed line end, since no pick-up can occur there. In order to achieve even in this case immediate tripping over 100 % of the line length, an additional echo function is available (see Section 4.4.10).



Z1B	Fault in overreach zone Z1B	T1B	Delay of overreach zone (normally 0)
Forw.direc.	Fault in parameterized direction	T_d	Delay of transmission signal
T	Transmitter	T_s	Prolongation of transmission signal
R	Receiver		

Figure 4.21 Permissive overreach transfer trip (release of Z1B) – block scheme

4.4.4 Directional comparison (fault detection zone release)

Directional comparison also performs a transfer release function.

Figure 4.22 shows a simplified block scheme.

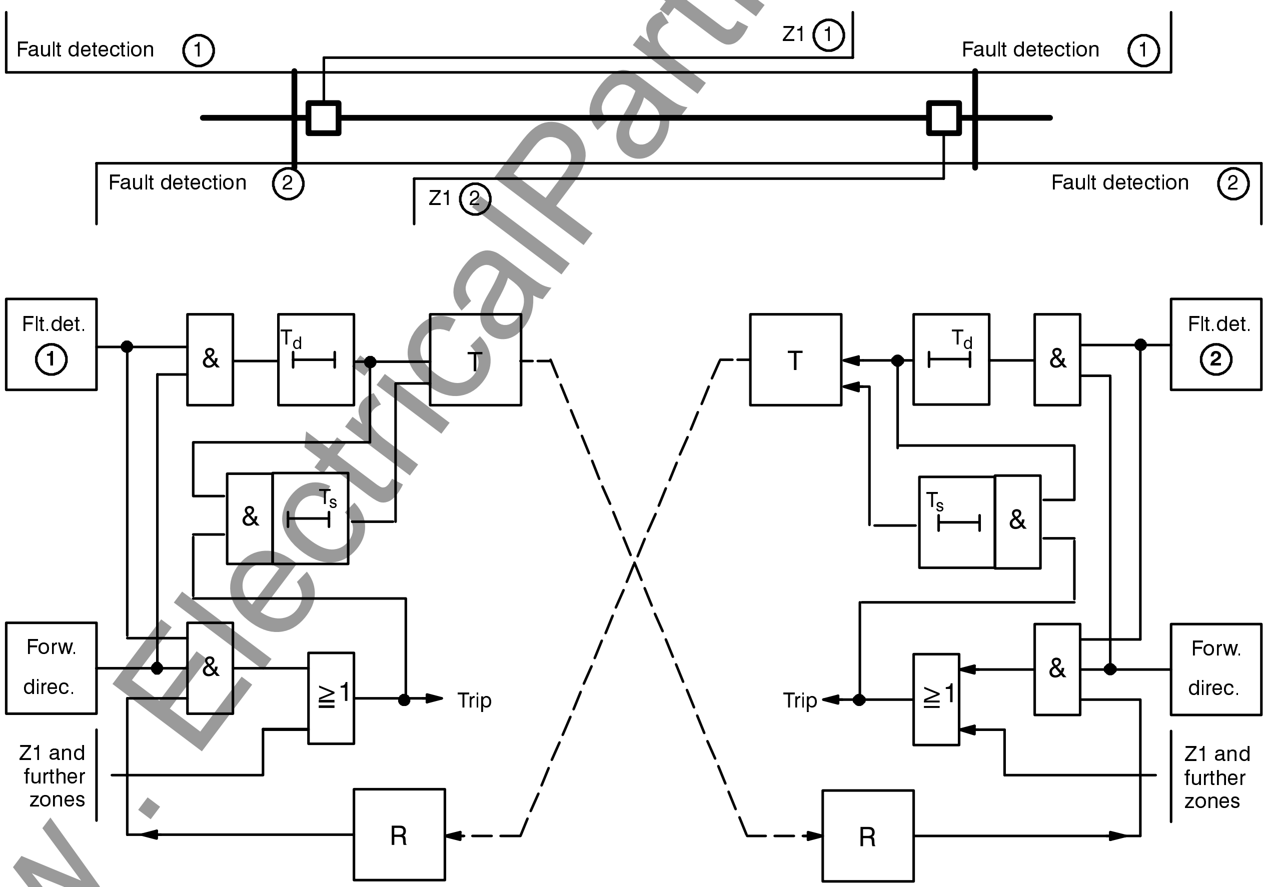
If the relay detects a fault in the line direction it sends (after a settable time t_d if desired) a release signal to the relay at the opposite line end and, when a corresponding confirmation signal is received, issues the tripping signal. The distance grading operates independently of the directional comparison.

The duration of the transmit signal can be increased by T_s (programmable), but this prolongation is effective only after the protection has issued a trip command. This ensures the remote line end to be released also in case the local line end is tripped very quickly by the independent first distance zone.2

If the transmission channel is monitored and a fault is detected, this will only block the directional comparison function, via the input channel "Reception faulty".

False signals which may have been caused by transient oscillations after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel lines, are rendered harmless by a transient blocking function (refer Section 4.4.11).

For lines which are fed from one line end only, no release signal can be formed at the unfed line end, since no pick-up can occur there. In order to achieve even in this case immediate tripping over 100 % of the line length, an additional echo function is available (see Section 4.4.10).2



T Transmitter
R Receiver
T_d Delay of transmission signal
T_s Prolongation of transmission signal

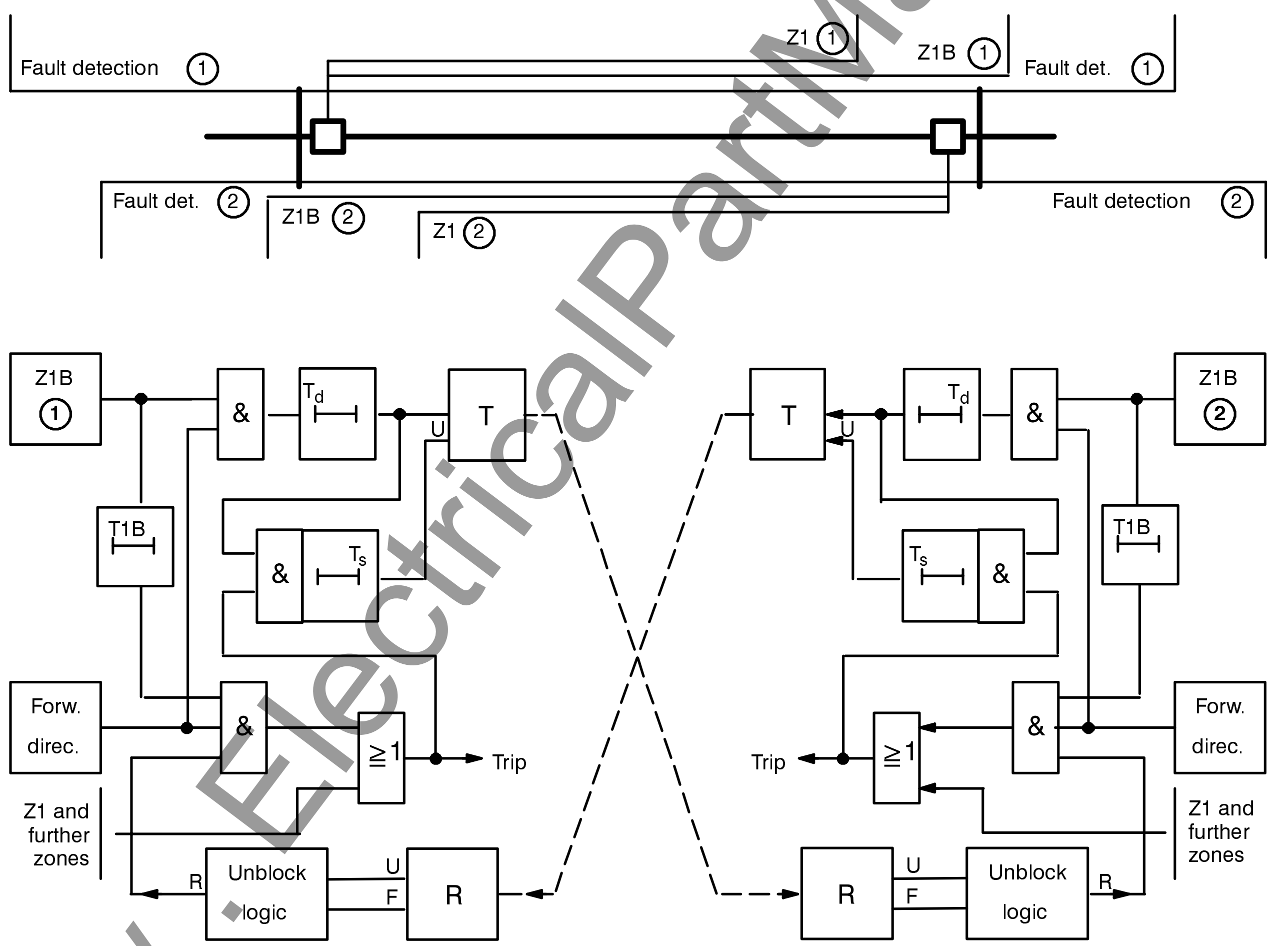
Figure 4.22 Directional comparison – block scheme

4.4.5 Unblocking mode with Z1B

The unblock mode is a releasing procedure. Zone Z1B is set to reach beyond the next station. The difference from permissive overreach transfer trip with Z1B (Section 4.4.3) is that a trip command is also possible when no release signal is received from the opposite end. It is therefore principally used for long lines, when the signal has to be transmitted over the protected line using a PLC system and the damping of the transmitted signal can be so large at the point of fault that its receipt from the other line end cannot be unconditionally guaranteed. For this particular case, a special unblocking logic comes into operation.

Figure 4.23 shows a simplified block scheme of this function.

For signal transmission one requires two signal frequencies which are shifted over from the transmitter output in 7SA510. If the PLC system incorporates channel monitoring (e.g. Siemens voice frequency unit SWT 500 F6) then the monitoring frequency f_0 is switched to a working frequency. If the relay detects a fault within the overreach zone Z1B, it initiates transmission of the working frequency f_U (unblocking frequency, can be delayed by T_d). Under normal conditions or with a fault outside the Z1B zone, or in the direction opposite to that set, the monitoring frequency f_0 is transmitted. If the transmission channel is distorted, the receiver unit will issue the fault signal F. Received signal and fault signal pass through an unblocking logic circuit which can be seen in Figure 4.25.



Z1B	Fault in overreach zone Z1B	T1B	Delay of overreach zone (normally 0)
Forw.direc.	Fault in parameterized direction	T_d	Delay of transmission signal
T	Transmitter	T_s	Prolongation of transmission signal
R	Receiver		

Figure 4.23 Unblocking mode with Z1B – block scheme

If the unblocking signal U is faultlessly received, then the release signal R is formed (in Figure 4.25 upper signal route), that is, the tripping signal of zone Z1B is forwarded to the tripping relay (as with overreach transfer with Z1B). If fault signal F appears, no release is given.

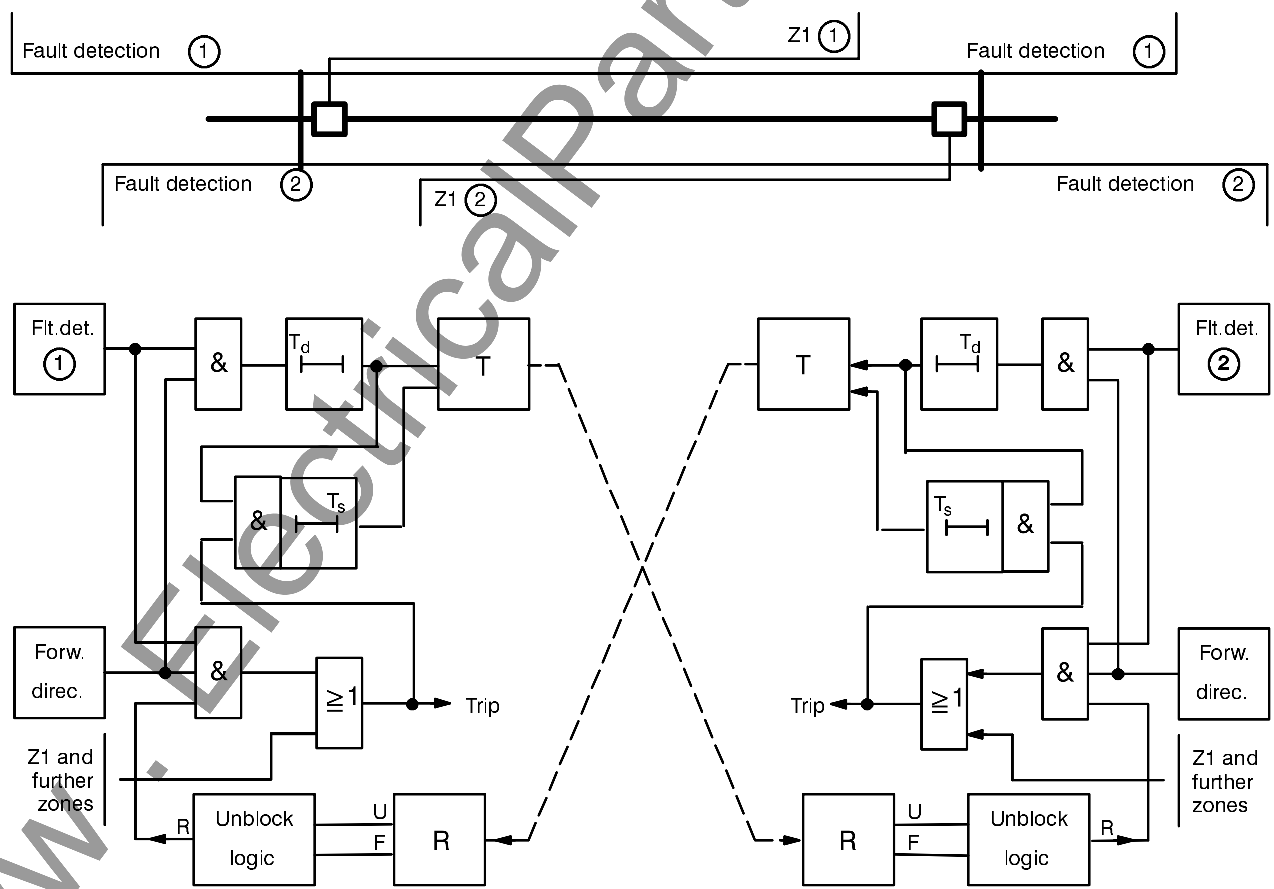
If the signal to be transmitted does not reach the other line end, because a short circuit on the line causes excessive damping or reflection of the signal, the receiver recognizes a fault and issues fault signal F. In this case, after a safety delay time of 20 ms, release signal R is dispatched, but by the time stage 100/100 ms it is cancelled after a further 100 ms. When the fault signal disappears again, the quiescent condition is reestablished after another 100 ms (reset delay of time stage 100/100 ms), that is, the upper release route in Figure 4.25 is again available.

For all zones with the exception of Z1B, tripping is permitted without release, so that the relay operates independent of signal transmission. The overreach zone Z1B can then be initiated from the automatic reclosing system (see Section 4.10.1).

If the transmission device has no channel supervision facility but only demodulates the two frequencies (unblocking frequency and blocking frequency), the fault signal F can be produced by a simple logic according to Figure 4.26. Instead of the AND gate, an exclusive–OR gate can be incorporated. Standing transmission faults will be recognized by 7SA510 after approximately 10 s and annunciated.

False signals which may have been caused by transient oscillations after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel lines, are rendered harmless by a transient blocking function (refer Section 4.4.11).

For lines which are fed from one line end only, no release signal can be formed at the unfed line end since no pick-up can occur there. In order to achieve even in this case immediate tripping over 100 % of the line length, an additional echo function is available (see Section 4.4.10).



T Transmitter
R Receiver

T_d Delay of transmission signal
T_s Prolongation of transmission signal

Figure 4.24 Directional comparison unblocking mode with fault detection – block scheme

4.4.6 Directional unblocking mode with fault detection

The unblocking mode is a release procedure. The difference from directional comparison procedures (Section 4.4.4.) is that a tripping signal is also possible when no release signal is received from the opposite end. It is therefore principally used for long lines when the signal must be transmitted over the protected line by a PLC system and the damping of the transmitted signal at the point of fault is so large that receipt from the other line end cannot be unconditionally guaranteed. In this case, a special unblocking logic comes into operation.

Figure 4.24 shows a simplified block scheme of this function.

For signal transmission one requires two signal frequencies which are shifted over from the transmitter output in 7SA510. If the PLC system incorporates channel monitoring (e.g. Siemens voice frequency unit SWT 500 F6) then the monitoring frequency f_0 is switched to a working frequency. If the relay detects a fault in the line direction, it initiates transmission of the working frequency f_U (unblocking frequency, can be delayed). Under normal conditions or with a fault in the direction opposite to that set, the monitoring frequency f_0 is transmitted. If the transmission channel is distorted, the receiver unit will issue the fault signal F. Received signal and fault signal pass through an unblocking logic circuit which can be seen in Figure 4.25.

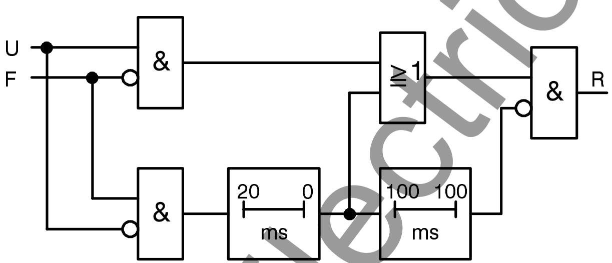


Figure 4.25 Unblocking Logic

If the unblocking signal U is faultlessly received, then the release signal R is formed (in Figure 4.25 upper signal route), that is, an undelayed tripping signal can be forwarded to the tripping relay for a detected fault in line direction (as with directional comparison). If fault signal F appears, no release is given.

If the signal to be transmitted does not reach the other line end, because a short circuit on the line causes excessive damping or reflection of the signal, the receiver recognizes a fault and issues fault signal F. In this case, after a safety delay time of 20 ms, release signal R is dispatched, but by the time stage 100/100 ms it is cancelled after a further 100 ms. When the fault signal disappears again, the quiescent condition is reestablished after another 100 ms (reset delay of time stage 100/100 ms), that is, the upper release route in Figure 4.25 is again available.

If the transmission device has no channel supervision facility but only demodulates the two frequencies (unblocking frequency and blocking frequency), the fault signal F can be produced by a simple logic in accordance with Figure 4.26. Instead of the AND gate, an exclusive OR gate can be incorporated. Standing transmission faults will be recognized by 7SA510 after approximately 10 s and annunciated.

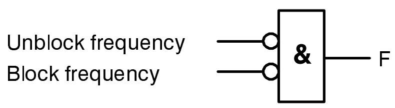


Figure 4.26 Producing the fault signal F

False signals which may have been caused by transient oscillations after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel lines, are rendered harmless by a transient blocking function (refer Section 4.4.11).

For lines which are fed from one line end only, no release signal can be formed at the unfed line end, since no pick-up can occur there. In order to achieve even in this case immediate tripping over 100 % of the line length, an additional echo function is available (see Section 4.4.10).

4.4.7 Blocking mode

In the blocking procedure, the transmission link is used to send a blocking signal from one line end to the other. The signal is transmitted when the relay detects a fault in the reverse direction.

Figure 4.27 shows a simplified block scheme.

Faults in the overreach zone Z1B, which is set to approximately 120 % of the line length, lead to a trip signal as long as no blocking signal is received from the opposite line end. Because of possible differences in the pick-up times of the relays at each line end and because of the transmission time, zone Z1B must be somewhat delayed with time T1B.

Equally, to avoid competition, a dispatched signal will be lengthened by the adjustable time T–SEND–PRL (T_s in Figure 4.27). Also the receive signal will be lengthened by the transient blocking time T–TRANSBLO (TB in Figure 4.27) provided it has been received for the waiting time (TW). The transient blocking time again comes into operation to render harmless fault signals which may have been caused by transient oscillations after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel line. (See transient blocking function, Section 4.4.11.).

If the teleprotection channel is monitored and a transmission fault is detected, the receiving end logic can be made ineffective by the input of a binary signal. Distance protection then operates with normal grading (rapid trip in Z1). Overreach zone Z1B can then be initiated from the AR function (see Section 4.10.1.).

An inherent characteristic of the blocking function is that rapid disconnection of single end fed faults is ensured even without special measures since no blocking signal can be formed at the non-feeding end. Also the procedure is particularly suitable when the signal must be transmitted via the protected line using a PLC system and the damping of the transmitted signal can be so large at the point of fault that its receipt from the other line end cannot be unconditionally guaranteed.

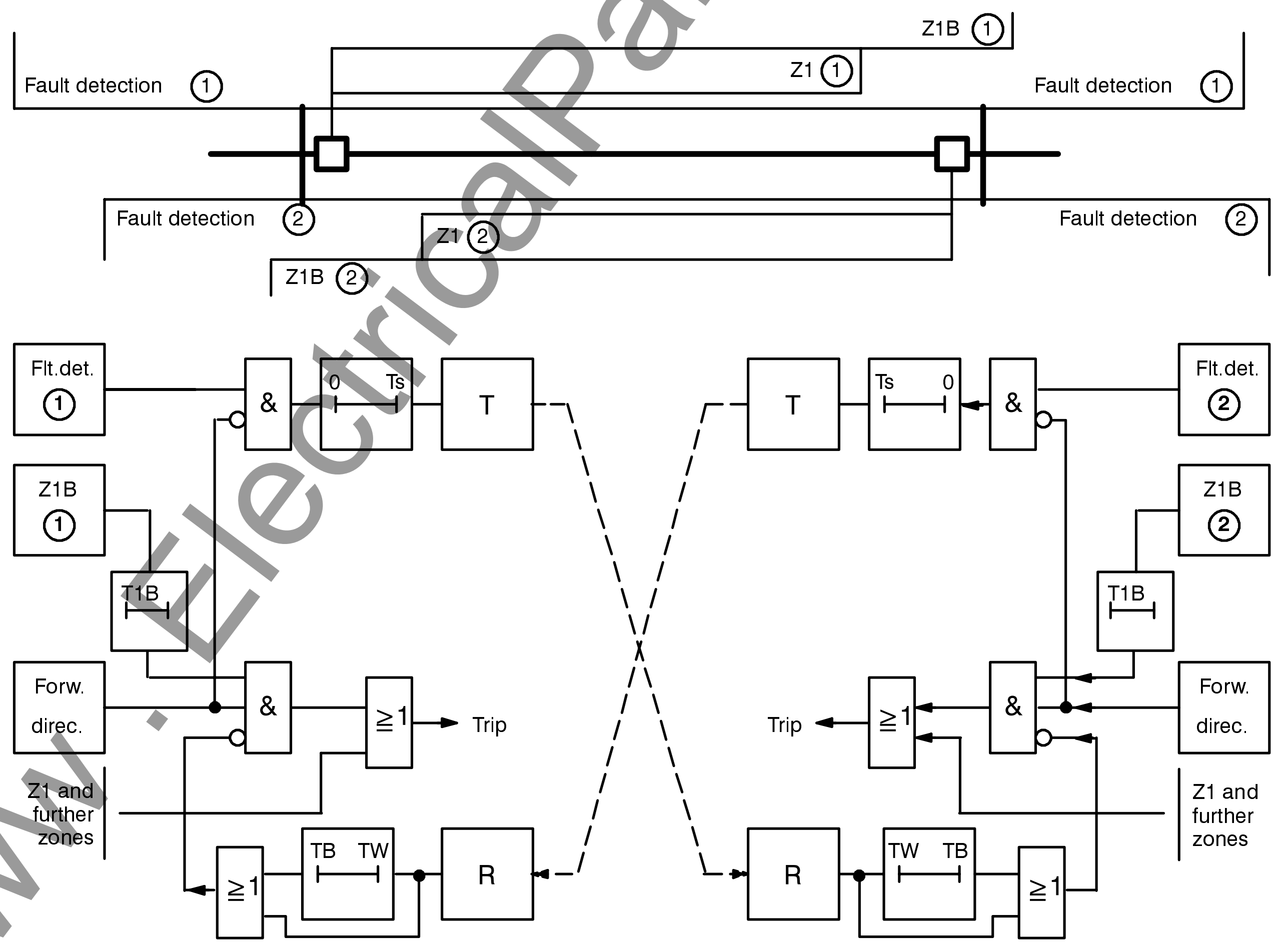


Figure 4.27 Blocking mode – block scheme

4.4.8 Overreaching zone comparison via pilot wires

In this mode the overreach zone Z1B takes on the function of the instantaneous stage at both ends of the protected line. Zone Z1B is set beyond the next station. The comparison function prevents non-selective tripping.

The information exchange between the two line ends is made via a pilot wire or control core loop, connected at each end via an auxiliary relay, and fed from the d.c. battery of one of the substations. For each line end an interposing relay 7PA5210 is therefore necessary (Figure 4.28). Connection diagrams are included in Appendix B.

Under healthy conditions the pilot wires carry direct current thus achieving pilot wire monitoring. Both auxiliary relays K2 are energized (in contrast to the illustration in Figure 4.28).

Distance protection pick-up at either line end will interrupt the wire loop via the send signal and auxiliary relay K1. Both K2 drop off and block tripping in Z1B via the receive signal. If the relay then detects the fault within the overreach zone Z1B, the send signal disappears again. If the loop at the opposite end station is also closed by the same procedure, relays K2 are energized again and, as a result, the receive signals disappear and tripping is released at both line ends.

If a fault occurs beyond the protected line, the d.c. loop will be interrupted by fault detector pick-up of the devices at both ends. Since, however, at least one line end will not de-energize the send signal (fault not in zone Z1B in line direction), the loop remains open. The receive signals are maintained at both line ends and therefore no trip results. The remaining distance stages however operate independently, so that the back-up protection functions are not affected.

For lines shorter than the shortest distance setting one must nevertheless observe that the first distance zone shall be set to be either ineffective or the time T1 shall be set equal to the second distance zone.

With single end feed, instantaneous trip will equally be achieved for the total protected line length. Since no pick-up results at the non-feeding end, the loop is not interrupted there. When, at the other end the fault is detected within Z1B the loop is again closed and the trip signal released.

So that sufficient time is available to open and close the pilot wire loop between pick-up and trip signal from the relay, T1B must be slightly delayed. If the overreaching zone comparison via pilot wires is achieved with two different relay types at the two line ends (e.g. 7SA510 at one end and a conventional relay at the other), it must be ensured that possible fundamental differences in pick-up and tripping times of both relays do not lead to false release signals. This is also to be covered by the delay time T1B.

The normally closed d.c. pilot wire loop allows continuous monitoring of the pilot wires. Since, with each line fault, the loop is interrupted, the pilot wire interruption signal is delayed for 10 seconds. The comparison function is then blocked. The remaining stages of the distance protection continue to function normally. The input "Reception faulty" on 7SA510 is **not** used, because a pilot wire fault will be recognized within the relay itself.

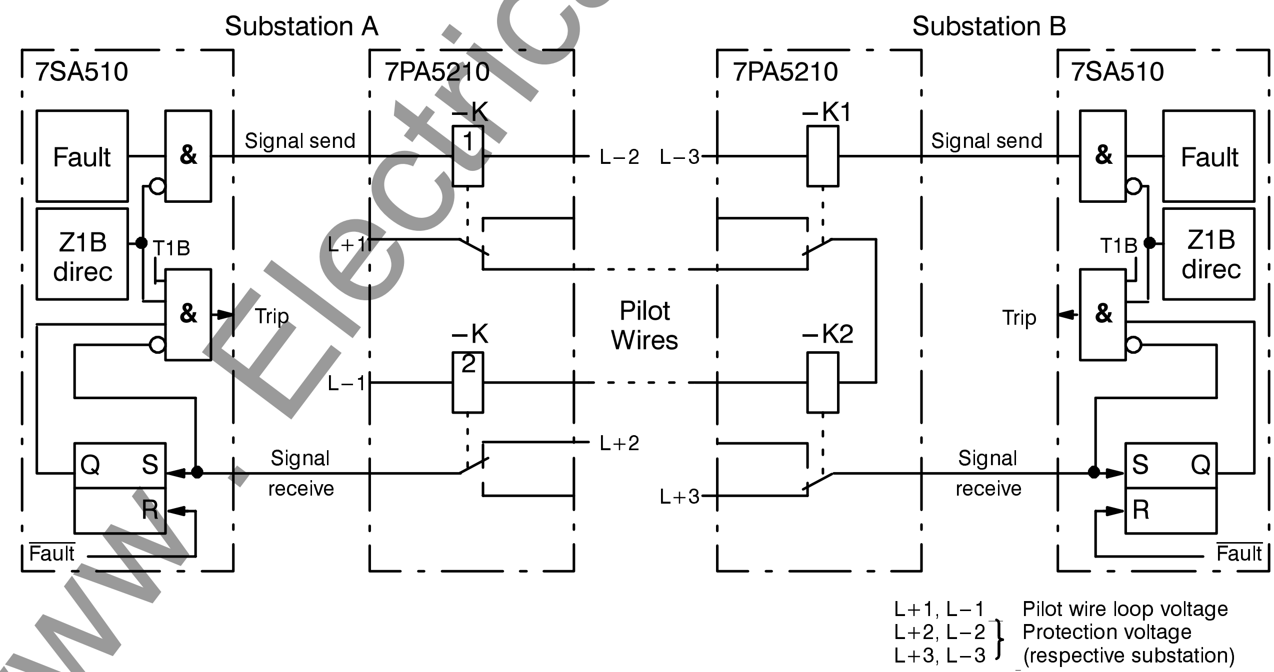


Figure 4.28 Overreaching zone comparison via pilot wires − schematic diagram

4.4.9 Reverse interlocking

If the protection system is installed as back-up protection in a single end feed transformer circuit, the distance relay can be used to provide high speed protection for the bus-bar, without endangering the selectivity for the outgoing lines.

Distance zones Z1 and Z2 then serve as back-up stages for faults on the outgoing lines, for example, at B, as illustrated in Figure 4.29. The distance zone settings should be based on the characteristics of the shortest line.

The overreaching zone Z1B, whose delay time T1B will be set higher than the pick-up time of any subordinate relay, will be blocked if a subordinate relay has picked up. As illustrated in Figure 4.29. the pick-up signal will be fed through the receiver input, to the protection system. However, in accordance with its purpose and in the absence of such an input signal, this zone guarantees rapid disconnection of the bus-bar, in the case of:

– fault in the outgoing transformer circuit, for example, in A
– failure of a line protection relay.

Reverse interlocking is achieved by deliberate release or blocking of the overreaching zone Z1B. It can be used in a blocking mode (as shown in Figure 4.29) or in release mode by a normally closed circuit.

To avoid transient false signals after disconnection of external faults the blocking function is extended by a transient blocking time T−TRANSBLO (TB in Figure 4.29) under reverse interlock conditions.

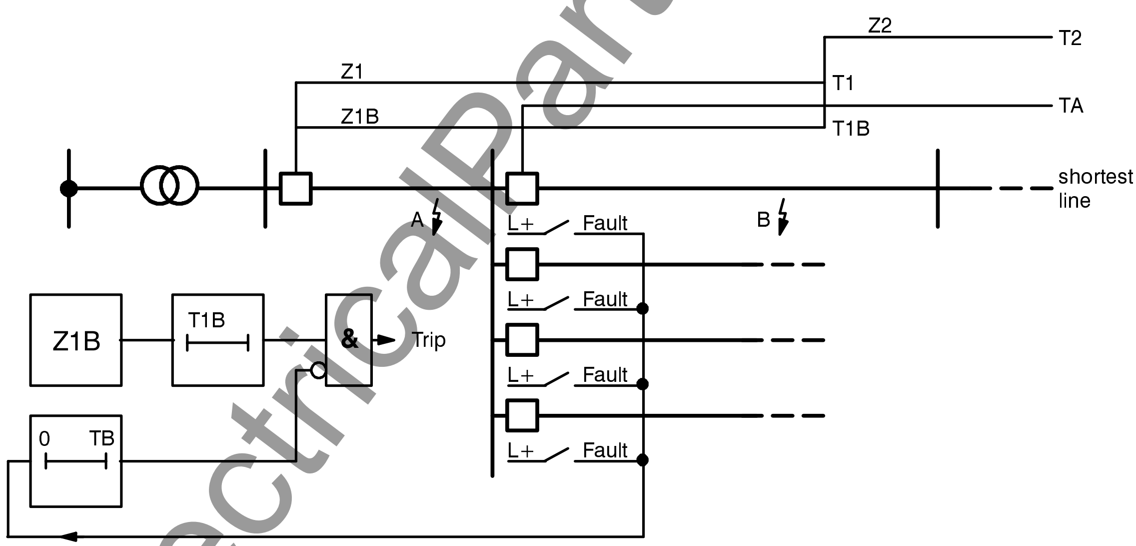


Figure 4.29 Reverse interlocking scheme, grading of distance zones (example)

4.4.10 **Weak infeed measures** (echo function)

In those cases, where at one line end there is no or only a weak infeed so that the protection device at that end cannot pick up and therefore cannot send any release signal, an echo intertrip signal can be sent in conjunction with overreaching modes with release signal. This feature can be made effective or ineffective by a software ON/OFF switch. Figure 4.30 shows the logic diagram.

In the event of pick-up failure at one line end, the echo function ensures that the received signal is sent back to the other line end as an "echo" and there permits release of the tripping command. The duration of the echo impulse is adjustable (T−ECHO−IMP).

The echo is delayed by an adjustable time T−ECHO−DEL. This delay is necessary so that the echo is not effective when the relay at one line end has a higher pick-up time or when it picks up somewhat later because of unfavourable short circuit current distribution. If, however, the circuit breaker at the non-feeding line end is open, delay of the echo is not necessary. The echo delay time can then be bypassed, as long as the relay is informed of the status of the circuit breaker via a binary input.

To prevent the formation of an echo after disconnection of the line and reset of the fault detection element, no echo can be formed when fault detection has previously been present (RS−memory in Figure 4.30). For the same reason an adjustable time T−ECHO−BLO prevents formation of an echo after a tripping command.

With the blocking mode and for transfer trip modes, the echo function is not effective. Equally it has no function in overreaching zone comparison via pilot wires or reverse interlocking schemes.

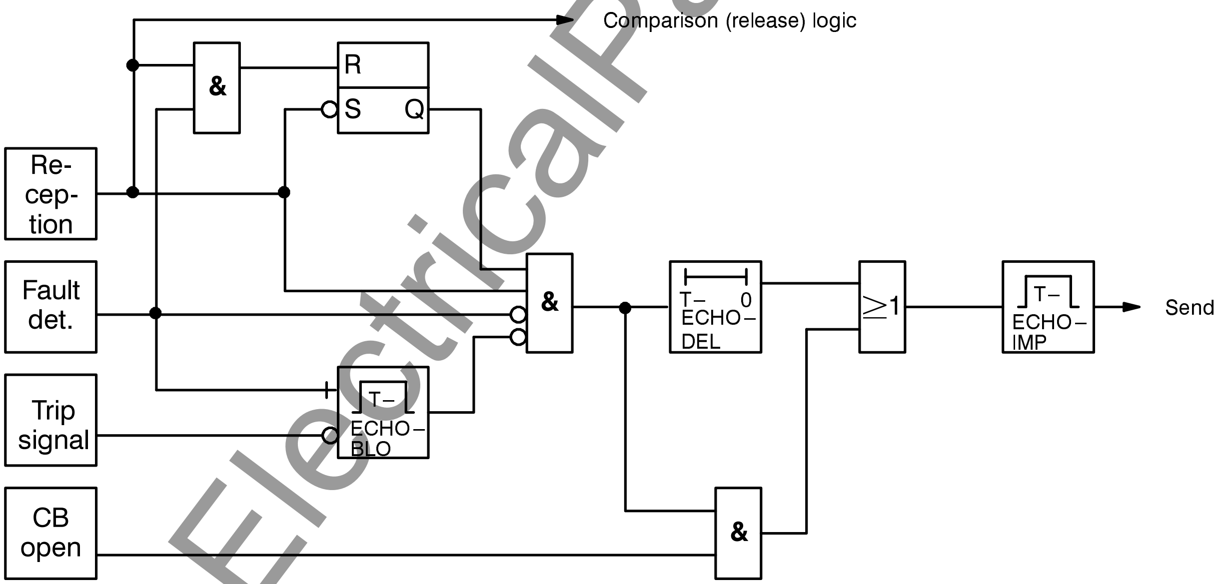


Figure 4.30 Block diagram of echo function (for release modes)

4.4.11 Transient blocking

In overreach transfer and comparison modes, transient blocking provides additional security against false signals which may have been caused by transient oscillation after the interruption of external faults or by reversal of direction of flow after interruption of faults on parallel lines.

The principle of transient blocking is that after the occurrence of an external fault, formation of a release signal is prevented for a specific (adjustable) time T–TRANSBLO. In the release modes this is accomplished by blocking the transmission and receiver circuits, in the blocking mode by lengthening of the blocking signal at the receiver end.

Figure 4.31 shows the principle of transient blocking for a release mode. If, after fault detection, a fault is shown to be in the reverse direction (opposite to the set direction), the transmission circuit and the release of overreaching zone Z1B or directional trip will be blocked after a waiting time of 40 ms. This blocking will be maintained for the transient blocking time T–TRANSBLO – identified in Figure 4.31 with TB – even after the blocking criterion has been removed.

Similarly, the release of overreaching zone Z1B or directional trip can be restricted when, after fault detection, no release signal is received from the opposite line end within the settable waiting time TW. This blocking will also be extended by the transient blocking time. Normally, this mode of transient blocking is reasonable only when the protection scheme at the remote line end has no transient blocking feature. Transient blocking is suppressed when the waiting time TW is set to infinity.

In the blocking mode, non-receipt of the release signal qualifies as receipt of a blocking signal. Here, transient blocking means prolongation of the blocking signal. The blocking signal must have been received for the waiting time TW. The transmission signal can be lengthened by the time T–SEND–PRL (see also Section 4.4.7).

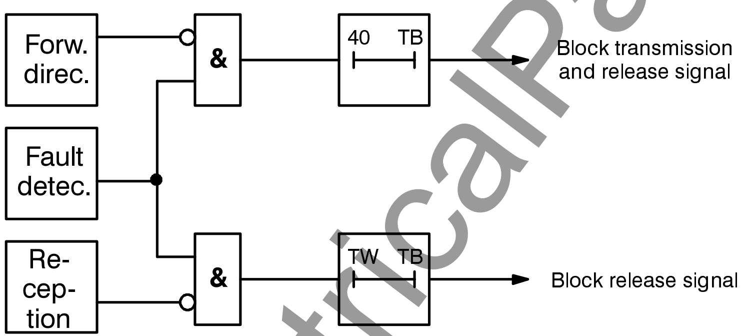


Figure 4.31 Transient blocking with release mode

4.5 User definable logic functions, trip commands, and annunciations

7SA510 contains two user definable logic modules. These comprise each a timer which can be started and blocked via a binary input (Figure 4.32). A pick-up time delay and a drop-off time delay can be set. The times can also be set to 0 or ∞.

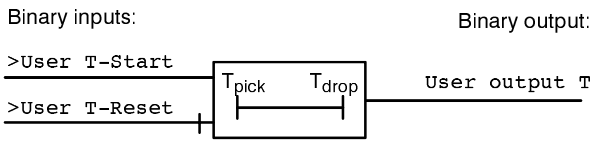


Figure 4.32 User definable logic, one module

The outputs are included in the annunciation processing of the device. They can be assigned to signal relays, LEDs or trip relays.

The following functions can be realized, for example:

- pick-up delay with T_{pick} (T_{drop} = 0),
- drop-off delay (pulse lengthening) with T_{drop} (T_{pick} = 0),
- pick-up delay and drop-off delay,
- bistable memory (flip–flop) (refer to Figure 4.33),
- flip–flop with delay.

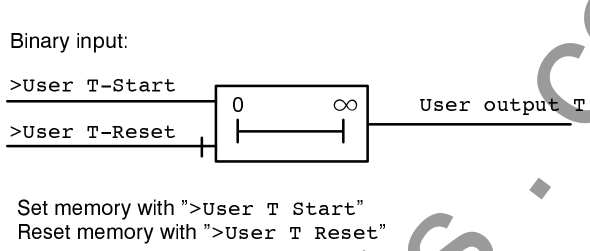


Figure 4.33 Flip–flop

Any desired trip signal from an external protection or supervision unit can be incorporated into the processing of 7SA510. The signal is coupled as "External signal" via a binary input. Like the internal protection and supervision signals, it can be annunciated as "External fault", and transmitted to the trip relays.

Additionally, four annunciations are available, which can be defined by the user himself. Signals and messages of other devices which have no interfaces (PC or LSA interface) can be included in the annunciation processing of the device. Like the internal annunciations, they can be allocated to signal relays, LEDs or trip relays, or transmitted to the front display, a PC or LSA.

4.6 Emergency overcurrent time protection

7SA510 provides an emergency overcurrent time protection. Whereas distance protection can operate only as long as the line voltages are properly available, the overcurrent time protection needs the currents only.

The overcurrent function comes automatically into operation when failure of the measured voltages is detected by any one of the following conditions:

– operation of the fuse failure monitor or three-phase voltage failure supervision (refer to Section 4.13.4.3) or
– the signal ”VT mcb tripped” is applied to a binary input.

If either of these factors occurs, distance protection is immediately blocked and emergency overcurrent protection may become operative (selectable).

Under this condition, selectivity can only be achieved by time delay, just as for all other types of overcurrent protection scheme.

As soon as the device recognizes that the measured voltages have reappeared, the system switches back to distance protection.

The emergency overcurrent time protection is designed two-stage for phase current, with an additional earth current stage. All stages are independent from each other and can be set individually:

– I>> high current limit value threshold for phase currents
– $T_{I>>}$ corresponding delay time

– $I_{ph}>$ definite time limit value threshold for phase currents
– $T_{I>}$ corresponding delay time

– $I_E>$ definite time limit value threshold for earth currents
– $T_{IE>}$ corresponding delay time

Under conditions of manual closing onto fault, the emergency overcurrent protection can also provide a rapid trip. A choice can be made whether the I>> stages or the I> stages are decisive for an undelayed trip, i.e. the associated time delay is bypassed for this condition. The emergency protection can also be used in conjunction with auto–reclosure. In these cases the I>> stages becomes valid before reclosure.

4.7 Thermal overload protection

The thermal overload protection prevents the power line, particularly in case of cables, from damage caused by thermal overloading.

The unit computes the temperature rise according to a thermal single-body model as per the following thermal differential equation:

$$\frac{d\Theta}{dt} + \frac{1}{\tau} \cdot \Theta = \frac{1}{\tau} \cdot I^2$$

where

- Θ – actual temperature rise referred to the final temperature rise for the maximum permissible cable current $k \cdot I_N$
- τ – thermal time constant for heating-up of the cable
- I – actual cable current (r.m.s. value) referred to the maximum permissible cable current $I_{max} = k \cdot I_N$

When the temperature rise reaches the first set threshold, a warning alarm is given, in order to render possible an early load reduction. If the second temperature threshold is reached the line can be disconnected from the network (selectable).

The temperature rises are calculated separately for each individual phase. A choice can be made whether the maximum calculated temperature rise of the three phases, the average temperature rise, or the temperature rise calculated from the phase with maximum current should be decisive. A true r.m.s. value measurement is performed in order to include for the effect of harmonic content.

The maximum permissible continuous thermal overload current I_{max} is described as a multiple of the rated current I_N:

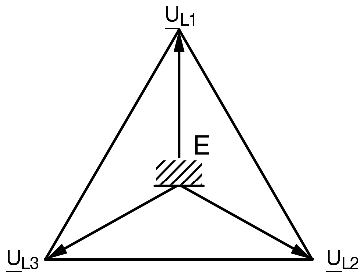
$$I_{max} = k \cdot I_N$$

In addition to this k–value, the time constant τ as well as the alarm temperature Θ_{warn} must be entered into the protection unit.

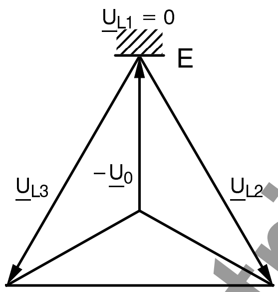
Apart from the thermal warning stage, the overload protection also includes a current-dependent warning stage. This latter alarm stage can give an early annunciation of an impending overload current even if the temperature rise has not yet reached the alarm or trip temperature rise values.

4.8 Earth fault detection in systems with non-earthed starpoint (optional)

In systems whose starpoint is either isolated or earthed through an arc suppression coil (Petersen coil), single phase earth faults will not be detected by the short circuit protection, since no significant earth fault current flows. Furthermore, since network operation is not immediately affected by an earth fault (the voltage triangle is maintained, Figure 4.34) rapid disconnection is not normally desired. It is more important that the earth fault be recognized, indicated and, when possible, located. After switching to alternative network routes it can then be cleared. But it is also possible to trip on directional earth fault in non-earthed systems.



a) Healthy network, without earth fault



b) Earth fault in phase L1

Figure 4.34 Earth fault in non-earthed neutral network

Dependent upon the chosen model, the relay can be fitted with optional earth fault detection module, which includes the following functions:

– Detection of an earth fault (pick-up) by monitoring the displacement voltage,

– Determination of the faulted phase by measuring the phase to earth voltages,

– Determination of the direction of the earth fault (residual) current by high accuracy real and reactive component measurement.

4.8.1 Fault detection

The earth fault protection function can be switched on and off by parameter. When on, pick-up occurs when an adjustable threshold for the displacement voltage $U_E>$ is exceeded. To ensure measurement of stable values, all earth fault detection functions are delayed until 1 second (settable) after inception of voltage displacement. Further, each alteration of the earth fault conditions (e.g. altered direction) is recognized only after this delay. Earth fault annunciation is only issued after earth fault detection is ensured according 4.8.2.

4.8.2 Determination of the earth-faulted phase

After recognition of displaced voltage conditions the first objective of the device is selective detection of the earth-faulted phase. For this purpose the individual phase-to-earth voltages are measured. The affected phase is the one in which the voltage is below the settable threshold $U_{ph}<$ when simultaneously the other two voltages exceed an equally settable maximum threshold $U_{ph}>$.

4.8.3 Sensitive earth fault directional determination

The direction of the earth fault can be determined from the direction of the earth fault capacitive or ohmic current related to the displacement voltage. The only reservation is that the active or reactive current components must be available in sufficient magnitude at the point of measurement.

In networks with isolated starpoint, the earth fault current flows as capacitive current from the healthy lines via the measuring point to the point of fault. This capacitive current determines the direction.

In networks with arc suppression coils, the Petersen coil superimposes a corresponding inductive current on the capacitive earth fault current when an earth fault occurs, so that the capacitive current at the point of fault is compensated. Dependent upon the point of measurement in the network the resultant measured current can however be inductive or capacitive and the reactive current is therefore not suitable for the determination of direction. In this case, only the ohmic residual current which results from the losses of the Petersen coil can be used for directional determination. This earth fault ohmic current is only a few percent of the capacitive earth fault current.

In 7SA510 the earth fault direction is determined from a highly accurate calculation of active and reactive power using the definitions:

Active power:

$$P_{Ea} = \frac{1}{T} \cdot \int_{t}^{t+T} U_E(t) \cdot i_E(t) \cdot dt$$

Reactive power:

$$P_{Er} = \frac{1}{T} \cdot \int_{t}^{t+T} U_E(t - 90^\circ) \cdot i_E(t) \cdot dt$$

where T equals period of integration.

The use of an efficient calculation algorithm and simultaneous numerical filtering allows the directional determination to be achieved with high accuracy and sharply defined threshold limits (see Figure 4.35) and insensitivity to harmonic influences – particularly the frequently strong third and fifth harmonics which occur particularly in ohmic earth fault currents. The directional decision results from the signs of active and reactive power.

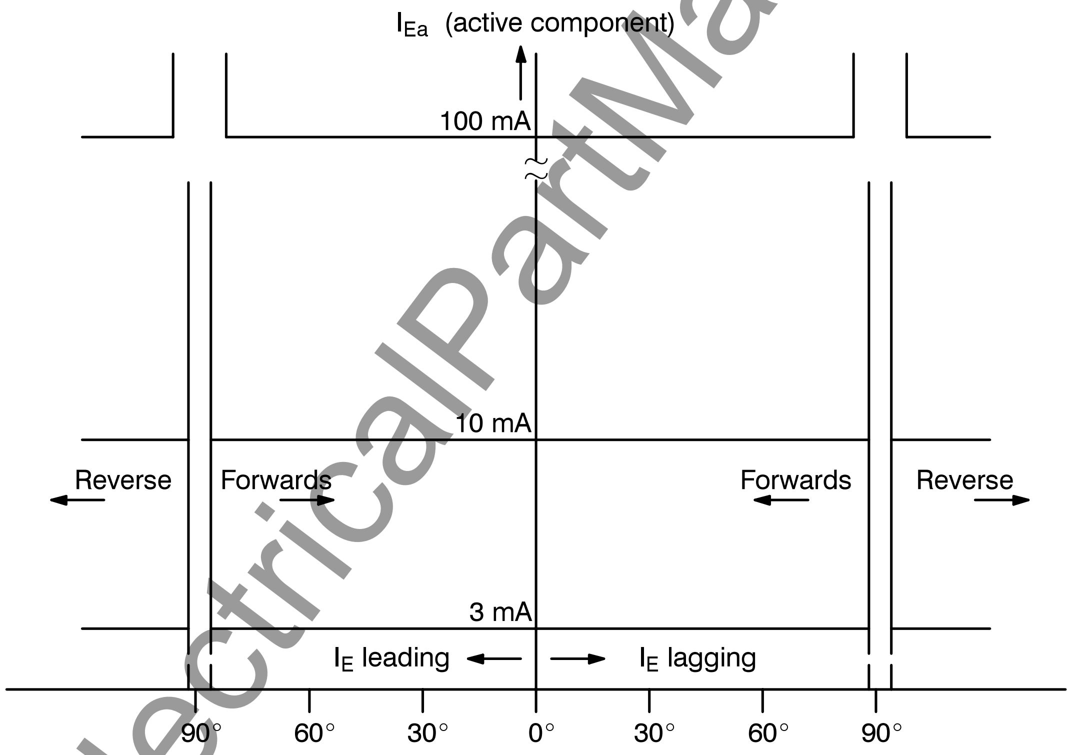


Figure 4.35 Directional earth fault measurement characteristic

Since the active and reactive component of the current – not the power – determine pick-up of the earth fault directional decision, these current components are calculated from the power components. Thus for determination of the direction of the earth fault active and reactive components of the earth fault current as well as the direction of the active and reactive power are evaluated.

In networks with **isolated starpoint** the following criteria apply

– earth fault forwards, when $P_{Er} > 0$ and $I_{Er} >$ set value,

– earth fault backwards, when $P_{Er} < 0$ and $I_{Er} >$ set value.

In **compensated networks** with **arc suppression coil** the following criteria apply

– earth fault forwards, when $P_{Ea} > 0$ and $I_{Ea} >$ set value,

– earth fault backwards, when $P_{Ea} < 0$ and $I_{Ea} >$ set value.

In the latter case it must be noted that, dependent upon the location of the protective relay, a considerable reactive component may be superimposed which, in the most unfavourable cases, can attain 50 times the active component. Even the extremely high accuracy of the calculation algorithm is then inadequate if the current transformers do not exactly convert the primary values.

The measurement input circuit of the relay model with earth fault detection is particularly designed for this purpose and permits an extremely high sensitivity for the directional determination of the wattmetric residual current. In order to utilize this sensitivity it is recommended that window-type current transformers be used for earth fault detection in compensated networks. As even the core balance transformers have an angle of error, the protection system allows the setting of factors which, dependent upon the reactive current, will correct the error angle.

4.8.4 Faulted line location

In radial networks, location of the faulted line is relatively simple. Since all circuits on a busbar (Figure 4.36) carry a capacitive partial current, the measuring point on the faulted line in an isolated network sees almost the entire prospective earth fault current of the network; in compensated networks the wattmetric residual current from the Petersen coil flows through the measuring point. For the faulted line or cable, a definite "forwards" decision will result, whilst in the remaining circuits a "reverse" indication will be given unless the earth current is so small that no measurement can be taken. In any case the faulted cable can be clearly determined.

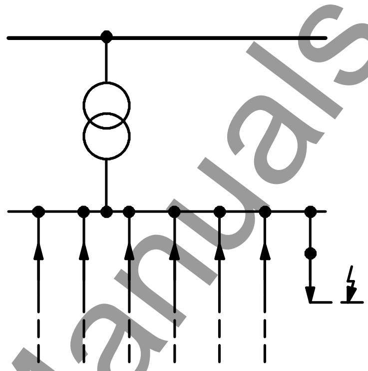


Figure 4.36 Faulted line location in radial network

In meshed or ring networks the measuring points at the ends of the faulted cable equally see a maximum of earth fault (capacitive or ohmic) current. Only in this cable will the direction "forwards" be indicated on both line ends (Figure 4.37). Even the remaining directional indications in the network can aid location of the earth fault. But under certain circumstances one or more indications may not be given due to insufficient earth current. Further advice can be found in the leaflet "Earth-fault detection in isolated neutral or arc-suppression coil earthed high voltage systems".

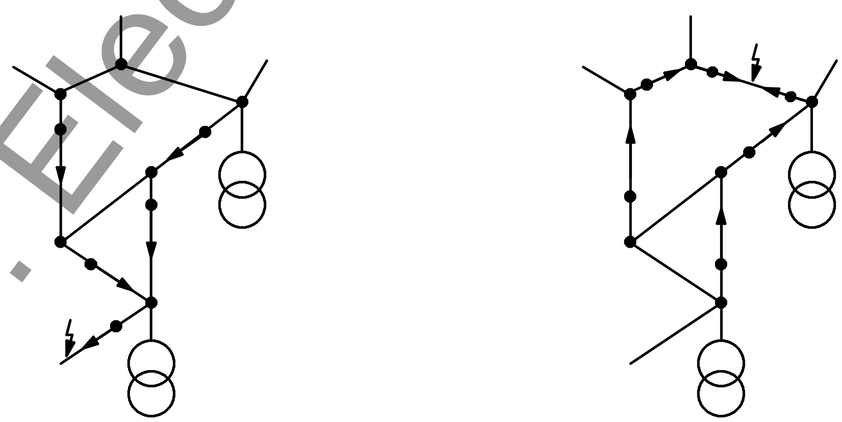


Figure 4.37 Location of earth fault based on the directional indicators in a meshed network

4.9 High-resistance earth fault protection in earthed systems (optional)

In earthed networks in which the earth path resistance can be extremely high (e.g. overhead lines without lightning protection conductor, or sandy soils) the overcurrent – sometimes even the underimpedance – element will often not pick up, so that no phase selection is possible for the distance measurement. Even when using impedance fault detection, earth fault impedances can occur which appear to lie outside the pick-up characteristic of the distance relay.

Protection relay 7SA510, dependent upon the model ordered (see Section 2.3 Ordering data), can provide protective functions for such high resistance earth faults. One of the following features can then be selected:

– directional earth fault protection (definite time earth overcurrent protection) with non-directional back-up and stand-by protection function,

– non-directional inverse time lag overcurrent time protection for earth faults, with selectable characteristics.

The directional earth fault protection can be extended by an integrated directional comparison logic so that by means of a carrier channel fast and selective tripping for high resistance earth faults is also possible.

The non-directional inverse time protection is used mostly for highly interlinked, all-round earthed networks with high resistance earth faults, where the ends of the faulty line section carry the largest fault current and thus produce the shortest tripping time.

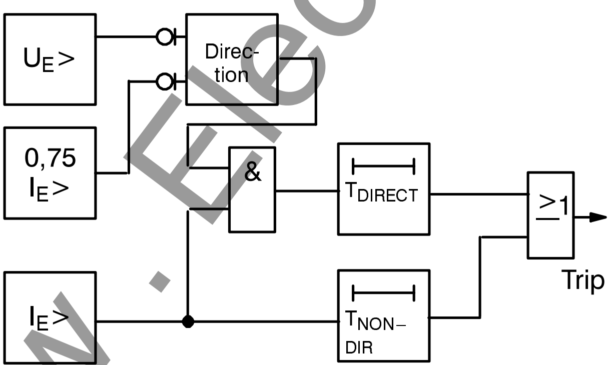


Figure 4.38 Directional earth protection with non-directional back-up stage

4.9.1 Directional earth fault protection

The directional earth fault protection (Figure 4.38) has an adjustable earth current detection element I_E> and an adjustable delay time. Because of the possibility of directional comparison (see Section 4.9.2), detection is two-stage; a lower value $0.75 \cdot I_E$> releases directional determination. For tripping, the high value stage must additionally be exceeded (corresponding to the set value of I_E>).

Directional determination requires a least value displacement voltage, for which the U_E> setting is used. If the displacement voltage is too small, a directional determination and thus directional-dependent tripping is not possible. Directional determination is also suppressed and tripping prevented when the indication "voltage transformer protective device tripped" is signalled to the relay via a binary input.

The criterion for the delay time is the setting T–DIRECT.

A further time stage T–NON–DIR. will cause tripping without directional measurement. It can be set as a non-directional back-up stage for the directional stage. If the displacement voltage is too small or if the voltage transformer protective device has operated, this stage remains effective and can also serve as an emergency function for the directional earth fault protection and the earth fault directional comparison protection.

The earth fault directional function is blocked from the distance protection or emergency overcurrent protection. When the fault is detected by the distance protection or emergency overcurrent time protection the earth fault protection does not operate. This gives selective fault determination by the distance protection preference over tripping by the earth fault protection. In case a fault is cleared by an external protection device, blocking of the earth fault protection can be extended by an adjustable time T–BLOCK, e.g. to allow a single phase auto-reclosing cycle to be carried out by an external auto-reclosure relay. A binary input of the relay must then be used to block the earth fault protection.

4.9.2 Directional comparison earth fault protection

With the aid of the integrated comparison logic, the directional earth fault protection can be extended to form a directional comparison protection. For this purpose a carrier channel is necessary for each direction, which transmits the signals of the directional earth fault protection, (e.g. via PLC) to the associated other line end. This can also be the same channel as for signal transmission with distance protection (Section 4.4) under the condition that a corresponding comparison procedure (4.4.3 Permissive overreach transfer trip with Z1B or 4.4.4 Directional comparison) has been selected at the distance protection element!

After the pick-up $0.75 \cdot I_E>$ the relay carries out directional determination using the earth current I_E (= $3 \cdot I_0$) and the displacement voltage U_E (= $\sqrt{3} \cdot U_0$). With an earth fault in the line direction a release signal is sent to the opposite end; if a release signal is then received from that end, tripping results, as long as this relay has also detected an earth fault in the line direction and the set pick-up value $I_E>$ is exceeded (Figure 4.39). Transmission signal and tripping can both be made dependent on a delay time T–DELAY.

Any faulty signals which could be caused by transient oscillations during the clearance of external faults or during change of direction after clearance of faults on parallel lines, are made harmless by means of a transient blocking function (Figure 4.40). The principle of this transient blocking is that after the occurrence of an external fault the formation of a release signal is prevented for a specific (adjustable) time T–TRANSBLO.

If, after fault detection, it is determined that the fault is in the reverse direction (opposite to the set direction) the transmission circuit and release are suppressed after a waiting time of 40 ms. This blocking will be maintained for the transient blocking time T–TRANSBLO – in Figure 4.40 abbreviated to TB – even after the blocking criterion is removed.

Similarly, the release of directional trip can be restricted when, after fault detection, no release signal is received from the opposite line end within the settable waiting time TW. This blocking will also be extended by the transient blocking time. Normally, this mode of transient blocking is necessary only when the protection scheme at the remote line end has no transient blocking feature. Transient blocking is suppressed when the waiting time TW is set to infinity.

For lines with single end infeed or star point earthing at one line end only, no release can be formed from the residual-current-free line, since no fault detection signal occurs at that end. To achieve tripping by the directional comparison element even in this case, an echo function is additionally available (Figure 4.41). This has the effect that when the low value detection signal is not present at one line end ($0.75 \cdot I_E>$) the received signal will be sent back to the other line end as an "echo" and thus permits the release of a tripping command at that end. The duration of this echo impulse is adjustable (T–ECHO–IMP).

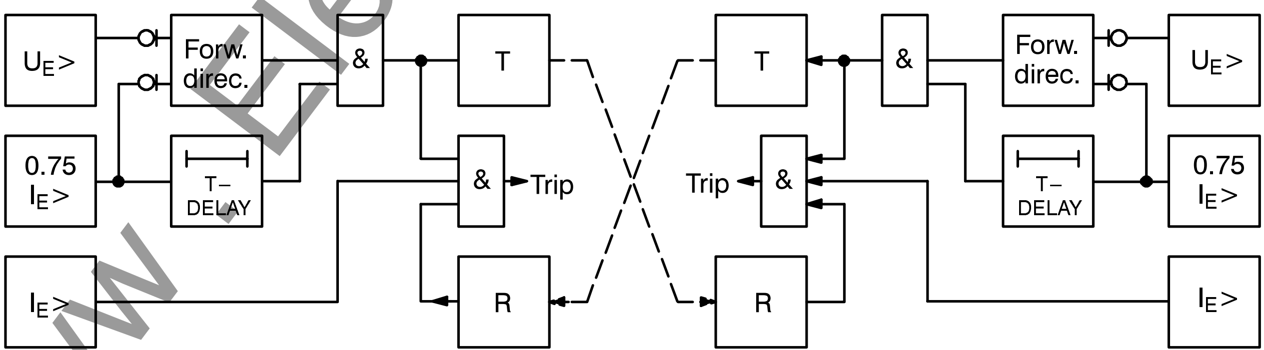


Figure 4.39 Earth fault directional comparison protection

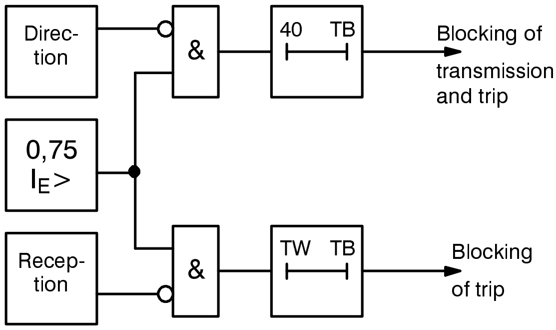


Figure 4.40 Transient Blocking

The echo is delayed by an adjustable time (T−ECHO−DEL). This delay is necessary so that the echo will not be effective when the protection at one line end has a higher fault detection time or if it picks up somewhat later due to unfavourable earth current distribution. If, however, the circuit breaker at the non-infeed line end is open, the delay of the echo is not necessary. The echo delay time can then be by-passed if the relay is informed of the position of the circuit breaker, through a binary input.

To prevent the formation of an echo after clearance of the line and reset of the fault detection elements, an echo is not formed when a pick-up has already been present (RS memory in Figure 4.41). For the same reason, no echo is permitted for an adjustable time T−ECHO−BLO after a tripping command has been issued.

Independent of the result of the directional comparison, the directional earth fault stage described in Section 4.9.1 is effective with the time T−DIRECT and the non-directional back-up stage with the time T−NON−DIR. If one of these stages is not required, the corresponding time must be set to infinity.

The earth fault directional comparison protection function is blocked from the distance protection or emergency overcurrent protection. Therefore, if a fault is recognized by the distance protection or emergency overcurrent time protection then the earth fault protection does not operate. This gives selective fault evaluation by the distance protection preference over tripping via the earth fault protection. In case a fault is cleared by an external protection device, blocking of the earth fault protection can be extended by an adjustable time T−BLOCK, e.g. to allow a single phase auto-reclosing cycle to be carried out by an external auto-reclosure relay. A binary input of the relay must then be used to block the earth fault protection.

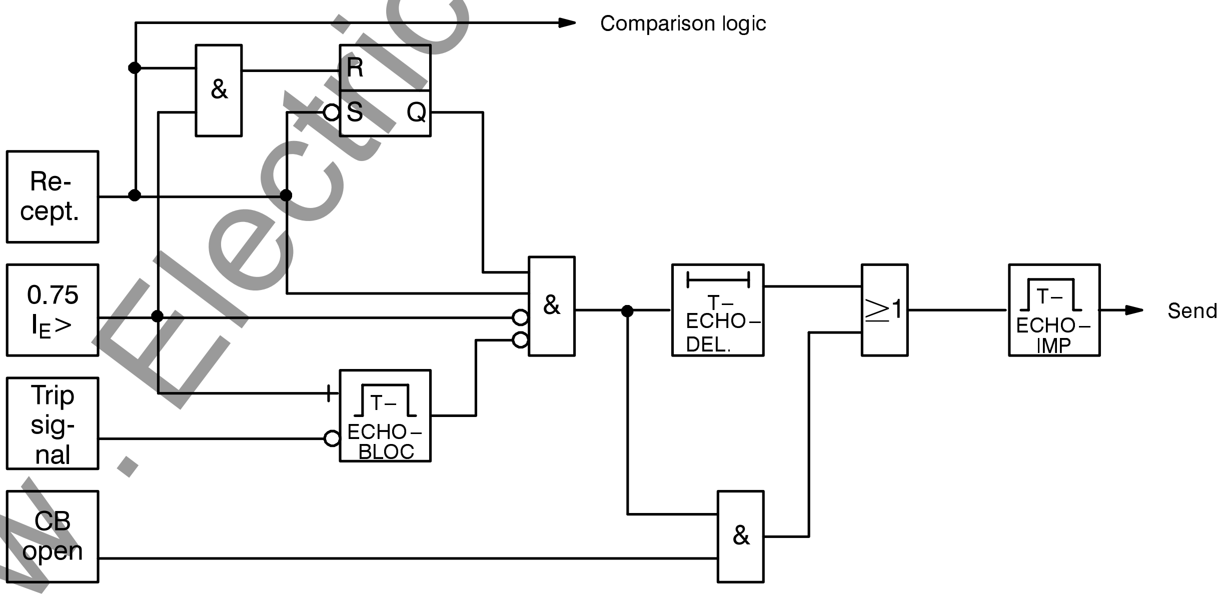


Figure 4.41 Block diagram of echo function for directional comparison

4.9.3 Inverse time overcurrent time protection for earth faults

The inverse time overcurrent time protection is non-directional. It can be used instead of the directional earth fault protection described in Section 4.9.1 or 4.9.2. The required characteristics can be chosen from the three which are available:

- normal inverse (type A) IEC 60255−3 / BS 142
- very inverse (type B) IEC 60255−3
- extremely inverse (type C) IEC 60255−3.

The shape of the characteristics and the formulae on which they are based are given in the Technical data (Section 3.8, Figure 3.3).

Tripping time is then dependent on the level of current. If this value changes during the fault, the tripping time will be determined strictly in accordance with the changing current value. This is achieved by an integrating process similar to that of conventional inverse time overcurrent protection relays. Thus the grading plan can easily be coordinated with inverse time overcurrent relays of conventional construction. In strongly meshed, all-round earthed networks, the largest fault currents flow at the ends of the faulty line section; the inverse characteristic has the effect that here the shortest response time occurs and the remaining relays reset.

The range of definition of the characteristics goes further than that of the IEC standards. They are defined from 20 % above the set value up to 20 times the set value. Beyond that point no further reduction of the tripping time occurs.

The earth fault overcurrent time protection function is blocked from the distance protection or emergency overcurrent protection. Therefore, if a fault is recognized by the distance protection or emergency overcurrent time protection, then the earth fault protection does not operate. This gives selective fault evaluation by the distance protection preference over tripping via the earth fault protection. In case a fault is cleared by an external protection device, blocking of the earth fault protection can be extended by an adjustable time T−BLOCK, e.g. to allow a single phase auto-reclosing cycle to be carried out. A binary input of the relay must then be used to block the earth fault protection.

4.10 Automatic reclosure (optional)

Experience has shown that approximately 85 % of short circuits are caused by an arc, on overhead lines, and self-extinguish after interruption by the protective device. The line can therefore be re-energized. This is carried out by the automatic reclosure (AR) function.

If the short circuit is still present after the auto-reclosure (arc not quenched or metallic short circuit), then the protective relay finally disconnects the power. Multiple auto-reclosure attempts, often with a first rapid auto-reclosure (RAR) and subsequent delayed auto-reclose cycles (DAR) are possible in some networks.

7SA510 allows three-pole auto-reclosure with one single shot or multi-shot with up to 9 successive reclosure attempts, depending on the ordered version (refer to Section 2.3 Orderind data).

7SA510 can also work in conjunction with an external auto-reclose system. In this case, the signal exchange between 7SA510 and the external AR-unit must be accomplished via the binary inputs and outputs (see Section 4.10.6).

Furthermore, it is also possible to allow the internal AR-function to be triggered from an external protection relay (see Section 4.10.7).

If more than one reclose attempt will be carried out, the second and any further auto-reclose cycle are designated in the following with DAR (delayed auto-reclosure) independent on the setting of the dead times of the cycles. It is possible to skip the RAR cycle so that only DAR cycles occur. For the DAR-function, the following programs are selectable:

- DAR PROG. = *NO DAR*, i.e. no DAR occurs; unsuccessful RAR results in final trip.
- DAR PROG. = *DAR WITHOUT RAR*, i.e. DAR cycles can be carried out even without a preceding RAR cycle (e.g. RAR is by-passed because blocked).
- DAR PROG. = *DAR AFTER RAR*, i.e. the DAR cycles can only be initiated after an unsuccessful RAR.

The possibilities and functions of the internal AR-unit are described in the following sections. Prerequisite for initiation of the AR-function is always that the circuit breaker is ready for operation when the AR-function is activated. This information has to be transmitted to the device via a binary input.

Furthermore, reclosure is blocked if the tripping command occurs after the action time, which can be set individually for RAR and DAR. Additionally, the auto–reclosure function is not ready when, at the moment of initiation, the circuit breaker is announced (via a binary input) to be open. This prevents from an accidental close command, should the auto–reclosure function receive an erroneous trip command – for any reason (e.g. via a binary input) – even though the breaker is open (and the line may be dead).

4.10.1 Selectivity during automatic reclosure

For the auto-reclosure sequence to be successful, faults on any part of the line must be cleared from both line ends within the same – shortest possible – time. Usually, therefore, an instantaneous stage of the short-circuit protection is set to operate before a reclosure by the AR-unit. Therefore, the short-circuit protection functions of 7SA510 which can initiate the auto-reclose functions provide a special RAR stage. Furthermore, one can decide for each short-circuit protection whether or not it shall initiate the auto-reclose function.

With distance protection the first AR-cycle (in the following called RAR) allows faults in the overreach zone Z1B to be cleared instantaneously; however, this can be changed when setting the relay. For possible further cycles (in the following called DAR), a separate zone Z1L with a separate time stage T1L becomes effective.

The normal distance zones Z1, Z2, Z3 and the directional and non-directional end stages of the distance protection are independent of the automatic reclose function. This must be considered when a fault shall be cleared after a time delay, for selectivity reasons, when no auto-reclose will occur. Thus, it is not reasonable to set a shorter time delay for normal distance zones than for the RAR overreach zone Z1B.

If the distance protection is operated with one of the carrier signal teleprotection systems described in Section 4.4, the overreach zone is controlled by the universal teleprotection interface, i.e. the interface determines if an undelayed trip (or with T1B) is permitted for faults in the overreach zone (i.e. to the limit of zone Z1B) and thus if tripping is simultaneous at both line ends. Whether the AR-function is ready for operation or not is irrelevant in this case, since the transmission system guarantees selectivity over 100 % of the line length **and** fast, simultaneous disconnection. Similar applies for directional comparison earth fault protection (refer to Section 4.9.2)

However, if the universal teleprotection is switched off or if the carrier device is faulty, then the AR-function determines which stage (Z1 or Z1B) is decisive for fast tripping. If no auto-reclosure is available (for example, circuit breaker not ready for operation), then the normal grading of the distance protection must be valid (i.e. instantaneous tripping only for faults within stage Z1) in order to maintain selectivity (Figure 4.42).

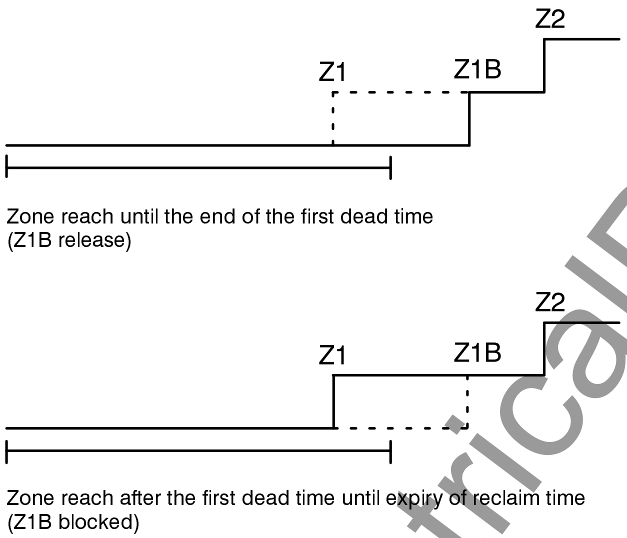


Figure 4.42 Zone reach control with the AR-function

It is also possible to block the AR-function if the teleprotection transmission system is not working.

If a line to be protected is composed of overhead line and cable sections, the controlled zones Z1B and Z1L may be used to distinguish between faults on the the overhead section and cable faults, to a certain degree. Reclosure can be blocked for cable faults using setting parameters (refer to Section 6.3.4.1). If, for example, a cable section is followed by an overhead line section (refer to Figure 4.43), zone Z1B is set to cover the cable section, and reclosure is blocked for faults within Z1B but released for faults out of Z1B. Conversely, the other line end is set such that faults within zone Z1B, which nearly covers the overhead line section, are cleared with auto-reclosure whereas reclosure is blocked for fault out of zone Z1B. Z1B. If further segregation is necessary (e.g. cable – overhead line – cable), distinction can be made by a further zone Z1L in similar way.

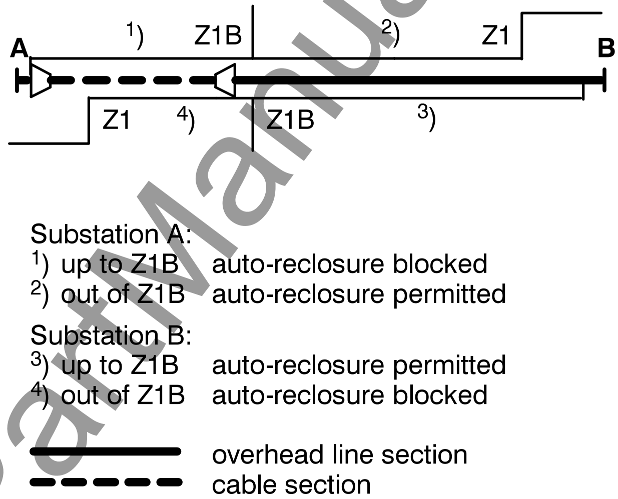


Figure 4.43 Line with overhead and cable section

For overcurrent time protection (emergency mode), stage I>> operates undelayed as RAR stage. Before any reconnection, i.e. when the RAR-function is ready for operation, disconnection is effected with I>>. After an unsuccessful auto-reclosure attempt or when the AR-function is not ready for operation, stage I>> is blocked. In order to maintain selectivity, disconnection then is effected with I> after expiry of the delay time TI>. When the AR-function is blocked or switched off, I>> is also blocked. This can be changed in that the I>> stage is effective always, independent of the RAR.

All protection functions which can operate directional can block reclosure in case the fault lies in reverse direction. This applies also if a trip command is given for a reverse fault before the action time has elapsed.

4.10.2 Action times and reclaim times

It is often appropriate to prevent readiness for reclosure, when the fault has persisted for a specified time; for example, when it can be assumed that the arc has burnt itself in to such an extent, that there is no chance of natural quenching during the dead time.

Tripping after faults which are cleared in a delayed time should, for reasons of selectivity also not result in an auto-reclosure.

The AR-functions of 7SA510 are provided with settable action times, separate for RAR and DAR, which are started by the fault detection signal. If, after expiry of the action time, no tripping signal has been given, reclosure is blocked.

The AR-functions of 7SA510 are provided with three settable reclaim times, which do not discriminate between RAR and DAR. Generally, the reclaim time is the time period during which no further reclosure attempt is permitted.

The reclaim time T–RECLAIM is started at every reclose command. If auto-reclosure has been successful, all functions reset to the quiescent condition after expiry of T–RECLAIM; any fault occurring after the expiry of the reclaim time is considered to be a new system fault. When a renewed trip command is given within this reclaim time, the next auto-reclose cycle is started if multi-shot AR is permitted; if no further AR cycle is permitted, a renewed trip command within the reclaim time is final: AR has been unsuccessful.

The lock-out time T–LOCK is the time period during which any further close command by the 7SA510 relay is blocked after final disconnection. If this time is set to ∞, closing is locked out until the AR function is reset by energization of the binary input ">AR Reset". After the reset signal all functions reset to the quiescent condition.

A special reclaim time T–BLOCK MC is provided for manual closing. During this time after manual close, reclosure is blocked; any trip command will be a final trip.

4.10.3 Interrogation for readiness of the circuit breaker

A pre-condition for a reclose attempt after short-circuit interruption is that the circuit breaker is ready for at least one TRIP–CLOSE–TRIP–cycle when the AR function is initiated (i.e. at the instant of trip command). The readiness information from the breaker has to be transmitted to the device via a binary input. In case that such readiness information is not available, interrogation can be suppressed since otherwise no auto-reclose would be possible at all.

When single-shot auto-reclosure is performed it is sufficient to interrogate the breaker readiness one single time before initiation of AR. As, for example, the air pressure for breaker operation will collapse during the trip execution, no further interrogation should be carried out.

When multi-shot auto-reclosure is used, it is advantageous to interrogate breaker readiness not only at the instant of the first trip command but also before every reclose attempt or before every other reclose attempt. If this facility is selected, reclosure is blocked as long as the circuit breaker is not ready for another TRIP–CLOSE sequence.

The recovery time of the circuit breaker can be supervised by the 7SA510 relay. This supervision time T–CB–SUPV will run as long as the circuit breaker does not inform about readiness. In this case, the dead time may be extended when the breaker is not ready after expiry of the set dead time. But if the breaker is not yet ready after expiry of the supervision time then reclosure is blocked. This blocking is canceled only after the lock-out time T–LOCK (refer to Section 4.10.2) has elapsed. If T–LOCK is set to ∞, closing is locked out until the AR function is reset by energization of the binary input ">AR Reset". After the reset signal all functions reset to the quiescent condition.

4.10.4 Three-pole auto-reclosure

When the AR function is ready for operation, the short-circuit protection trips for all faults within the stage valid for RAR (e.g. the distance protection in zone Z1B). The AR-function is initiated provided tripping occurs within the action time (refer to Section 4.10.2). With fault clearance, the (settable) dead time RAR T−3POL commences for three-pole RAR. After this, the circuit breaker receives a closing command, the duration of which is settable. Simultaneously, the (settable) reclaim time T−RECLAIM (Section 4.10.2) is started.

If the fault is cleared (successful RAR), the reclaim time T−RECLAIM (Section 4.10.2) expires and all functions reset to the quiescent condition. The network fault is cleared.

If the fault has not been cleared (unsuccessful AR) then the short-circuit protection carries out a final disconnection in the stage that is valid without RAR; when the universal teleprotection interface is in operation with distance protection, then Z1B can remain effective for distance protection – see Section 4.4. Also, every fault during the reclaim time will result in final disconnection.

After unsuccessful AR (final disconnection) the lock-out time T−LOCK (Section 4.10.2) is started. For this time any close command from 7SA510 is locked.

The above sequence comes into effect with single-shot RAR. With 7SA510, multiple AR-attempts (up to 9 DAR-shots, refer to Section 4.10.5) are also possible. Additionally, it is possible to skip the RAR cycle by a signal via a binary input of the device. In this case only DAR is effective (refer to Section 4.10.5).

4.10.5 Multi-shot auto-reclosure

The internal auto-reclose feature in 7SA510 will also permit multi-shot reclosure, up to 9 consecutive DAR-cycles. An individual DAR-zone Z1L with delay time T1L is available for the distance protection.

The set number of DAR cycles does not include the first RAR cycle. The action time and several dead times can be independently set for these DAR cycles.

Dead times can be individually set for the first three AR cycles; further cycles operate with the dead time of the third cycle. In this case, all AR cycles are decisive, i.e. also the RAR cycle. The RAR cycle operates with its dead time (RAR T−3POL for), the first DAR is the second cycle with the dead time for the second cycle DAR T3POL2, etc.! If no RAR cycle has occurred (e.g. RAR blocked) then the first DAR cycle operates with the dead time for the first cycle DAR T3POL1, etc.

Each new pick-up restarts the action time DAR T−ACT. within which a tripping command must occur. After fault clearance, the dead time begins. At the end of this, the circuit breaker is given a new closing command. Simultaneously, the reclaim time T−RECLAIM (Section 4.10.2) is started.

As long as the permitted number of cycles has not been reached, the reclaim time is reset by each new pick-up and recommences with the next closing command.

If one of the cycles is successful, that is, after reclose the fault is no longer present, the reclaim time T−RECLAIM equally runs out and all functions return to the quiescent condition. The network fault is cleared.

If none of the AR-cycles has been successful then the short-circuit protection carries out a final disconnection after the last permissible cycle. The lock-out time T−LOCK (Section 4.10.2) is started. For this time any close command from 7SA510 is locked.

The subsequent cycles (DAR) can be blocked by a binary input independently of the function of the RAR cycle.

4.10.6 Connection of external auto-reclose system

7SA510 can operate in conjunction with an external auto-reclose system. The internal AR-function cannot then be allowed to operate; it must be programmed to be ineffective (de-configured, see Section 5.4.2).

Signal exchange between 7SA510 and the external auto-reclose device must be made via the binary inputs and outputs of the relay. The following list may be regarded as a recommendation.

Binary input:

`383 >RAR Release`	The external AR device releases the RAR stages of the short-circuit protection functions within 7SA510 which shall operate with AR (e.g. zone Z1B of the distance protection) via this binary input.
`384 >DAR Release`	The external AR device controls the DAR stage Z1L of the distance protection (only relevant when multi–shot auto–reclosure is used).

Binary outputs:

`501 DeviceFltDet`	General fault detection of the device.
`515 Dev.Trip 3p`	Three-pole trip command of the device.

4.10.7 Control of the internal auto-reclose function by an external protective relay

If 7SA510 is fitted with an internal ARfunction, this can be controlled from an external protective device. This is applicable, for example, for line ends with duplicated protection or additional backup protection, when a second protective device is used for the same line end and shall operate with the AR-function incorporated in 7SA510.

Signal exchange between 7SA510 and the external auto-reclose device must be made via the binary inputs and outputs of the relay. The following list may be regarded as a recommendation.

The internal AR-function can be started, for example, via the binary inputs

`2711 >Start AR`	General start signal for AR,

The general start signal is the criterion for the start of the action times. At the issue of the tripping command the internal AR-function is initiated. The dead time is started with reset of the trip command.

To release the external relay's overreach zone, the following output functions are suitable:

`2817 RAR Zone Rel`	internal AR is ready for an RAR cycle, i.e. releases RAR zone for the external protection relay,
`2837 DAR Zone Rel`	internal AR is ready for a DAR cycle, i.e. releases DAR zone for the external protection relay,

4.11 Distance-to-fault location

Distance-to-fault measurement before clearance of the fault is an important addition to the function of a line protection relay. Availability of the line for energy transmission in the network can be increased by rapid location of point of fault and repair of any resultant damage.

Distance to fault location in distance protection relay 7SA510 is a function independent of distance protection. It possesses independent measured value stores and its own filter algorithms. Distance protection provides only a start-to-measure command in order to determine the valid measurement loop and the most favourable time interval for measured value storage.

Normally, the fault location function is started by the tripping command from the distance protection. Paired values of short circuit current and short circuit voltage, taken at intervals of 1/20 of a cycle and stored in a circulating buffer, are frozen 15 ms later which, even with extremely fast circuit breakers, ensures that the measurements are not distorted by the tripping transients. Filtering of the measured values and quantity of the impedance calculations are automatically matched to the number of incoming value pairs from the time of fault inception to 15 ms after tripping command.

Fault location can also be initiated via a binary input. Thus, calculation is possible when a different protection device effects clearance of a short circuit. Further, fault calculation can be started without receipt of any tripping command. In this case, the start-to-measure criterion is fault detection by the 7SA510 relay.

Evaluation of the measured values occurs after the fault has been cleared. From the stored and filtered values at least three resultant pairs for R and X are determined. If less than three resultant pairs are available, no fault location is given. From the resultant pairs, average value and standard deviation are calculated. After elimination of ”exceptions”, which are recognized by their excessive difference from the standard deviation, another average is again calculated for X. This average is taken as fault reactance.

As a result of the fault location calculation the following outputs are given:

– the short circuit loop, from which the fault reactance is determined,

– the reactance per phase in Ohms primary and secondary,

– the resistance per phase in Ohms primary and secondary,

– the fault distance in km line length proportional to the reactance, calculated on the basis of the set unit reactance of the line,

– the distance to fault in % of the line length, calculated on the basis of the set unit reactance and the set line length.

Note: Calculation of the distance in km and percent can only be applicable to homogeneous line lengths. But, if the line is made up of sections with differing reactance values, e.g. overhead line – cable combinations, the distance to fault can still be calculated manually from the reactance determined by the fault location, if the line characteristics are known.

4.12 Circuit breaker trip test

Numerical distance protection relay 7SA510 allows simple checking of the tripping circuit and the circuit breaker. If the device incorporates an internal auto-reclose system, a TRIP – CLOSE test cycle is also possible; the latter can also be performed with an external auto-reclose device.

Prerequisite for the start of a test cycle is that no protective function has picked up. If the circuit breaker auxiliary contacts advise the relay, through a binary input, of the circuit breaker position, the test cycle can only be started when the circuit breaker is closed. This additional security feature should not be omitted.

For starting a TRIP – CLOSE cycle a further condition is that the conditions for reclose (circuit breaker ready, AR not blocked) are fulfilled. This applies also for an external auto-reclose device.

Initiation of the test cycle can be given from the operator keyboard or via the operator interface.

The test sequence is supervised by 7SA510 by means of the circuit breaker auxiliary contact position provided the auxiliary contact is connected to a binary input. If the breaker does not react correctly then the test sequence is aborted; a corresponding message is given in the display or on the PC screen.

Trip test can also be started by energization of a binary input.

4.13 Ancillary functions

The ancillary functions of the distance protection relay 7SA510 include:

– Processing of annunciations,

– Storage of short circuit data for fault recording,

– Operational measurements and testing routines,

– Monitoring functions.

4.13.1 Processing of annunciations

After a fault in the network, information concerning the response of the protective device and knowledge of the measured values are of importance for an exact analysis of the history of the fault. For this purpose the device provides annunciation processing which is effective in three directions.

4.13.1.1 Indicators and binary outputs (signal relays)

Important events and conditions are indicated by optical indicators (LED) on the front plates. The modules also contain signal relays for remote indication. Most of the signals and indications can be marshalled, i.e. they can be allocated meanings other than the factory settings. In Section 5.5 the delivered condition and the marshalling facilities are described in detail.

The output signal relays are not latched and automatically reset as soon as the originating signal disappears. The LEDs can be arranged to latch or to be self-resetting.

The memories of the LEDs are saved against supply voltage failure. They can be reset:

– locally, by operation of the reset button on the relay,
– remotely by energization of the remote reset input,
– remotely via one of the interfaces,
– automatically, on occurrence of a new general fault detection signal.

Some indicators and relays indicate conditions; it is not appropriate that these should be stored. Equally they cannot be reset until the originating criterion has been removed. This mainly concerns fault indications such as ”auxiliary voltage fault”, ”emergency O/C”, etc.

A green LED indicates readiness for operation. This LED cannot be reset and remains illuminated when the microprocessor is working correctly and the unit is not faulty. The LED extinguishes when the self-checking function of the microprocessor detects a fault or when the auxiliary voltage is absent.

With the auxiliary voltage present but with an existing internal fault in the unit, a red LED illuminates (”Blocked”) and blocks the unit.

4.13.1.2 Information on the display panel or to a personal computer

Events and conditions can be read off in the display on the front plate of the device. Additionally, a personal computer, for example, can be connected via the operation interface, and all the informations can then be sent to it.

In the quiescent state, i.e. as long as no network faults are present, the display outputs selectable operating information (usually an operational measured value) in each of the two lines. In the event of a network fault, selectable information on the fault appears instead of the operating information, e.g. detected phase(s) and elapsed time from fault detection to trip command. The quiescent information is displayed again once these fault annunciations have been acknowledged. The acknowledgement is identical to resetting of the stored LED displays as in Section 4.13.1.1.

The device also has several event buffers, e.g. for operating messages, circuit breaker operation statistics etc. (see Section 6.4.5) which are saved against supply voltage failure by a buffer battery. These messages, as well as all available operating values, can be transferred into the front display at any time using the keyboard or to the personal computer via the operating interface.

After a fault, for example, important information concerning its history, such as pick-up and tripping, can be called up on the display of the device. The fault inception is indicated with the absolute time of the operating system provided the real time clock is available. The sequence of the events is tagged with the relative time referred to the moment at which the fault detector has picked up. Thus, the elapsed time until tripping is initiated and until reset can be read out. The resolution is 1 ms.

The events can also be read out with a personal computer by means of the appropriate program DIGSI®. This provides the comfort of a CRT screen and menu-guided operation. Additionally, the data can be documented on a printer or stored on a floppy disc for evaluation elsewhere.

The protection device stores the data of the last four network faults; if a fifth fault occurs the oldest fault is overwritten in the fault memory. The annunciations of the last three network fault can be read out in the local display.

A network fault begins with recognition of the fault by pick-up of any fault detector and ends with fault detector reset or expiry of the auto-reclose sequence so that non-successful auto-reclose attempts will also be stored as part of one network fault. Thus, one network fault can include different fault events (from pick-up until drop-off). This is particularly advantageous for allocation of time data.

4.13.1.3 Information to a central unit (optional)

In addition, all stored information can be transmitted via an optical fibre connector or the isolated second interface (system interface) to a control centre, for example, the SIEMENS Localized Substation Automation System LSA 678. Transmission uses a standardized transmission protocol according to IEC 60870–5–103 and VDEW/ZVEI.

4.13.2 Data storage and transmission for fault recording

The instantaneous values of the measured values

i_{L1}, i_{L2}, i_{L3}, i_E, u_{L1-N}, u_{L2-N}, u_{L3-N}, u_{EN}

are sampled at 1 ms intervals (for 50 Hz) and stored in a circulating shift register. In case of a fault, the data are stored over a selectable time period, but max. over 5 seconds. The maximum number of fault records within this time period is 8. These data are then available for fault analysis. They are saved by a back-up battery. For each renewed fault event, the actual new fault data are stored without acknowledgement of the old data.

The data can be transferred to a connected personal computer via the operation interface at the front and evaluated by the protection data evaluation program DIGSI®. The currents and voltages are referred to their maximum values, normalized to their rated values and prepared for graphic visualization. In addition, signals can be marked as binary traces, e.g. ”Pick-up” and ”Trip”.

Additionally, the fault record data can be transmitted to a control centre via the serial system interface (if fitted). Evaluation of the data is made in the control centre, using appropriate software programs. The currents and voltages are referred to their maximum values, normalized to their rated values and prepared for graphic visualization. In addition, signals can be marked as binary traces, e.g. ”Pick-up” and ”Trip”.

When the data are transferred to a central unit, readout can proceed automatically, optionally after each pick-up of the relay or only after a trip. The following then applies:

– The relay signals the availability of fault record data,

– The data remain available for recall until they are overwritten by new data.

– A transmission in progress can be aborted by the central unit.

4.13.3 Operating measurements and conversion

For local recall or transmission of data, the true r.m.s. values of the currents and voltages are always available as are active and reactive power, as well as the frequency calculated from an average of 100 ms, as long as at least one phase voltage is present.

The following is valid:

- I_{L1}, I_{L2}, I_{L3} — Phase currents in amps primary and in % of rated current I_N,
- U_{L1E}, U_{L2E}, U_{L3E} — Voltages (phase-earth) in kilovolts primary and in % of rated voltage $U_N/\sqrt{3}$,
- U_{L12}, U_{L23}, U_{L31} — Voltages (phase-phase) in kilovolts primary and in % of rated voltage U_N,
- P_a — Active power in megawatts primary and in % of $\sqrt{3} \cdot I_N \cdot U_N$,
- P_r — Reactive power in megvars primary and in % of $\sqrt{3} \cdot I_N \cdot U_N$,
- f — Frequency in % of rated frequency,
- Θ/Θ_{trip} — overload measured values, referred to trip temperature rise.

Additionally, the components of the earth fault current can be output for relays with highly sensitive earth fault detection in non-earthed systems:

- I_{Ea}, I_{Er} — active and reactive component of earth fault current in non-earthed systems.

Even the direction of the energy flow (forwards = line direction) can be recalled upon request. These data are particularly useful when checking that the transformer connections are correct during commissioning (see Section 6.7.2).

4.13.4 Monitoring functions

7SA510 incorporates comprehensive monitoring functions which cover both hardware and software; furthermore, the measured values are continuously checked for plausibility so that the current and voltage transformer circuits are also included in the monitoring system.

4.13.4.1 Hardware monitoring

The complete hardware is monitored for faults and inadmissible functions, from the measured value inputs to the output relays. In detail this is accomplished by monitoring:

– Auxiliary and reference voltages

The processor monitors the offset and reference voltage of the ADC (analog/digital converter). The protection is blocked as soon as impermissible deviations occur. Permanent faults are annunciated.

Failure or switch-off of the auxiliary voltage automatically puts the system out of operation; this status is indicated by a fail-safe contact. Transient dips in supply voltage of less than 50 ms will not disturb the function of the relay ($U_H \geq 110$ V).

– Measured value acquisition

The complete chain, from the input transformers up to and including the analog/digital converters are monitored by the plausibility check of the measured values.

In the **current path**, there are four input converters; the digitized sum of the outputs of these must always be zero. A fault in the current path is recognized when

$$|i_{L1} + i_{L2} + i_{L3} + k_I \times i_E| > \text{SUM.Ithres} \times I_N + \text{SUM.Fact.I} \times I_{max}$$

An adjustable factor k_I (parameter Ie/Iph) can be set to correct the different ratios of phase and earth current transformers (e.g. window-type transformer for earth fault detection). If the residual earth current is derived from the current transformer starpoint, $k_I = 1$. SUM.Ithres and SUM.Fact.I are setting parameters (refer 6.3.10). The component SUM.Fact.I x I_{max}

takes into account permissible current proportional transformation errors in the input converters which may particularly occur under conditions of high short circuit currents (Figure 4.44).

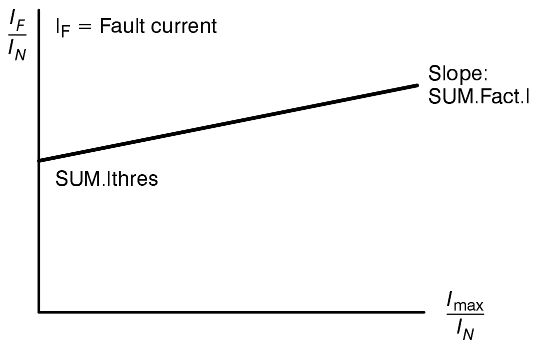


Figure 4.44 Current sum monitoring (current plausibility check)

– Command output channels:

The command relays for tripping are controlled by two command and one additional release channels. As long as no pick-up condition exists, the central processor makes a cyclic check of these command output channels for availability, by exciting each channel one after the other and checking for change in the output signal level. Change of the feed-back signal to low level indicates a fault in one of the control channels or in the relay coil. Such a condition leads automatically to alarm and blocking of the command output.

– Memory modules:

The memory modules are periodically checked for fault by:

- Writing a data bit pattern for the working memory (RAM) and reading it,
- Formation of the modulus for the program memory (EPROM) and comparison of it with a reference program modulus stored there,
- Formation of the modulus of the values stored in the parameter store (EEPROM) then comparing it with the newly determined modulus after each parameter assignment process.

4.13.4.2 Software monitoring

For continuous monitoring of the program sequences, a watchdog timer is provided which will reset the processor in the event of processor failure or if a program falls out of step. Further, internal plausibility checks ensure that any fault in processing of the programs, caused by interference, will be recognized. Such faults lead to reset and restart of the processor.

If such a fault is not eliminated by restarting, further restarts are initiated. If the fault is still present after three restart attempts the protective system will switch itself out of service and indicate this condition by drop-off of the availability relay, thus indicating "equipment fault" and simultaneously the LED "Blocked" comes on.

4.13.4.3 Monitoring of external measuring transformer circuits

To detect interruptions or short circuits in the external measuring transformer circuits or faults in the connections (an important commissioning aid) the measured values are checked at cyclic intervals, as long as no pick-up condition exists:

– Current symmetry

In healthy operation it can be expected that the currents will be approximately symmetrical. The following applies:

$| I_{min} | / | I_{max} | <$ SYM.Fact.I
if
$I_{max} / I_N >$ SYM.Ithres / I_N

I_{max} is always the largest of the three phase currents and I_{min} always the smallest. The symmetry factor SYM.Fact.I represents the magnitude of asymmetry of the phase currents, and the threshold SYM.Ithres is the lower limit of the processing area of this monitoring function (see Figure 4.45). Both parameters can be set (see Section 6.3.10).

– Measured voltage failure

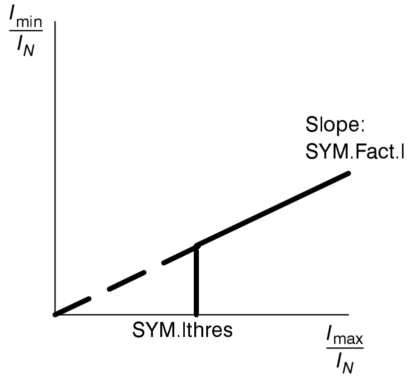


Figure 4.45 Current symmetry monitoring

– Voltage symmetry

In healthy operation it can be expected that the voltages will be approximately symmetrical. Therefore, the device checks the three phase-to-phase voltages for symmetry. Monitoring of the sum of the phase-to-phase voltages is not influenced by earth faults, which can be a lasting operating condition in non-earthed networks.

The following applies:

$|U_{min}| / |U_{max}| <$ SYM.Fact.U
if
$|U_{max}| >$ SYM.Uthres

whereby U_{max} is the largest of the three voltages and U_{min} the smallest. The symmetry factor SYM.Fact.U represents the magnitude of the asymmetry of the sum of the voltages. The threshold SYM.Uthres is the lower limit of the processing area of this monitoring function (see Figure 4.46). Both parameters can be set (see Section 6.3.10).

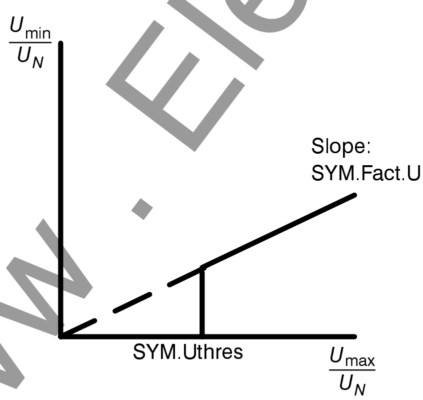


Figure 4.46 Voltage symmetry monitoring

Failure of the measurement voltage can be detected when a minimum current flows on the protected line but the current stages Iph> of the fault detectors have not yet picked up. Voltage failure is detected when

U_{ph-ph} < UMEAS U< and at the same time
I_{max} > UMEAS I>

whereby U_{ph-ph} represents any phase-phase voltage. UMEAS U< and UMEAS I> are setting parameters (see Section 6.3.10). This monitor does not operate once the minimum current threshold of any fault detector has been exceeded since this may indicate a system fault.

After this monitor has operated, distance protection is blocked and will not be released until the cause of the voltage failure has been removed. The distance protection function will then automatically be restored. Change-over to overcurrent emergency protection is possible.

– Fuse failure monitor

If any measured voltage is not present, due to short circuit or conductor breakage in the voltage transformer secondary system, it may appear that the voltage is zero for certain measured loops.

If no protective m.c.b. with appropriately set auxiliary contact is available in the VT secondary circuit, but instead, for example, fuses are fitted, the optional function "fuse failure monitor" can be made effective, in solidly earthed networks. Obviously, this function can also be used together with the above mentioned VT – protective m.c.b.

When a zero sequence voltage is indicated, without simultaneous recognition of an earth fault, this is indicative of a single phase fault in the secondary circuits of the voltage transformers. The distance function is then blocked and the relay can be switched to emergency overcurrent operation (see Section 4.6). Immediate blocking is performed provided at least one phase current is flowing.

If, within approximately 10 seconds of recognition of this criterion, an earth current occurs, distance protection automatically becomes operative for the duration of the time of the earth fault. If the fuse failure criterion lasts longer than approximately 10 seconds the distance protection is blocked and will not be released until the cause of the voltage failure has been removed. The distance protection function will then automatically be restored.

Note: When, for example, on lines fed by unearthed transformers, the earth current during earth fault is insignificantly small or absent, the fuse failure monitoring must **not** be activated! In non-earthed networks, this fuse failure monitoring facility is pointless and will be ignored by 7SA510!

– Phase rotation

Since correct functioning of measured value selection and directional determination relies upon a clockwise sequence of the phase voltages, the direction of rotation is monitored:

U_{L1} before U_{L2} before U_{L3}

This check is carried out when the measured voltages as described in 4.12.4.1 are plausible and have a minimum value of at least

$|U_{L1}|, |U_{L2}|, |U_{L3}| > 40\ V/\sqrt{3}$

Counter-clockwise rotation will cause an alarm.

Table 4.11 gives a survey of all the functions of the measured value monitoring system.

Monitoring	Failure covered, reaction
1. Plausibility check of currents $\lvert i_{L1} + i_{L2} + i_{L3} + \textbf{Ie/Iph} \times i_E \rvert >$ $\textbf{SUM.Ithres} \times I_N + \textbf{SUM.Fact.I} \times I_{max}$	Relay failures in the signal acquisition circuits i_{L1}, i_{L2}, i_{L3}, i_E delayed alarm "`Failure ΣI`"
2. Current unbalance $\frac{\lvert I_{min} \rvert}{\lvert I_{max} \rvert} < \textbf{SYM.Fact.I}$ and $\frac{\lvert I_{max} \rvert}{\lvert I_N \rvert} > \frac{\textbf{SYM.Ithres}}{I_N}$	Single, or phase-to-phase short circuits or broken conductors in the c.t. circuits i_{L1}, i_{L2}, i_{L3} or Unbalanced load delayed alarm "`Failure Isymm`"
3. Voltage unbalance (phase–phase) $\frac{\lvert U_{min} \rvert}{\lvert U_{max} \rvert} < \textbf{SYM.Fact.U}$ and $\lvert U_{max} \rvert > \textbf{SYM.Uthres}$	Short-circuit or interruption (1-phase, 2-phase) in v.t. secondary circuits or unbalanced voltage on the system delayed alarm "`Failure Usymm`"
4. Measured voltage failure $U_{ph-ph} < \textbf{UMEAS U<}$ and $I_{max} > \textbf{UMEAS I>}$	Loss of measured voltages delayed alarm "`Failure Umeas`" and block of distance protection
5. Fuse failure monitor $\lvert u_{L1} + u_{L2} + u_{L3} \rvert > \textbf{FFM 3*Uo}$ and $\lvert i_{L1} + i_{L2} + i_{L3} \rvert < \textbf{FFM Ie}$	Fuse failure or conductor interruption (non-symmetric) in v.t. secondary circuit delayed alarm "`Fuse-Failure`" and immediate block of distance protection
6. Phase rotation u_{L1} before u_{L2} before u_{L3}, as long as $\lvert U_{L1} \rvert, \lvert U_{L2} \rvert, \lvert U_{L3} \rvert > 40\ V/\sqrt{3}$	Swopped voltage connections or reverse rotation sequence delayed alarm "`Fail.PhaseSeq`"

Bolted figures are setting values.

Table 4.11 Summary of measuring circuit monitoring

5 Installation instructions

Warning

The successful and safe operation of this device is dependent on proper handling and installation by qualified personnel under observance of all warnings and hints contained in this manual.

In particular the general erection and safety regulations (e.g. IEC, DIN, VDE, or national standards) regarding the correct use of hoisting gear must be observed. Non-observance can result in death, personal injury or substantial property damage.

5.1 Unpacking and repacking

When dispatched from the factory, the equipment is packed in accordance with the guidelines laid down in IEC 60255–21, which specifies the impact resistance of packaging.

This packing shall be removed with care, without force and without the use of inappropriate tools. The equipment should be visually checked to ensure that there are no external traces of damage.

The transport packing can be re-used for further transport when applied in the same way. The storage packing of the individual relays is not suited to transport. If alternative packing is used, this must also provide the same degree of protection against mechanical shock, as laid down in IEC 60255–21–1 class 2 and IEC 60255–21–2 class 1.

Before initial energization with supply voltage, the relay shall be situated in the operating area for at least two hours in order to ensure temperature equalization and to avoid humidity influences and condensation.

5.2 Preparations

The operating conditions must accord with VDE 0100/5.73 and VDE 0105 part 1/7.83, or corresponding national standards for electrical power installations.

Caution!

The modules of digital relays contain CMOS circuits. These shall not be withdrawn or inserted under live conditions! The modules must be so handled that any possibility of damage due to static electrical charges is excluded. During any necessary handling of individual modules the recommendations relating to the handling of **e**lectrostatically **e**ndangered **c**omponents (EEC) must be observed.

In installed conditions, the modules are in no danger.

5.2.1 Mounting and connections

5.2.1.1 Model 7SA510★–★B★★★ for panel surface mounting

– Secure the unit with four screws to the panel. For dimensions refer to Figure 2.2.

– Connect earthing terminal (Terminal 16) of the unit to the protective earth of the panel.

– Make a solid low-ohmic and low-inductive operational earth connection between the earthing surface at the side of the unit using at least one standard screw M4, and the earthing continuity system of the panel; recommended grounding strap DIN 72333 form A, e.g. Order-No. 15284 of Messrs Druseidt, Remscheid, Germany.

– Make connections via screwed terminals.

5.2.1.2 Model 7SA510★–★C★★★ for panel flush mounting or 7SA510★–★E★★★ for cubicle installation

– Lift up both labelling strips on the lid of the unit and remove cover to gain access to four holes for the fixing screws.

– Insert the unit into the panel cut-out and secure it with the fixing screws. For dimensions refer to Figure 2.3.

– Connect earthing screw on the rear of the unit to the protective earth of the panel or cubicle.

– Make a solid low-ohmic and low-inductive operational earth connection between the earthing surface at the rear of the unit using at least one standard screw M4, and the earthing continuity system of the panel or cubicle; recommended grounding strap DIN 72333 form A, e.g. Order-No. 15284 of Messrs Druseidt, Remscheid, Germany.

– Make connections via the screwed or snap-in terminals of the sockets of the housing. Observe labelling of the individual connector modules to ensure correct location; observe the max. permissible conductor cross-sections. The use of the screwed terminals is recommended; snap-in connection requires special tools and must not be used for field wiring unless proper strain relief and the permissible bending radius are observed.

5.2.2 Checking the rated data

The rated data of the unit must be checked against the plant data. This applies in particular to the auxiliary voltage and the rated current of the current transformers.

5.2.2.1 Control d.c. voltage of binary inputs

When delivered from factory, the binary inputs are designed to operate with a control voltage which corresponds with the rated voltage of the power supply of the relay. In order to optimize the operation of the inputs, they should be matched to the real control voltage.

Table 5.1 shows the assignment of the presettings of the control voltage of the binary inputs against the rated supply voltage of the relay. If the control voltage of a binary input is of the same magnitude as the supply voltage of the relay, no matching is necessary. Even with higher control voltage the binary input will operate. But it is advisable to fit a higher pick-up threshold to increase stability against stray voltages. If a binary input is to be controlled by a lower voltage, then the pick-up threshold must be matched! Otherwise it could not be energized.

Order code 7SA510★–	Rated auxiliary voltage range	Presetting of binary inputs
2★★★★–★★★★	24/48 Vdc	24 Vdc
4★★★★–★★★★	60/110/125 Vdc	60 Vdc
5★★★★–★★★★	220/250 Vdc	220 Vdc

Table 5.1 Presetting of control voltage for binary inputs

Table 5.2 shows the setting possibilities for the binary inputs on the basic p.c.b. of the basic input/output module. Figure 5.1 shows the printed circuits board, viewed from the component side, with the setting plugs for the control voltage of the binary inputs. If the actual control voltage is not found on the p.c.b., select the setting for the next lower voltage. The figures show further plugs, which must not be changed.

Binary input	Settings for rated control voltage			
	24/48 Vdc	60 Vdc	110/125 Vdc	220/250 Vdc
BI 1	plug X50 – X51	plug X52 – X53	plug X54 – X55	no plug [1])
BI 2	plug X56 – X57	plug X58 – X59	plug X60 – X61	no plug [1])
BI 3	plug X44 – X45	plug X47 – X48	plug X49 – X62	no plug [1])
BI 4	plug X75 – X76	plug X77 – X78	plug X79 – X80	no plug [1])

[1]) Unused plugs may be parked on the pins X36 to X43

Table 5.2 Checking for control voltages of binary inputs 1 to 4 on the basic module

– Open housing cover.

– Loosen the basic module using the pulling aids provided at the top and bottom.

Caution!

Electrostatic discharges via the component connections, the PCB tracks or the connecting pins of the modules must be avoided under all circumstances by previously touching an earthed metal surface.

– Pull out basic module and place onto a conductive surface.

– Check the plugs according to Figure 5.1, and change if necessary.

– Insert basic module into the housing; ensure that the releasing lever is pushed fully to the left before the module is pressed in.

– Firmly push in the module using the releasing lever.

– Close housing cover.

5.2.3 Inserting the back-up battery

The device annunciations are stored in NV – RAMs. Even the fault recording data are stored in NV – RAMs. A back-up battery is available so that they are retained even with a longer failure of the d.c. supply voltage. The back-up battery is also required for the internal system clock with calender to continue in the event of a power supply failure.

The battery is installed at delivery so that no activities are necessary here. It is possible to check that the battery is right in place in analogy to the descriptions in Section 7.2.

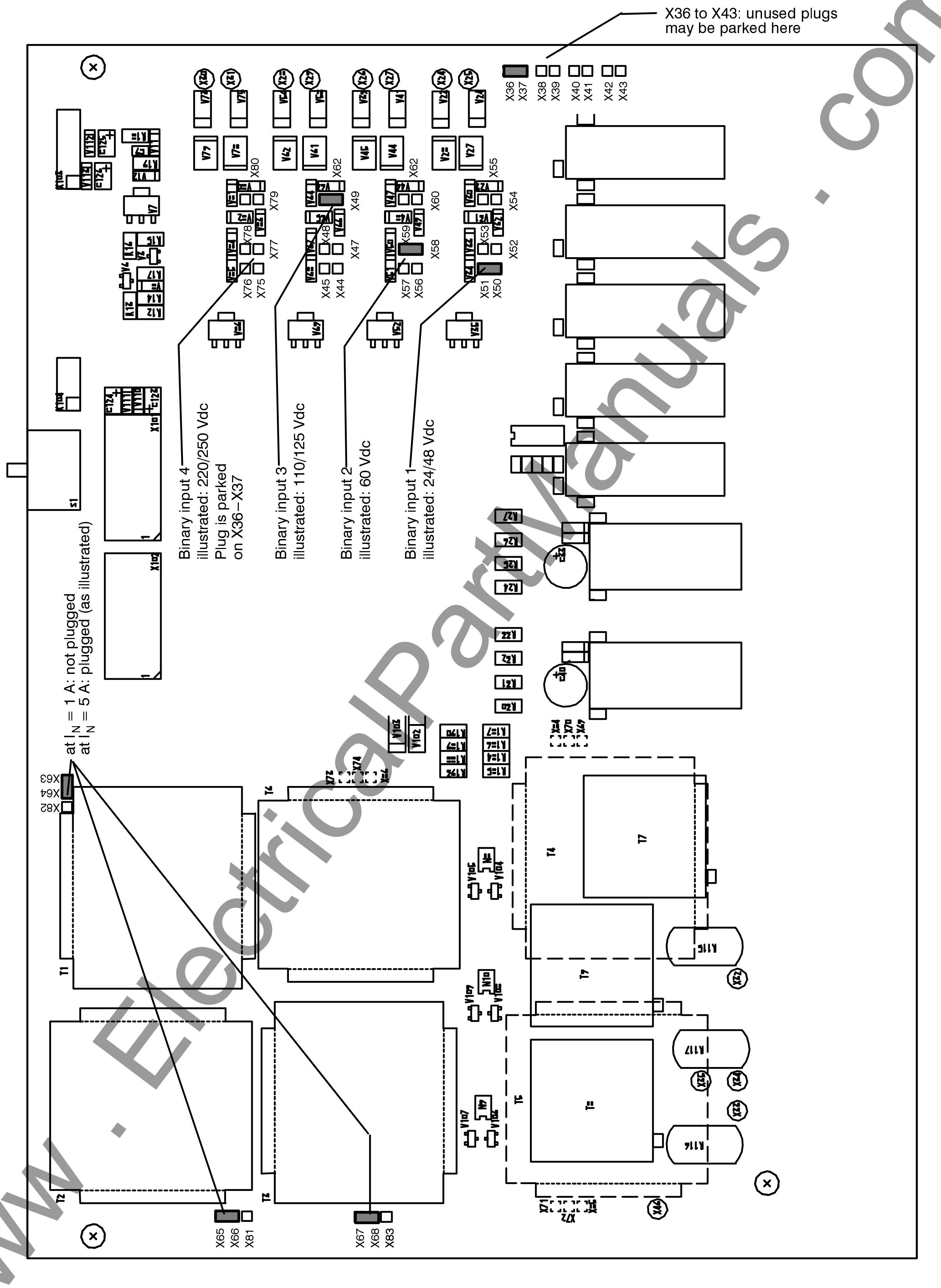


Figure 5.1 Setting plugs on basic input/output module

5.2.4 Checking LSA transmission link

For models with interface for a central data processing station (e.g. LSA) these connections must also be checked. It is important to visually check the allocation of the transmitter and receiver channels. Since each connection is used for one transmission direction, the transmit connection of the relay must be connected to the receive connection of the central unit and vice versa.

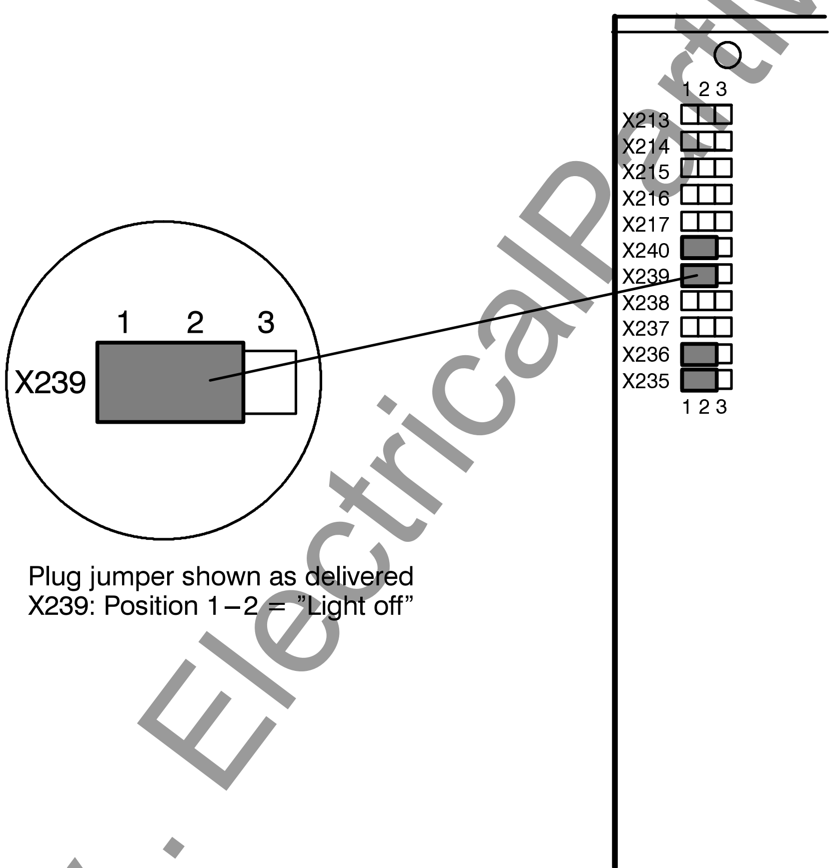
Transmission via optical fibre is particularly insensitive against disturbances and automatically provides galvanic isolation. Transmit and receive connector are designated with the symbols —●⟶ for transmit output and ⟶● for receive input.

The normal signal position for the data transmission is factory preset as "light off". This can be changed by means of a plug jumper X239 which is accessible when the input/output module is removed from the case. The jumper is situated in the rear area of the power supply board (centre board) (Figure 5.2).

Jumper	Position	Normal signal position
X239	1 – 2	"Light off"
X239	2 – 3	"Light on" *)

*) compatible with IEC 60870–5–103 and VDEW/ZVEI

The figure shows, additionally, the position of further plugs which are preset by the factory and must not be changed!



Plug jumper shown as delivered
X239: Position 1–2 = "Light off"

with optical fibre interface

Figure 5.2 Position of the jumper X239 on the power supply board

5.2.5 Connections

General and connection diagrams are shown in Appendix A and B. The marshalling possibilities of the binary inputs and outputs are described in Section 5.5.

5.2.6 Checking the connections

⚠ Warning

Some of the following test steps are carried out in presence of hazardous voltages. They shall be performed by qualified personnel only which is thoroughly familiar with all safety regulations and precautionary measures and pay due attention to them.
Non-observance can result in severe personal injury.

Before initial energization with supply voltage, the relay shall be situated in the operating area for at least two hours in order to ensure temperature equalization and to avoid humidity influences and condensation.

– Switch off the circuit breakers for the dc supply and the voltage transformer circuits!

– Check the continuity of all the current and voltage transformer circuits against the plant and connection diagrams:

  • Are the current transformers correctly earthed?

  • Are the polarities of the current transformer connections consistent?

  • Is the phase relationship of the current transformers correct?

  • Are the voltage transformers correctly earthed?

  • Are the polarities of the voltage transformer circuits correct?

  • Is the phase relationship of the voltage transformers correct?

  • Is the polarity of the residual current path or the summation current transformer (if used) correct?

– If test switches have been fitted in the secondary circuits, check their function, particularly that in the "test" position the current transformer secondary circuits are automatically short-circuited.

– Ensure that the miniature slide switch on the front plate is in the "OFF" ◯· position. (refer to Figure 6.1).

– Fit a dc ammeter in the auxiliary power circuit; range approx. 1.5 A to 3 A.

– Close the battery supply circuit breaker; check polarity and magnitude of voltage at the terminals of the unit or at the connector module.

– The measured current consumption should be insignificant. Transient movement of the ammeter pointer only indicates the charging current of the storage capacitors.

– Put the miniature slide switch of the front plate in the "ON" position ⊙ . The unit starts up and, on completion of the run-up period, the green LED on the front comes on, the red LED gets off after at most 7 sec.

– Open the circuit breaker for the dc power supply.

– Remove dc ammeter; reconnect the auxiliary voltage leads.

– Close the voltage transformer m.c.b. (secondary circuit).

– Check the direction of phase rotation at the relay terminals (clockwise!).

– Open the m.c.b.'s for voltage transformer secondary circuits and dc power supply.

– Check through the tripping circuits to the circuit breaker.

– Check through the control wiring to and from other devices.

– Check the signal circuits.

– Reclose the protective m.c.b.'s.

5.3 Configuration of operation and memory functions

5.3.1 Operational preconditions and general

For most operational functions, the input of a codeword is necessary. This applies for all entries via the membrane keyboard or front interface which concern the operation on the relay, for example

– configuration parameters for configuration of the interfaces and the device functions,

– allocation or marshalling of annunciation signals, binary inputs, optical indications, and trip relays,

– setting of functional parameters (thresholds, functions),

– initiation of test procedures.

The codeword is not required for the read-out of annunciations, operating data or fault data, or for the read-out of setting parameters.

To indicate authorized operator use, press key **CW**, enter the six figure code **0 0 0 0 0 0** and confirm with **E**. Codeword entry can also be made retrospectively after paging or direct addressing to any setting address.

```
E N T E R   C O D E W O R D :
@ @ @ @ @ @
```

```
C W   A C C E P T E D
```

```
C O D E W O R D   W R O N G
```

The entered characters do not appear in the display, instead only a symbol @ appears. After confirmation of the correct input with **E** the display responds with **CW ACCEPTED**. Press the entry key **E** again.

If the codeword is not correct the display shows **CODEWORD WRONG**. Pressing the **CW** key allows another attempt at codeword entry.

Address blocks 70 to 79 are provided for configuration of the software operating system. These settings concern the operation of the relay, communication with external operating and processing devices via the serial interfaces, and the interaction of the device functions.

The simplest way of arriving at the beginning of this configuration blocks is to use key **DA**, followed by the address number **7 0 0 0** and ENTER, key **E**. The address 7000 appears, which forms the heading of the configuration blocks:

```
⇑ 7 0 0 0 █ O P .   S Y S T E M
⇓ C O N F I G U R A T I O N
```

Beginning of the block ”Operating system configuration”

The double arrow key ⇑ switches over to the first configuration block (see below). Use the key ↑ to find the next address. The display shows the four-digit address number, i.e. block and sequence number. The title of the requested parameter appears behind the bar (see below). The second line of the display shows the text applicable to the parameter. The present text can be rejected by the ”No” – key **N**.

The next text choice then appears, as shown in the boxes below. The chosen alternative **must be confirmed with enter key E!**

The setting procedure can be ended at any time by the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question ”SAVE NEW SETTINGS?”.

Confirm with the "Yes"–key **Y** that the new settings shall become valid now. If you press the "No"–key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

If one tries to leave the setting range for the configuration blocks (i.e. address blocks 60 to 79) with keys ⇑ ⇓, the display shows the question "END OF CODEWORD OPERATION ?". Press the "No"–key **N** to continue configuration. If you press the "Yes"–key **J/Y** instead, another question appears: "SAVE NEW SETTINGS ?". Now you can confirm with **J/Y** or abort with **N**, as above.

When one exits the setting program, the altered parameters, which until then have been stored in buffer stores, are permanently secured in EEPROMs and protected against power outage. If configuration parameters have been changed the processor system will reset and re-start. During re-start the device is not operational.

5.3.2 Settings for the integrated operation – address block 71

Operating parameters can be set in address block 71. This block allows the date format to be selected. Messages on the front display can be selected here for the quiescent state of the unit or after a fault event. To change any of these parameters, codeword entry is necessary.

When delivered from factory, the date is shown in the European format.

⇑ ⇓
```
7100 INTEGRATED
OPERATION
```

Beginning of the block "Integrated operation"

```
7102 DATE FORMAT
DD.MM.YYYY
```

```
MM/DD/YYYY
```

The date in the display is preset to the European format Day.Month.Year. Switch-over to the American format Month/Day/Year is achieved by depressing the "No"–key **N**; then confirm with the entry key **E**.

DD two figures for the day
MM two figures for the month
YYYY four figures for the year (incl. century)

```
7105 OPER. 1st L
IL1[%] =
```

```
IL2[%] =
```

```
IL3[%] =
```

etc.

Message to be displayed in the **1st** display line during operation. Any of the operational measured values according to Section 6.4.6 can be selected as messages in the the quiescent state of the relay by repeatedly depressing the "No"–key **N**; The value selected by the entry key **E** under address 7105 will appear in the **first** line of the display.

```
7106 OPER.   2nd  L
UL12[%]  =
```
etc.

Message to be displayed in the **2nd** display line during operation. The value selected by the entry key **E** under address 7106 will appear in the **second** line of the display.

Fault event annunciations can be displayed after a fault on the front. These can be chosen under addresses 7107 and 7108. The possible messages can be selected by repeatedly pressing the "No"–key **N**. The desired message is confirmed with the enter key **E**. These spontaneous messages are acknowledged during operation with the RESET key or via the remote reset input of the device or via the system interface (if fitted). After acknowledgement, the operational messages of the quiescent state will be displayed again as chosen under addresses 7105 and 7106.

```
7107 FAULT   1st  L
Fault  Type
```
After a fault event, the **first** line of the display shows:

type of fault (faulty phases),

```
Trip  Type
```
type of trip command (for 7SA510 always three-pole trip),

```
Prot.Pick-up
```
protection function which has picked up,

```
Prot.Trip
```
protection function, which has tripped,

```
T-Drop
```
the elapsed time from pick-up to drop-off,

```
T-Trip
```
the elapsed time from pick-up to trip command,

```
Fault  locat.
```
for the fault location, each of the fault locator messages according 6.4.3 can be selected.

```
7108 FAULT   2nd  L
T-Trip
```
etc.

After a fault event, the **second** line of the display shows:

the possibilities are the same as under address 7107.

```
7110 FAULT   INDIC
WITH  FAULT  DETEC
```
```
WITH  TRIP  COMM.
```
Stored LED indications and the fault event messages in the display can be displayed either with each fault detection or only after trip command is given. This mode can be changed by depressing the "No"–key **N** and confirmed with the enter–key **E**.

5.3.3 Configuration of the serial interfaces – address block 72

The device provides one or two serial interfaces: one PC interface in the front for operation by means of a personal computer and – dependent of the ordered model – a further system interface for connection of a central control and storage unit, e.g. Siemens LSA 678. Communication via these interfaces requires some data prearrangements: identification of the relay, transmission format, transmission speed.

These data are entered to the relay in address block 72. Codeword input is necessary (refer to Section 5.3.1). The data must be coordinated with the connected devices.

All annunciations which can be processed by the LSA are stored within the device in a separate table. This is listed in Appendix C.

```
7200 PC/SYSTEM
INTERFACES
```

Beginning of the block ”Interfaces for personal computer and central computer system”

```
7201 DEVICE ADD.
1
```

Identification number of the relay within the substation; valid for both the interfaces (operating and system interface). The number can be chosen at liberty, but must be used only once within the plant system

Smallest permissible number: **1**
Largest permissible number: **254**

```
7202 FEEDER ADD.
1
```

Number of the feeder within the substation; valid for both the interfaces (operating and system interface)

Smallest permissible number: **1**
Largest permissible number: **254**

```
7203 SUBST. ADD.
1
```

Identification number of the substation, in case more than one substation can be connected to a central device

Smallest permissible number: **1**
Largest permissible number: **254**

```
7208 FUNCT. TYPE
128
```

Function type in accordance with VDEW/ZVEI; for distance protection no. 128.
This address is mainly for information, it should not be changed.

Addresses 7211 to 7216 are valid for the operating (PC) interface on the front of the relay.

Note: For operator panel 7XR5, the PC–interface format (address 7211) must be *ASCII*, the PC Baud-rate (address 7215) must be *1200 BAUD*, the PC parity (address 7216) must be *NO 2 STOP*.

The setting of the PC GAPS (address 7214 for the operating interface) or SYS GAPS (address 7224 for the system interface) is relevant only when the relay is intended to communicate via a modem. The setting is the maximum time period which is tolerated by the relay when gaps occur during transmission of a telegram. Gaps may occur, when modems are used, by compression of data, error correction, and differences of the Baud-rate. With good transmission quality, 1.0 s is adequate. The value should be increased when transmission quality is not so good. It must be noted that GAPS must be smaller than the setting of "reaction time protection relay" in the protection software DIGSI® V3. Recommended value:

$$GAPS \approx \frac{\text{'reaction time protection relay'}}{2}$$

Higher values for "reaction time protection relay" reduce the transmission speed in case of transmission errors. If the relay interface is connected directly to a personal computer, then GAPS may be set to 0.0 s.

```
7211 PC INTERF.
DIGSI V3
```

Data format for the PC (operating) interface:

format for Siemens protection data processing program *DIGSI*® Version *V3*

```
ASCII
```

ASCII format

```
7214 PC GAPS
0.0 s
```

Maximum time period of data gaps within telegrams which may occur during data transmission via modem on the operating (PC) interface

Smallest setting value: **0.0** s
Largest setting value: **5.0** s

```
7215 PC BAUDRATE
9600 BAUD
```

```
19200 BAUD
```

```
1200 BAUD
```

```
2400 BAUD
```

```
4800 BAUD
```

The transmission Baud-rate for communication via the PC (operating) interface at the front can be adapted to the operator's communication interface, e.g. personal computer, if necessary. The available possibilities can be displayed by repeatedly depression of the "No"–key **N**. Confirm the desired Baud-rate with the entry key **E**.

```
7216 PC PARITY
DIGSI V3
```

Parity and stop-bits for the PC (operating) interface:

format for Siemens protection data processing program *DIGSI*® Version *V3* with even parity and 1 stop-bit

```
NO 2 STOP
```

transmission with *NO* parity and *2 STOP*–bits

```
NO 1 STOP
```

transmission with *NO* parity and *1 STOP*–bit, e.g. modem

Addresses 7221 to 7235 are valid for the system interface (if fitted).

```
7221 SYS INTERF.
VDEW COMPATIBLE
```

Format of annunciations and fault records for the system interface:

only data in accordance with *VDEW*/ZVEI and IEC 60870–5–103

```
VDEW EXTENDED
```

data in accordance with *VDEW*/ZVEI (IEC 60870–5–103), extended by Siemens specified data

```
DIGSI V3
```

format for Siemens protection data processing program *DIGSI*® Version *V3*

```
7222 SYS MEASUR.
VDEW COMPATIBLE
```

Format of measured values for the system interface:

only data in accordance with *VDEW*/ZVEI and IEC 60870–5–103

```
VDEW EXTENDED
```

data in accordance with *VDEW*/ZVEI (IEC 60870–5–103), extended by Siemens specified data

```
7224 SYS GAPS
0.0 s
```

Maximum time period of data gaps within telegrams which may occur during data transmission via modem on the system interface

Smallest setting value:	**0.0** s
Largest setting value:	**5.0** s

```
7225 SYS BAUDR.
9600 BAUD
```

```
19200 BAUD
```

```
1200 BAUD
```

```
2400 BAUD
```

```
4800 BAUD
```

The transmission Baud-rate for communication via the system interface can be adapted to the system interface, if necessary. The available possibilities can be displayed by repeatedly depression of the ”No”–key **N**. Confirm the desired Baud-rate with the entry key **E**.

```
7226 SYS PARITY
VDEW/DIGSIV3/LSA
```

Parity and stop-bits for the system interface:

format for *VDEW*–protocol (IEC 60870–5–103) or Siemens protection data processing program *DIGSI*® *Version 3*

```
NO 2 STOP
```

transmission with *NO* parity and *2 STOP*–bits

```
NO 1 STOP
```

transmission with *NO* parity and *1 STOP*–bit, e.g. modem

It is possible to switch the VDEW–protocol (IEC 60870–5–103) over to the transmission protocol according to the operation software DIGSI® during operation. A precondition is that a transmission format is selected for the system interface which is compatible to the VDEW–protocol (IEC 60870–5–103), i.e. address 7221 SYS INTERF is switched to *VDEW COMPATIBLE* or *VDEW EXTENDED*. If this facility is to be used, address 7227 SYS SWITCH must be set to *YES*. This configuration address does only permit to switch over from VDEW–protocol (IEC 60870–5–103) to DIGSI®–protocol and vice versa at the system interface. The actual switch-over is arranged by a special telegram which is sent by DIGSI® to the system interface when to PC–operator initiates the corresponding command. When address 7235 (see below) is equally set to *YES*, then remote parameterizing is possible via the system interface by means of DIGSI®–procedures.

```
7227 SYS SWITCH
NO

YES
```

Switch-over between VDEW transmission protocol (IEC 60870–5–103) and DIGSI®–protocol via the system interface

NO – is not permitted

YES – is permitted

Address 7235 is relevant only in case the system interface is connected with a hardware that operates with the protection data processing program DIGSI®. This address determines whether it shall be permitted to change parameters via this interface. One of the following preconditions must be fulfilled:

- either address 7221 SYS INTERF is set to *DIGSI V3*,
- or address 7221 SYS INTERF is set to *VDEW COMPATIBLE* or *VDEW EXTENDED* and, at the same time, address 7227 SYS SWITCH (see above) is set to *YES*.

```
7235 SYS PARAMET
NO

YES
```

Remote parameterizing via the system interface

NO – is not permitted

YES – is permitted

5.3.4 Settings for fault recording – address block 74

The distance protection relay is equipped with a fault data store (see Section 4.13.2). Distinction must be made between the reference instant and the storage criterion (address 7402). Normally, the general fault detection signal of the protection is the reference instant. The storage criterion can be the general fault detection, too (*STORAGE BY FD*), or the trip command (*STORAGE BY TRIP*). Alternatively, the trip command can be selected as reference instant (*START WITH TRIP*), in this case, the trip command is the storage criterion, too.

A fault event begins with the fault detection of any protection functions and ends with drop-off of the latest fault detection. The scope of a fault record is normally this fault event (address 7403). If auto–reclosure is carried out, the complete network fault sequence – with one or more reclosure attempts – can be recorded until final fault clearance. This shows the total time sequence of the fault but utilizes more memory space even during the dead time(s).

The actual recording time starts with the pre-trigger time T–PRE (address 7411) before the reference instant and ends with the post-fault time T–POST (address 7412) after the recording criterion has disappeared. The permissible recording time for each record is set under address 7410. Altogether 5 s are available for fault recording. In this time range up to 8 fault records can be stored.

Note: The set times are related on a system frequency of 50 Hz. They are to be matched, accordingly, for different frequencies.

Data storage can also be initiated via a binary input or by operator action from the membrane keyboard on the front of the relay or via the operating interface (see also Section 6.7.7). The storage is triggered dynamically, in these cases. The length of the data storage is determined by the settings in addresses 7431 and 7432, but max. T–MAX, address 7410. Pre-trigger time and post-fault time are additive to the set values. If the storage time for start via binary input is set to ∞, then the storage time ends after de-energization of the binary input (statically), but not after T–MAX (address 7410).

```
7400
FAULT RECORDINGS
```

Beginning of block ”Fault recordings”

```
7402 INITIATION
STORAGE BY FD.
```

```
STORAGE BY TRIP
```

```
START WITH TRIP
```

Data storage is initiated:

– fault detection is reference instant
  fault detection is storage criterion
– fault detection is reference instant
  trip command is storage criterion
– trip command is reference instant
  trip command is storage criterion

```
7403 SCOPE
FAULT EVENT
```

```
FAULT IN POW.SYS
```

Scope of a fault record:

a fault record is stored for each *FAULT EVENT*, i.e. from pick-up until drop-off

a fault record comprises the total *NETWORK FAULT* including auto-reclosure attempts

```
7410 T-MAX
1.00 s
```

Maximum time period of a fault record
Smallest setting value: **0.30** s
Largest setting value: **5.00** s

```
7 4 1 1█ T - P R E
0 . 1 0   s
```

Pre-trigger time before the reference instant
Smallest setting value: **0.05** s
Largest setting value: **0.50** s

```
7 4 1 2█ T - P O S T
0 . 1 0   s
```

Post-fault time after the storage criterion disappears
Smallest setting value: **0.05** s
Largest setting value: **0.50** s

```
7 4 3 1█ T - B I N A R Y   I N
0 . 5 0   s
```

Storage time when fault recording is initiated via a binary input, pre-trigger and post-fault times are additive
Smallest setting value: **0.10** s
Largest setting value: **5.00** s
or ∞, i.e. as long as the binary input is energized (but not longer than T−MAX)

```
7 4 3 2█ T - K E Y B O A R D
0 . 5 0   s
```

Storage time when fault recording is initiated via the membrane keyboard, pre-trigger and post-fault times are additive
Smallest setting value: **0.10** s
Largest setting value: **5.00** s

5.4 Configuration of the protective functions

5.4.1 Introduction

The **device** 7SA510 is capable of providing a series of **protection** and additional functions. The scope of the hard- and firm-ware is matched to these functions. Furthermore, individual functions can be set (configured) to be effective or non-effective or the interaction of the functions can be modified by configuration parameters. Additionally, the relay can be adapted to the system frequency.

Example for configuration of the scope of the device:

Assume a network comprising overhead lines and cable sections. Since the thermal overload protection is meaningful only for the cable sections, this function will be "de-configured" for the devices protecting the overhead line sections.

The configuration parameters are input through the integrated operation keyboard at the front of the device or by means of a personal computer, connected to this front-interface. The use of the integrated operating keyboard is described in detail in Section 6.2. Alteration of the programmed parameters requires the input of the codeword (see Section 5.3.1). Without codeword, the setting can be read out but not altered.

For the purpose of configuration, addresses 78⋆⋆ and 79⋆⋆ are provided. One can access the beginning of the configuration blocks either by direct dial

– press direct address key **DA**,
– type in address **7 8 0 0**,
– press execute key **E** ;

or by paging with the keys ⇑ (forwards) or ⇓ (backwards), until address 7800 appears.

Within the bock 78 one can page forward with ↑ or back with ↓. Each paging action leads to a further address for the input of a configuration parameter. In the following sections, each address is shown in a box and explained. In the upper line of the display, behind the number and the bar, stands the associated device function. In the second line is the associated text (e.g. "*EXIST*"). If this text is appropriate the arrow keys ↑ or ↓ can be used to page the next address. If the text should be altered press the "No" – key **N**; an alternative text then appears (e.g. "*NON – EXIST*"). There may be other alternatives which can then be displayed by repeated depression of the "No" – key **N**. The required alternative **must be confirmed with the key E!**

Use of the double arrow key ⇑ brings one to the next address block, in this case 79. There one finds further setting parameters which can equally be confirmed or altered.

The configuration procedure can be ended at any time by the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question "SAVE NEW SETTINGS ?". Confirm with the "Yes" – key **J/Y** that the new settings shall become valid now. If you press the "No" – key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

If one tries to leave the setting range for the configuration blocks (i.e. address blocks 60 to 79) with keys ⇑ ⇓, the display shows the question "END OF CODEWORD OPERATION ?". Press the "No" – key **N** to continue configuration. If you press the "Yes" – key **J/Y** instead, another question appears: "SAVE NEW SETTINGS ?". Now you can confirm with **J/Y** or abort with **N**, as described above.

When one exits the setting program, the altered parameters, which until then have been stored in volatile memories, are then permanently secured in EEPROMs and protected against power outage. The processor system will reset and re-start. During restart the device is not operational.

5.4.2 Programming the scope of functions – address block 78

The available protective and additional functions can be programmed as existing or not existing. For some functions it may also be possible to select between multiple alternatives.

Functions which are **configured** as *NON EXIST* will not be processed in 7SA510: There will be no annunciations and the associated setting parameters (functions, limit values) will not be requested during setting (Section 6.3). In contrast, **switch-off** of a function means that the function will be processed, that indication will appear (e.g. "... switched off") but that the function will have no effect on the result of the protective process (e.g. no tripping command).

The following boxes show the possibilities for the maximum scope of the device. In an actual case, functions which are not available will not appear in the display.

```
7800 SCOPE OF
FUNCTIONS
```

Beginning of the block "Scope of functions"

Distance protection:

```
7812 DIST. PROT.
EXIST
```

```
NON-EXIST
```

Fault detection mode for distance protection:

```
7813 DIST.F.DET.
OVERCURRENT
```

```
IMPEDANCE ZONE
```

```
U/I FAULT DET.
```

Power swing detection:

```
7820 POWER SWING
NON-EXIST
```

```
EXIST
```

Teleprotection for distance protection:

```
7821 TELEPROTEC.
NON-EXIST
```

```
UNDERREACH
```

```
OVERREACH
```

User definable logic functions:

```
7823 USER LOGIC
NON-EXIST
```

```
EXIST
```

Emergency overcurrent time protection:

```
7826 EMERG. O/C
EXIST
```

```
NON-EXIST
```

Thermal overload protection:

```
7827 THERMAL OL
NON-EXIST
```

```
EXIST
```

Earth fault detection in non-earthed systems:

```
7830 ISOL. E/F
NON-EXIST
```

```
EXIST
```

Earth fault protection in earthed systems:

```
7831 EARTH FAULT
NON-EXIST
```

```
DIR/NON-DIR
```

```
DIREC.COMPARISON
```

```
INVERSE TIME
```

Internal auto-reclosure function:

```
7834 INTERNAL AR
NON-EXIST
```

```
EXIST
```

Fault location:

```
7838 FAULT LOCAT
EXIST
```

```
NON-EXIST
```

Parameter change-over:

```
7885 PARAM. C/O
NON-EXIST
```

```
EXIST
```

The rated system frequency must comply with the setting under address 7899. If the system frequency is not 50 Hz, address 7899 must be changed.

```
7899 FREQUENCY
fN 50 Hz
```

```
fN 60 Hz
```

Rated system frequency *50 Hz* or *60 Hz*

5.4.3 Setting the device configuration – address block 79

The configuration affects the interaction of the protective and additional functions, above all, for 7SA510, the interaction of the auto-reclosing system with the protection functions and the circuit breaker test facility.

```
7900 DEVICE
CONFIGURATION
```

Beginning of the block "Device configuration"

```
7910 CB TEST BI
THREE-POLE TRIP

TRIP-CLOSE 3POLE
```

Circuit breaker test via binary input is carried out

THREE−POLE TRIP will be initiated or

TRIP−CLOSE 3POLE, that is three-pole AR cycle (only models with internal AR function)

```
7912 AR w/ DIST.
YES

NO
```

Auto-reclosing works together with distance protection or not

```
7921 AR w/o TELE
YES

NO
```

When signal transmission is distorted or switched off

YES – AR operates as set

NO – AR is blocked

```
7926 AR w/ EMERG
YES

NO
```

Auto-reclosing works together with emergency over-current time protection or not

```
7930 AR w/ IS.EF
YES

NO
```

Earth fault detection in non-earthed systems

YES – AR works in accordance with the setting (only when tripping on earth fault is allowed)

NO – AR is blocked

```
7931 AR w/ E/F
YES

NO
```

Auto-reclosing works together with earth fault protection for earthed systems or not

```
7941 AR w/ EXT.
YES

NO
```

With external trip via binary input

YES – AR will be carried

NO – no AR will be carried out

5.5 Marshalling of binary inputs, binary outputs and LED indicators

5.5.1 Introduction

The functions of the binary inputs and outputs represented in the general diagrams (Appendix A) relate to the factory settings. The assignment of the inputs and outputs of the internal functions can be rearranged and thus adapted to the on-site conditions.

Marshalling of the inputs, outputs and LEDs is performed by means of the integrated operator panel or via the operating interface. The operation of the operator panel is described in detail in Section 6.2. Marshalling begins at the parameter address 6000.

The input of the codeword is required for marshalling (refer to Section 5.3.1). Without codeword entry, parameters can be read out but not be changed. During codeword operation, i.e. from codeword entry until the termination of the marshalling procedure, the solid bar in the display flashes.

When the 7SA510 programs are running the specific logic functions will be allocated to the physical input and output modules or LEDs in accordance with the selection.

Example: Fault detection is registered from the distance protection. This event is generated in 7SA510 as an "Annunciation" (logical function) and should be available at certain terminals of the unit as a N.O. contact. Since specific unit terminals are hard-wired to a specific (physical) signal relay, e.g. to the signal relay 2, the processor must be advised that the logical signal "`Device FltDet`" should be transmitted to the signal relay 2. Thus, when marshalling is performed two statements of the operator are important: **Which** (logical) annunciation generated in the protection unit program should trigger **which** (physical) signal relay? Up to 20 logical annunciations can trigger one (physical) signal relay.

A similar situation applies to binary inputs. In this case external information (e.g. voltage transformer m.c.b. tripped) is connected to the unit via a (physical) input module and should initiate a (logical) function, namely blocking. The corresponding question to the operator is then: **Which** signal from a (physical) input relay should initiate **which** reaction in the device? One physical input signal can initiate up to 10 logical functions.

The trip relays can also be assigned different functions. Each trip relay can be controlled by each command function or combination of command functions.

The logical annunciation functions can be used in multiple manner. E.g. one annunciation function can trigger several signal relays, several trip relays, additionally be indicated by LEDs, and be controlled by a binary input unit. The restriction is, that the total of all physical input/output units (binary inputs plus signal relays plus LEDs plus trip relays) which are to be associated with one logical function must not exceed a number of 10. If this number is tried to be exceeded, the display will show a corresponding message.

The marshalling procedure is set up such that for each (physical) binary input, each output relay, and for each marshallable LED, the operator will be asked which (logical) function should be allocated.

The offered logical functions are tabulated for the binary inputs, outputs and LEDs in the following sections.

The beginning of the marshalling parameter blocks is reached by directly selecting the address 6000, i.e.

– press direct address key **DA**,
– enter address **6 0 0 0**,
– press enter key **E**

or by paging with keys ⇑ (forwards) or ⇓ (backwards) until address 6000 has been reached. The beginning of the marshalling blocks then appears:

```
⇑ 6 0 0 0 █
⇓ M A R S H A L L I N G
```

Beginning of marshalling blocks

One can proceed through the marshalling blocks with the key ⇑ or go back with the key ⇓ . Within a block, one goes forwards with ↑ or backwards with ↓. Each forward or backward step leads to display of the next input, output or LED position. In the display, behind the address and the solid bar, the physical input/output unit forms the heading.

The key combination **F** ↑, i.e. depressing the function key **F** followed by the arrow key ↑, switches over to the selection level for the logical functions to be allocated. During this change-over (i.e. from pressing the **F** key until pressing the ↑ key) the bar behind the address number is replaced by a ”F”. The display shows, in the upper line, the physical input/output unit, this time with a three digit index number. The second display line shows the logical function which is presently allocated.

On this selection level the allocated function can be changed by pressing the ”No” – key **N**. By repeated use of the key **N** all marshallable functions can be paged through the display. Back-paging is possible with the backspace key **R**. When the required function appears press the execute key **E**. After this, further functions can be allocated to the same physical input or output module (with further index numbers) by using the key ↑. **Each selection must be confirmed by pressing the key E!** If a selection place shall not be assigned to a function, selection is made with the function ”`not allocated`”.

You can leave the selection level by pressing the key combination **F** ↑ (i.e. depressing the function key **F** followed by the arrow key ↑). The display shows again the four digit address number of the physical input/output module. Now you can page with key ↑ to the next input/output module or with ↓ to the previous to repeat selection procedure, as above.

The logical functions are also provided with function numbers which are equally listed in the tables. If the function number is known, this can be input directly on the selection level. Paging through the possible functions is then superfluous. With direct input of the function number, leading zeros need not be entered. After input of the function number, use **the enter key E**. Immediately the associated identification of the function appears for checking purposes. This can be altered either by entering a different function number or by paging through the possible functions, forwards with the ”No” – key **N** or backwards with the backspace key **R**. If the function has been changed, another confirmation is necessary with **the enter key E**.

In the following paragraphs, allocation possibilities for binary inputs, binary outputs and LED indicators are given. The arrows ⇑ ⇓ or ↑ ↓ at the left hand side of the display box indicate paging from block to block, within the block or on the selection level. The character F before the arrow indicates that the function key **F** must be pressed before pushing the arrow key ↑.

The function numbers and designations are listed completely in Appendix C.

The marshalling procedure can be ended at any time by the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question ”SAVE NEW SETTINGS?”. Confirm with the ”Yes” – key **J/Y** that the new allocations shall become valid now. If you press the ”No” – key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

If one tries to leave the setting range for the configuration blocks (i.e. address blocks 60 to 79) with keys ⇑ ⇓, the display shows the question ”END OF CODEWORD OPERATION ?”. Press the ”No” – key **N** to continue marshalling. If you press the ”Yes” – key **J/Y** instead, another question appears: ”SAVE NEW SETTINGS ?”. Now you can confirm with **J/Y** or abort with **N**, as above.

When one exits the marshalling program, the altered parameters, which until then have been stored in volatile memory, are then permanently secured in EEPROMs and protected against power outage. The processor system will reset and re-start. During re-start the device is not operational.

5.5.2 Marshalling of the binary inputs – address block 61

The unit contains 4 binary inputs which are designated INPUT 1 to INPUT 4. They can be marshalled in address block 61. The address block is reached by paging in blocks ⇑ ⇓ or by direct addressing with **DA 6 1 0 0 E**. The selection procedure is carried out as described in Section 5.5.1.

A choice can be made for each individual input function as to whether the desired function should become operative in the "normally open" mode or in the "normally closed" mode, whereby:

NO – "normally open" mode: the input acts as a NO contact, i.e. the control voltage at the input terminals activates the function;

NC – "normally closed" mode: the input acts as a NC contact, i.e. control voltage present at the terminals turns off the function, control voltage absent activates the function.

When paging through the display, each input function is displayed with the index "NO" or "NC" when proceeding with the "No"–key **N**.

Table 5.3 shows a complete list of all the binary input functions with their associated function number **FNo**. Input functions naturally have no effect if the corresponding protection function is not fitted in the relay or has been programmed out ("de-configured", refer to Section 5.4.2).

With direct input of the function number, leading zeros need not be used. To indicate the contact mode the function number can be extended by a decimal point followed by **0** or **1**, whereby

.0 means "normally open" mode, corresponds to "NO" as above.

.1 means "normally closed" mode, corresponds to "NC" as above.

If the extension with .0 or .1 is omitted the display first indicates the function designation in "normally open" mode NO. By pressing the "No"–key **N** the mode is changed to NC. After direct input other functions can be selected by paging through the functions forwards with the "No"–key **N** or backwards with the backspace key **R**. The changed function then must be re-confirmed by the entry key **E**.

Note: One logical function must not be marshalled to two or more binary inputs, because an OR–logic of the signals can not be guaranteed!

The assignment of the binary inputs as delivered from factory is shown in the general diagrams in Appendix A. The following boxes show, as an example, the allocation for binary input 1. Table 5.4 shows all binary inputs as preset from the factory.

⇑⇓
```
6100█ MARSHALLING
BINARY INPUTS
```
Beginning of block "Marshalling binary inputs"

The first binary input is reached with the key ↑:

F↕
```
6101█ BINARY
INPUT 1
```
Allocations for binary input 1

Change over to the selection level with **F** ↑:

```
001█ INPUT 1
>LED reset      NO
```
Reset of stored LED indications, FNo 5;
"normally open" operation:
LEDs are reset when control voltage present

```
002█ INPUT 1
not allocated
```
No further functions are initiated by binary input 1

Leave the selection level with key combination **F** ↑. You can go then to the next binary input with the arrow key ↑.

```
6 1 0 1 █ B I N A R Y
I N P U T   1
```

Marshalling binary input 1

FNo	Abbreviation	Description
1	not allocated	Binary input is not allocated to any input function
3	>Time Synchro	Synchronize internal real time clock
4	>Start FltRec	Start fault recording from external command via binary input
5	>LED reset	Reset LED indicators
7	>ParamSelec.1	Parameter set selection 1 (in connection with FNo 8)
8	>ParamSelec.2	Parameter set selection 2 (in connection with FNo 7)
11	>Annunc. 1	User definable annunciation 1
12	>Annunc. 2	User definable annunciation 2
13	>Annunc. 3	User definable annunciation 3
14	>Annunc. 4	User definable annunciation 4
15	>Sys-Test	System interface messages/values are marked with "Test operation"
16	>Sys-MM-block	System interface messages and measured values are blocked
354	>CB Aux.3p cl	Circuit breaker is 3-pole closed (from CB auxiliary contact)
356	>Manual Close	Circuit breaker is manually closed (from discrepancy switch)
361	>VT mcb Trip	Voltage transformer secondary m.c.b. (feeder) has tripped
383	>RAR Release	Release RAR stages from external (e.g. external AR device)
384	>DAR Release	Release DAR stage from external (e.g. external AR device)
1106	>Start FltLoc	Start fault locator from external command via binary input
1156	>CB Test	Trigger circuit breaker test
1251	>E/F Det. on	Switch on earth fault detection for non-earthed system
1252	>E/F Det. off	Switch off earth fault detection for non-earthed system
1253	>E/F Det.bloc	Block earth fault detection for non-earthed system
1303	>E/F block	Block earth fault protection for earthed system
1311	>E/F comp. on	Switch on directional comparison earth fault protection
1312	>E/F comp.off	Switch off directional comparison earth fault protection
1316	>E/F Recept	Carrier reception signal for directional E/F comparison
1317	>E/F Rec.Fail	Carrier reception for directional earth fault comparison faulty
1501	>O/L on	Switch on overload protection
1502	>O/L off	Switch off overload protection
1503	>O/L block	Block overload protection
2003	>Emer. block	Block emergency overcurrent protection
2010	>I>> block	Block I>> stage of emergency overcurrent protection
2701	>AR on	Switch on internal auto−reclose function
2702	>AR off	Switch off internal auto−reclose function
2703	>AR block	Block internal auto−reclose function statically
2704	>AR reset	Reset internal auto−reclose function
2708	>RAR block	Block RAR-function
2709	>DAR block	Block DAR-function
2711	>Start AR	Start signal from external protection for internal AR
2716	>Trip 3p AR	Trip signal from external protection for internal AR
2721	>DAR aft. RAR	DAR is permitted only after unsuccessful RAR
2730	>CB ready	Circuit breaker ready for AR cycle
2731	>Sync.release	Reclose release from an external synchronism−check relay

Table 5.3 Marshalling possibilities for binary inputs (Continued next page)

FNo	Abbreviation	Description
3603	>Dist. block	Block distance protection
3611	>Extens. Z1B	Release distance overreaching zone Z1B from external
3612	>Extens. Z1L	Release distance overreaching zone Z1L from external
4004	>Dis. Recept	Carrier reception signal for distance protection
4005	>Dis.RecFail	Carrier reception for distance protection faulty
4011	>Dis.POTT on	Switch on permissive overreach transfer function
4012	>Dis.POTT off	Switch off permissive overreach transfer function
4021	>Dis.PUTT on	Switch on permissive underreach transfer function
4022	>Dis.PUTT off	Switch off permissive underreach transfer function
4403	>Ext.Trip blk	Block trip signal from external protection function
4416	>Ext.Trp.woAR	Trip signal from external protection function
4415	>Ext.Trp.L123	Trip signal from external protection function without auto–reclosure
6206	>User T1Start	User definable logic function 1 start
6207	>User T1Reset	User definable logic function 1 reset
6208	>User T2Start	User definable logic function 2 start
6209	>User T2Reset	User definable logic function 2 reset

Table 5.3 Marshalling possibilities for binary inputs

Addr	1st display line	2nd display line	FNo	Remarks
6100	MARSHALLING	BINARY INPUTS		Heading of the address block
6101	BINARY INPUT 1	INPUT 1 >LED reset NO	5	Acknowledge and reset of stored LED and display indications, LED–test
6102	BINARY INPUT 2	INPUT 2 >VT mcb Trip NO	361	Voltage transformer secondary m.c.b. has tripped
6103	BINARY INPUT 3	INPUT 3 >Dis. Recept NO	4004	From carrier device for teleprotection with distance protection
6104	BINARY INPUT 4	INPUT 4 >Manual Close NO	356	Manual close command from discrepancy switch

Table 5.4 Preset binary inputs

5.5.3 Marshalling of the signal output relays – address block 62

The unit contains 5 signal outputs (alarm relays). The signal relays are designated SIGNAL RELAY 1 to SIGNAL RELAY 5 and can be marshalled in address block 62. The block is reached by paging in blocks with ⇑ ⇓ or by directly addressing **DA 6 2 0 0 E**. The selection procedure is carried out as described in Section 5.5.1. Multiple annunciations are possible, i.e. one logical annunciation function can be given to several physical signal relays (see also Section 5.5.1).

Table 5.5 gives a listing of all annunciation functions with the associated function numbers **FNo**. Annunciation functions are naturally not effective when the corresponding protection function is not fitted in the relay or has been programmed out (”de-configured” – refer to Section 5.4.2).

Note as to Table 5.5: Annunciations which are indicated by a leading ”>” sign, represent the direct confirmation of the binary inputs and are available as long as the corresponding binary input is energized.

Further information about annunciations see Section 6.4.

The assignment of the output signal relays as delivered from factory is shown in the general diagrams in Appendix A. The following boxes show an example for marshalling of signal relay 1. Table 5.6 shows all signal relays as preset from the factory.

```
⇑ 6200█MARSHALLING
⇓ SIGNAL RELAYS
```

Beginning of the block ”Marshalling of the output signal relays”

The first signal relay is reached with the key ↑:

```
F↑ 6201█SIGNAL
 ↓ RELAY 1
```

Allocations for signal relay 1

Change over to the selection level with **F** ↑:

```
↑ 001█RELAY 1
↓ Dis. Send
```

Signal relay 1 has been preset for:
Transmission signal for carrier for teleprotection with distance protection, FNo 4056;

```
↑ 002█RELAY 1
↓ not allocated
```

no further functions are preset for signal relay 1

Leave the selection level with key combination **F** ↑. You can go then to the next signal output relay with the arrow key ↑.

```
↑ 6201█SIGNAL
↓ RELAY 1
```

Allocations for signal relay 1

FNo	Abbreviation	Description
1	not allocated	No annunciation allocated
3	>Time Synchro	Synchronize internal real time clock
4	>Start FltRec	Start fault recording by external command via binary input
5	>LED reset	Reset LED indicators
7	>ParamSelec.1	Parameter set selection 1 (in connection with FNo 8)
8	>ParamSelec.2	Parameter set selection 2 (in connection with FNo 7)
11	>Annunc. 1	User definable annunciation 1
12	>Annunc. 2	User definable annunciation 2
13	>Annunc. 3	User definable annunciation 3
14	>Annunc. 4	User definable annunciation 4
15	>Sys-Test	System interface messages/values are marked with "Test operation"
16	>Sys-MM-block	System interface messages and measured values are blocked
51	Dev.operative	Protection device operative
52	Prot. operat	At least one protection function is operative
60	LED reset	Stored annunciations are reset
95	Param.running	Parameters are being set
96	Param. Set A	Parameter Set A is activated
97	Param. Set B	Parameter Set B is activated
98	Param. Set C	Parameter Set C is activated
99	Param. Set D	Parameter Set D is activated
141	Failure 24V	Failure 24 V internal dc supply
143	Failure 15V	Failure 15 V internal dc supply
144	Failure 5V	Failure 5 V internal dc supply
145	Failure 0V	Failure 0 V A/D converter
151	Failure I/O 1	Failure in input/output module
161	I supervision	General failure detected by current supervision
162	Failure ΣI	Failure supervision ΣI (measured currents)
163	Failure Isymm	Failure supervision symmetry I
164	U supervision	General failure detected by voltage supervision
167	Failure Usymm	Failure supervision symmetry U
168	Failure Umeas	Failure measured voltage
169	Fuse-Failure	Fuse failure monitor operated
171	Fail.PhaseSeq	Failure supervision phase sequence
354	>CB Aux.3p cl	Circuit breaker position is ON (from CB auxiliary contact)
356	>Manual Close	Circuit breaker is manually closed (from discrepancy switch)
361	>VT mcb Trip	Voltage transformer secondary m.c.b. (feeder) has tripped
383	>RAR Release	Release RAR stages from external (e.g. external AR device)
384	>DAR Release	Release DAR stage from external (e.g. external AR device)
501	Device FltDet	General fault detection of the device
503	Dev.FltDet L1	Fault detection of the device phase L1
504	Dev.FltDet L2	Fault detection of the device phase L2
505	Dev.FltDet L3	Fault detection of the device phase L3
506	Dev.FltDet E	Fault detection of the device earth fault
511	Device Trip	General trip of the device
515	Dev.Trip 3p	Trip by the device three-pole
516	Dev.Trip forw	Trip by the device on fault in forward (line) direction
517	Dev.Trip rev.	Trip by the device on fault in reverse (bus-bar) direction
561	Manual Close	Manual close indication of circuit breaker
562	Man.Close Cmd	Manual close command for the circuit breaker
563	CB Alarm Supp	Circuit breaker operation alarm suppressed
1106	>Start FltLoc	Start fault locator by external command via binary input
1156	>CB Test	Trigger circuit breaker test
1174	CB in Test	Circuit breaker test is in progress

Table 5.5 Marshalling possibilities for signal relays and LEDs (Continued next page)

FNo	Abbreviation	Description
1181	CB Test Trip	Trip by internal circuit breaker test function, general
1185	CB Test 3p	Trip by internal circuit breaker test function three-pole
1251	>E/F Det. on	Switch on earth fault detection for non-earthed system
1252	>E/F Det. off	Switch off earth fault detection for non-earthed system
1253	>E/F Det.bloc	Block earth fault detection for non-earthed system
1261	E/F Det. off	Earth fault detection for non-earthed system is switched off
1262	E/F Det.block	Earth fault detection for non-earthed system is blocked
1263	E/F Det.activ	Earth fault detection for non-earthed system is active
1271	E/F Detection	Earth fault in non-earthed system detected
1272	E/F Detec. L1	Earth fault (non-earthed) in phase L1 detected
1273	E/F Detec. L2	Earth fault (non-earthed) in phase L2 detected
1274	E/F Detec. L3	Earth fault (non-earthed) in phase L3 detected
1276	E/F forwards	Earth fault (non-earthed) in forward direction detected
1277	E/F reverse	Earth fault (non-earthed) in reverse direction detected
1278	E/F undefined	Earth fault (non-earthed) direction undefined
1281	E/F Det. Trip	Trip by earth fault detection
1303	>E/F block	Block earth fault protection for earthed networks
1311	>E/F comp. on	Switch on earth fault protection
1312	>E/F comp.off	Switch off earth fault protection
1316	>E/F Recept	Reception signal for directional comparison earth fault protection
1317	>E/F Rec.Fail	Reception failure for directional comparison earth fault protection
1331	E/F Prot. off	Earth fault protection is switched off
1332	E/F blocked	Earth fault protection is blocked
1333	E/F active	Earth fault protection is active
1334	E/F Dir.block	Earth fault protection directional stage is blocked
1341	E/F Flt75%Ie>	Earth fault protection low value stage 75 % I_E picked up
1342	E/F Flt Ie<->	Earth fault protection non-directional stage I_E picked up
1343	E/F Flt Ie ->	Earth fault protection directional stage I_E picked up
1344	E/F Ue>	Earth fault displacement voltage Ue> picked up
1351	E/F T-Delay	Earth fault protection delay time expired
1352	E/F T->	Earth fault protection directional delay time expired
1353	E/F T<->	Earth fault protection non-directional delay time expired
1361	E/F Trip	Trip by earth fault protection (general)
1381	E/F Dir off	Directional earth fault protection is switched off
1384	E/F Send	Carrier transmission signal for directional comparison E/F protection
1385	E/F Echo	Echo signal sent for directional comparison E/F protection
1386	E/F TransBloc	Transient blocking of earth fault protection after external fault
1501	>O/L on	Switch on thermal overload protection
1502	>O/L off	Switch off thermal overload protection
1503	>O/L block	Block thermal overload protection
1511	O/L Prot. off	Thermal overload protection is switched off
1512	O/L blocked	Thermal overload protection is blocked
1513	O/L active	Thermal overload protection is active
1515	O/L Warn I	Thermal overload protection current warning stage picked up
1516	O/L Warn Θ	Thermal overload protection thermal warning stage picked up
1517	O/L pickup Θ	Thermal overload protection fault detection of trip stage
1521	O/L Trip	Thermal overload protection trip by trip stage
2003	>Emer. block	Block emergency overcurrent time protection
2010	>I>> block.	Block I>> stage of emergency overcurrent time protection
2051	Emer. off	Emergency overcurrent time protection is switched off
2052	Emer. block	Emergency overcurrent time protection is blocked
2053	Emer. active	Emergency overcurrent time protection is active
2054	Emer. mode	Emergency overcurrent time mode is running

Table 5.5 Marshalling possibilities for signal relays and LEDs (Continued next page)

FNo	Abbreviation	Description
2061	Emer.Gen.Flt	General fault detection of emergency overcurrent protection
2062	Emer. Flt L1	Fault detection L1 of emergency overcurrent protection
2063	Emer. Flt L2	Fault detection L2 of emergency overcurrent protection
2064	Emer. Flt L3	Fault detection L3 of emergency overcurrent protection
2065	Emer. Flt E	Earth fault detection of emergency overcurrent protection
2091	Emer.I>>	Fault detection by I>> stage of emergency O/C protection
2093	Emer.I>	Fault detection by I> stage of emergency O/C protection
2097	Emer.IE>	Fault detection by I_E> stage of emergency O/C protection
2121	Emer. TI>>	Emergency O/C protection time T−I>> expired
2123	Emer. TI>	Emergency O/C protection time T−I> expired
2127	Emer. TIE>	Emergency O/C protection time T−I_E> expired
2141	Emer.Gen.Trip	General trip by emergency overcurrent protection
2145	Emer.Trip 3p	Trip three-pole by emergency overcurrent protection
2701	>AR on	Switch on internal auto-reclose function
2702	>AR off	Switch off internal auto-reclose function
2703	>AR block.	Block internal auto-reclose function (abort)
2704	>AR reset	Reset internal auto-reclose function
2708	>RAR block	Block rapid auto-reclosure (RAR, 1st shot)
2709	>DAR block	Block delayed auto-reclosure (DAR, further shots)
2711	>Start AR	Start signal from external protection for AR
2716	>Trip 3p AR	Trip signal from external protection for AR
2721	>DAR aft. RAR	DAR is permitted only after unsuccessful RAR
2730	>CB ready	Circuit breaker ready for AR cycle
2731	>Sync.release	Reclose release by an external synchronism-check relay
2781	AR off	Internal auto-reclose function is switched off
2782	AR on	Internal auto-reclose function is switched on
2783	AR inoperativ	Internal auto-reclose function is not operative
2784	AR not ready	Internal auto-reclose function is not ready for reclose
2785	AR block.dyn.	Internal auto-reclose function is blocked dynamically
2787	CB not ready	Circuit breaker not ready for a trip/reclose cycle
2788	AR T-CB Exp.	Circuit breaker supervision time expired
2801	AR in prog.	Auto-reclose cycle is in progress
2811	RAR only	Internal AR function is programmed to perform only RAR cycle
2812	RAR T-act.run	Auto-reclose function action time for RAR is running
2814	RAR T-3p run.	Auto-reclose function dead time for RAR is running
2817	RAR Zone Rel.	Internal AR function is ready to permit trip in RAR stage
2831	DAR only	Internal AR function is programmed to perform only DAR cycles
2832	DAR T-act run	Auto-reclose function action time for DAR is running
2833	DAR T-3p1 run	Auto-reclose function dead time for first DAR is running
2834	DAR T-3p2 run	Auto-reclose function dead time for second DAR is running
2835	DAR T-3p3 run	Auto-reclose function dead time for further DAR is running
2837	DAR Zone Rel.	internal AR function is ready to permit trip in DAR stage
2851	AR Close Cmd.	Reclose command by internal auto-reclose function
2853	RAR 3p Close	Reclose command RAR (rapid AR)
2854	DAR 3p Close	Reclose command DAR (delayed AR)
2861	AR T-Recl.run	Auto-reclose function reclaim time is running
2862	AR successful	Auto-reclosure was successful
2863	Definit.Trip	Definitive (final) trip signal
2865	Sync.Meas.Req	Internal AR function request for synchronism or voltage check

Table 5.5 Marshalling possibilities for signal relays and LEDs (Continued next page)

FNo	Abbreviation	Description
3603	>Dist. block	Block distance protection
3611	>Extens. Z1B	Release distance overreaching zone Z1B from external
3612	>Extens. Z1L	Release distance overreaching zone Z1L from external
3651	Dist. off	Distance protection is switched off
3652	Dist. blocked	Distance protection is blocked
3653	Dist. active	Distance protection is active
3661	DisZ1B AR blk	Distance protection blocks reclosure after fault in zone Z1B
3662	DisZ1L AR blk	Distance protection blocks reclosure after fault in zone Z1L
3671	Dist.Gen.Flt.	Distance protection: General fault detection
3672	Dist.Fault L1	Distance protection: Fault detection L1
3673	Dist.Fault L2	Distance protection: Fault detection L2
3674	Dist.Fault L3	Distance protection: Fault detection L3
3675	Dist.Fault E	Distance protection: Earth fault detection
3701	Loop L1-E f	Distance protection: Fault in loop L1 – E in forward direction
3702	Loop L2-E f	Distance protection: Fault in loop L2 – E in forward direction
3703	Loop L3-E f	Distance protection: Fault in loop L3 – E in forward direction
3704	Loop L1-2 f	Distance protection: Fault in loop L1 – L2 in forward direction
3705	Loop L2-3 f	Distance protection: Fault in loop L2 – L3 in forward direction
3706	Loop L3-1 f	Distance protection: Fault in loop L3 – L1 in forward direction
3707	Loop L1-E r	Distance protection: Fault in loop L1 – E in reverse direction
3708	Loop L2-E r	Distance protection: Fault in loop L2 – E in reverse direction
3709	Loop L3-E r	Distance protection: Fault in loop L3 – E in reverse direction
3710	Loop L1-2 r	Distance protection: Fault in loop L1 – L2 in reverse direction
3711	Loop L2-3 r	Distance protection: Fault in loop L2 – L3 in reverse direction
3712	Loop L3-1 r	Distance protection: Fault in loop L3 – L1 in reverse direction
3719	Dist. For.Dir	Distance protection: Fault in forward direction
3720	Dist. Rev.Dir	Distance protection: Fault in reverse direction
3771	Dist. T1	Distance protection: Time T1 (1st stage) expired
3774	Dist. T2	Distance protection: Time T2 (2nd stage) expired
3777	Dist. T3	Distance protection: Time T3 (3rd stage) expired
3778	Dist. T4	Distance protection: Time T4 (4th stage, directional) expired
3779	Dist. T5	Distance protection: Time T5 (final stage) expired
3780	Dist. T1B	Distance protection: Time T1B (1st extended stage) expired
3783	Dist. T1L	Distance protection: Time T1L (2nd extended stage) expired
3801	Dis.Gen. Trip	Distance protection: General Trip command
3805	Dis.Trip 3p	Distance protection: Trip three-pole
3808	Dis.Trip back	Distance protection: Trip with a higher (back-up) stage
3812	Dis.TripZ1/3p	Distance protection: Trip in stage Z1/T1
3814	Dis.TripZ1B3p	Distance protection: Trip in extended stage Z1B/T1B
3815	Dis.Trip Z1L	Distance protection: Trip in extended stage Z1L/T1L
3817	Dis.TripZ2/3p	Distance protection: Trip in stage Z2/T2
3818	Dis.TripZ3/T3	Distance protection: Trip in stage Z3/T3
3819	Dis.Trip FD->	Distance protection: Trip in directional stage (fault detection)
3820	Dis.Trip <->	Distance protection: Trip in non-directional stage (fault detection)
4004	>Dis. Recept	Carrier reception signal for distance protection
4005	>Dis.RecFail	Carrier reception faulty signal for distance protection
4011	>Dis.POTT on	Switch on permissive overreach transfer function
4012	>Dis.POTT off	Switch off permissive overreach transfer function
4021	>Dis.PUTT on	Switch on permissive underreach transfer function
4022	>Dis.PUTT off	Switch off permissive underreach transfer function
4051	Dis.Tele. on	Teleprotection with distance protection is switched on
4052	Dis.Tele. off	Teleprotection with distance protection is switched off
4054	Dis. Recept	Carrier signal for distance protection received
4055	Dis. RecFail	Carrier reception for distance protection faulty

Table 5.5 Marshalling possibilities for signal relays and LEDs (Continued next page)

FNo	Abbreviation	Description
4056	Dis. Send	Transmission signal from distance protection
4067	Dis.POTT Echo	Echo signal (distance protection) transmitted
4068	Dis.TransBlo	Transient blocking (distance protection) is running
4164	Power Swing	Power swing detected
4165	P/S T-action	Power swing action time is running
4166	O/S Trip	Out-of-step Trip command
4403	>Ext.Trip blk	Block trip signal by external trip function
4415	>Ext.Trp.L123	Trip signal by external trip function
4416	>Ext.Trp.woAR	Trip signal by external trip function without auto–reclosure
4431	Ext.Gen.Trip	General trip by external trip function
4435	Ext.Trip 3p	Trip by external trip function
4436	Ext.Trip woAR	Trip by external trip function without auto–reclosure
6206	>User T1Start	User definable logic function 1 start
6207	>User T1Reset	User definable logic function 1 reset
6208	>User T2Start	User definable logic function 2 start
6209	>User T2Reset	User definable logic function 2 reset
6254	User output 1	Output signal of user definable logic function 1
6255	User output 2	Output signal of user definable logic function 2

Table 5.5 Marshalling possibilities for signal relays and LEDs

Addr	1st display line	2nd display line	FNo	Remarks
6200	MARSHALLING	SIGNAL RELAYS		Heading of the address block
6201	SIGNAL RELAY 1	RELAY 1 Dis. Send	4056	Transmission signal for carrier from telepro-tection with distance protection
6202	SIGNAL RELAY 2	RELAY 2 Device FltDet	501	General fault detection of the device
6203	SIGNAL RELAY 3	RELAY 3 Dev.Trip Rev.	517	Fault in reverse direction
6204	SIGNAL RELAY 4 RELAY 4 RELAY 4 RELAY 4 RELAY 4 RELAY 4 RELAY 4	RELAY 4 >VT mcb Trip Failure ΣI Failure Isymm Failure Usymm Failure Umeas Fuse-Failure Fail.PhaseSeq	 361 162 163 167 168 169 171	Group annunciation of all disturbances in measured quantities
6205	SIGNAL RELAY 5	RELAY 5 Dev.operative	51	The NC contact of this relay indicates ”De-vice fault”

Table 5.6 Preset annunciations for signal relays

5.5.4 Marshalling of the LED indicators − address block 63

The unit contains 8 LEDs for optical indications, 6 of which can be marshalled. They are designated LED 1 to LED 6 and can be marshalled in address block 63. The block is reached by paging in blocks with ⇑ ⇓ or by directly addressing with **DA 6 2 0 0 E**. The selection procedure is carried out as described in Section 5.5.1. Multiple annunciations are possible, i.e. one logical annunciation function can be given to several LEDs (see also Section 5.5.1).

Apart from the logical function, each LED can be marshalled to operate either in the stored mode (m for **m**emorized) or unstored mode (nm for "**n**ot **m**emorized"). Each annunciation function is displayed with the index m or nm when proceeding with the **N**− key.

The marshallable annunciation functions are the same as those listed in Table 5.5. Annunciation functions are, of course, not effective when the corresponding protection function is not fitted in the relay or has been programmed out (de-configured).

With direct input of the function number it is not necessary to input the leading zeros. To indicate whether the stored or unstored mode shall be effective the function number can be extended by a decimal point followed by 0 or 1, whereby

.0 unstored indication (not memorized) corresponds to "nm" as above,
.1 stored indication (memorized) corresponds to "m" as above.

If the extension with .0 or .1 is omitted the display shows first the function designation in unstored mode with "nm". Press the "No"−key **N** to change to stored mode "m". After direct input other functions can be selected by paging through the functions forwards with the "No"−key **N** or backwards with the backspace key **R.** The changed function then must be re-confirmed by the enter−key **E**.

The assignment of the LEDs as preset by the factory is shown in the front of the unit (Figure 6.1). The following boxes show, as an example, the assignment for LED 1. Table 5.7 shows all LED indicators as they are preset from the factory.

```
⇑  6300▮MARSHALLING
⇓  LED INDICATORS
```

Beginning of the block "Marshalling of the LED indicators"

The first marshallable LED is reached with the key ↑:

```
↑  6301▮LED 1
↓
```

Allocations for LED 1,
Meaning: "Failure in measured quantities"

Change over to the selection level with **F** ↑:

```
↑  001▮LED 1
↓  >VT mcb Trip   nm
```

LED 1 has been preset for:
1st: Voltage transformer secondary m.c.b. has tripped, FNo 361;

```
↑  002▮LED 1
↓  Failure ΣI     nm
```

LED 1 has been preset for:
2nd: Failure detected by measured current sum monitor, FNo 162:

```
↑  003▮LED 1
↓  Failure Isymm  nm
```

LED 1 has been preset for:
3th: Failure detected by measured current symmetry monitor, FNo 163;

```
↑  004▮LED 1
↓  Failure Usymm  nm
```

LED 1 has been preset for:
4th: Failure detected by measured voltage symmetry monitor phase-to-phase, FNo 167;

```
005 LED 1
Failure Umeas nm
```

LED 1 has been preset for:
5th: Failure detected by measured voltage monitor (measured voltage collapsed), FNo 168;

```
006 LED 1
Fuse-Failure nm
```

LED 1 has been preset for:
6th: Failure detected by fuse-failure monitor, FNo 169;

```
007 LED 1
Fail.PhaseSeq nm
```

LED 1 has been preset for:
7th: Failure detected by phase sequence monitor, FNo 171;

```
008 LED 1
not allocated
```

no further functions are preset for LED 1

After input of all annunciation functions for LED 1, change-back to the marshalling level is carried out with **F** ↑:

```
6301 LED 1
```

Allocations for LED 1 ,
Meaning: ”Failure in measured quantities”

Addr	1st display line	2nd display line	FNo	Remarks
6300	MARSHALLING	LEDs		Heading of the address block
6301	LED 1 LED 1 LED 1 LED 1 LED 1 LED 1 LED 1 LED 1	 >VT mcb Trip nm Failure ΣI nm Failure Isymm nm Failure Usymm nm Failure Umeas nm Fuse-Failure nm Fail.PhaseSeq nm	 361 162 163 167 168 169 171	Group annunciation of all disturbances in measured quantities
6302	LED 2 LED 2 LED 2	 Dist.Fault L1 m Emer. Flt L1 m	 3672 2062	Fault detection annunciations of the distance protection function or the emergency overcurrent time protection
6303	LED 3 LED 3 LED 3	 Dist.Fault L2 m Emer. Flt L2 m	 3673 2063	
6304	LED 4 LED 4 LED 4	 Dist.Fault L3 m Emer. Flt L3 m	 3674 2064	
6305	LED 5 LED 5 LED 5	 Dist.Fault E m Emer. Flt E m	 3675 2065	
6306	LED 6 LED 6	 Device Trip m	 511	General trip command of the device

Table 5.7 Preset LED indicators

5.5.5 Marshalling of the command (trip) relays – address block 64

The unit contains 2 trip relays which are designated TRIP RELAY 1 and TRIP RELAY 2. Each trip relay can be controlled by up to 10 logical commands. The trip relays can be marshalled in the address block 64. The block is reached by paging in blocks with ⇑ ⇓ or by directly addressing with **DA**, input of the address number **6 4 0 0** and pressing the enter key **E**. The selection procedure is carried out as described in Section 5.5.1. Multiple commands are possible, i.e. one logical command function can be given to several trip relays (see also Section 5.5.1).

Most of the annunciation functions in accordance with Table 5.5 can be marshalled to output command relays. But those listed in Table 5.8 are particularly suitable for trip relay output. Regard the table as a recommended pre-selection. Command functions are naturally not effective when the corresponding protection function is not fitted in the relay or has been programmed out (de-configured).

The assignment of the trip relays as delivered from factory is shown in the general diagrams in Appendix A. The following boxes show an example for marshalling of trip relays 1.Table 5.9 shows all trip relays as preset from the factory.

```
6400 MARSHALLING
TRIP RELAYS
```

Beginning of the block "Marshalling of the trip relays"

The first trip relay is reached with the key ↑:

```
6401 TRIP
RELAY 1
```

Allocations for trip relay 1

Change over to the selection level with **F** ↑:

```
001 TRIP REL. 1
Device Trip
```

Trip relay 1 has been preset for:
Trip by any function of the device, FNo 511;

```
002 TRIP REL. 1
not allocated
```

no further functions are preset for trip relay 1

Leave the selection level with key combination **F** ↑. You can go then to the next trip relay with the arrow key ↑.

FNo	Abbreviation	Logical command function
1	not allocated	No function allocated
501	Device FltDet	General fault detection of the device
511	Device Trip	General trip of the device
515	Dev.Trip 3p	General trip by the device three-pole

Table 5.8 Command functions (Continued next page)

FNo	Abbreviation	Logical command function
516	Dev.Trip forw	Trip by the device on fault in forward (line) direction
517	Dev.Trip rev.	Trip by the device on fault in reverse (bus-bar) direction
562	Man.Close Cmd	Trip by internal circuit breaker test function three-pole
1185	CB Test 3p	Manual close command for the circuit breaker
1281	E/F Det. Trip	Trip by earth fault detection in non-earthed systems
1341	E/F Flt75%Ie>	Earth fault protection low value stage 75 % I_E picked up
1342	E/F Flt Ie<->	Earth fault protection non-directional stage I_E picked up
1343	E/F Flt Ie ->	Earth fault protection directional stage I_E picked up
1351	E/F T-Delay	Earth fault protection delay time expired
1352	E/F T->	Earth fault protection directional delay time expired
1353	E/F T<->	Earth fault protection non-directional delay time expired
1361	E/F Trip	Trip by earth fault protection
1384	E/F Send	Carrier transmission signal of directional comparison E/F
1521	O/L Trip	Thermal overload protection trip by trip stage
2061	Emerg.Gen.Flt	General fault detection of emergency overcurrent protection
2145	Emer.Trip 3p	Trip three-pole by emergency overcurrent protection
2851	AR Close Cmd.	Reclose command by internal auto-reclose function
2853	RAR 3p Close	Reclose command RAR (rapid AR)
2854	DAR 3p Close	Reclose command DAR (delayed AR)
3671	Dist.Gen.Flt.	Distance protection: General fault detection
3805	Dis.Trip 3p	Distance protection: Trip three-pole
3808	Dis.Trip back	Distance protection: Trip with a higher (back-up) stage
4056	Dis. Send	Transmission signal of distance protection
4166	O/S Trip	Out-of-step trip command
4435	Ext.Trip 3p	Trip three-pole by external trip function
6254	User output 1	Output signal of user definable logic function 1
6255	User output 2	Output signal of user definable logic function 2

Table 5.8 Command functions

Addr	1st display line	2nd display line	FNo	Remarks
6400	MARSHALLING	TRIP RELAYS		Heading of the address block
6401	TRIP TRIP REL. 1	RELAY 1 Device Trip	511	General trip command of the device
6402	TRIP TRIP REL. 2	RELAY 2 Device FltDet	501	General fault detection of the device

Table 5.9 Preset command functions for trip relays

6 Operating instructions

6.1 Safety precautions

⚠ Warning

All safety precautions which apply for work in electrical installations are to be observed during tests and commissioning.

⚠ Caution!

Connection of the device to a battery charger without connected battery may cause impermissibly high voltages which damage the device. See also Section 3.1.1 under Technical data for limits.

6.2 Dialog with the relay

Setting, operation and interrogation of digital protection and automation systems can be carried out via the integrated membrane keyboard and display panel located on the front plate. All the necessary operating parameters can be entered and all the information can be read out from here. Operation is, additionally, possible via the interface socket by means of a personal computer or similar.

6.2.1 Membrane keyboard and display panel

The membrane keyboard and display panel is externally arranged similar to a pocket calculator. Figure 6.1 illustrates the front view.

A two-line, each 16 character, liquid crystal display presents the information. Each character comprises a 5 x 8 dot matrix. Numbers, letters and a series of special symbols can be displayed.

During dialog, the upper line gives a four figure number, followed by a bar. This number presents the **setting address**. The first two digits indicate the address **block**, then follows the two-digit **sequence number**. In models with parameter change-over facility, the identifier of the parameter set is shown before the setting address.

The keyboard comprises 28 keys with numbers, Yes/No and control buttons. The significance of the keys is explained in detail in the following.

Numerical keys for the input of numerals:

[0] to [9] Digits 0 to 9 for numerical input

[•] Decimal point

[∞] Infinity symbol

[+/−] Change of sign (input of negative numbers)

Yes/No keys for text parameters:

[J/Y] Yes key: operator affirms the displayed question

[N] No key: operator denies the displayed question or rejects a suggestion and requests for alternative

Keys for paging through the display:

[↑] Paging forwards: the next address is displayed

[↓] Paging backwards: the previous address is displayed

[⇧] Block paging forwards: the beginning of the next address block is displayed

[⇩] Block paging backwards: the beginning of previous address block is displayed

Confirmation key:

E	Enter or confirmation key: each numerical input or change via the Yes/No keys must be confirmed by the enter key; only then does the device accept the change. The enter key can also be used to acknowledge and clear a fault prompt in this display; a new input and repeated use of the enter key is then necessary.

Control and special keys:

CW	Codeword: prevents unauthorized access to setting programs (not necessary for call-up of annunciations or messages)
R	Backspace erasure of incorrect entries
F	Function key; explained when used
DA	Direct addressing: if the address number is known, this key allows direct call-up of the address
M/S	Messages/Signals: interrogation of annunciations of fault and operating data (refer to Section 6.4)

The three keys ↑ ; ⇑ ; RESET which are somewhat separated from the rest of the keys, can be accessed when the front cover is closed. The arrows have the same function as the keys with identical symbols in the main field and enable paging in forward direction. Thus all setting values and event data can be displayed with the front cover closed. Furthermore, stored LED indications on the front can be erased via the RESET key without opening the front cover. During reset operation all LEDs on the front will be illuminated thus performing a LED test. With this reset, additionally, the fault event indications in the display on the front panel of the device are acknowledged; the display shows then the operational values of the quiescent state. The display is switched over to operating mode as soon as one of the keys **DA**, **M/S**, **CW** or ⇑ is pressed.

6.2.2 Operation with a personal computer

A personal computer allows, just as the operator panel, all the appropriate settings, initiation of test routines and read-out of data, but with the added comfort of screen-based visualization and a menu-guided procedure.

All data can be read in from, or copied onto, data carrier (e.g. for settings and configuration). Additionally, all the data can be documented on a connected printer. It is also possible, by connecting a plotter, to print out the fault history traces.

For operation of the personal computer, the instruction manuals of this device are to be observed. The PC program DIGSI® is available for setting and processing of all digital protection data. Note that the operating interface in the front of the relay is not galvanically isolated and that only adequate connection cables are applied (e.g. 7XV5100 – 2). Further information about facilities on request.

6.2.3 Operational preconditions

For most operational functions, the input of a codeword is necessary. This applies for all entries via the membrane keyboard or front interface which concern the operation on the relay, for example

- setting of functional parameters (thresholds, functions),
- allocation or marshalling of signals, binary inputs, LED indicators,
- configuration parameters for interface and device configuration,
- initiation of test procedures.

The codeword is not required for the read-out of annunciations, operating data or fault data, or for the read-out of setting parameters.

The method of entry of the codeword is explained in detail in the installation instructions under Section 5.3.

6.2.4 Representation of the relay (front view)

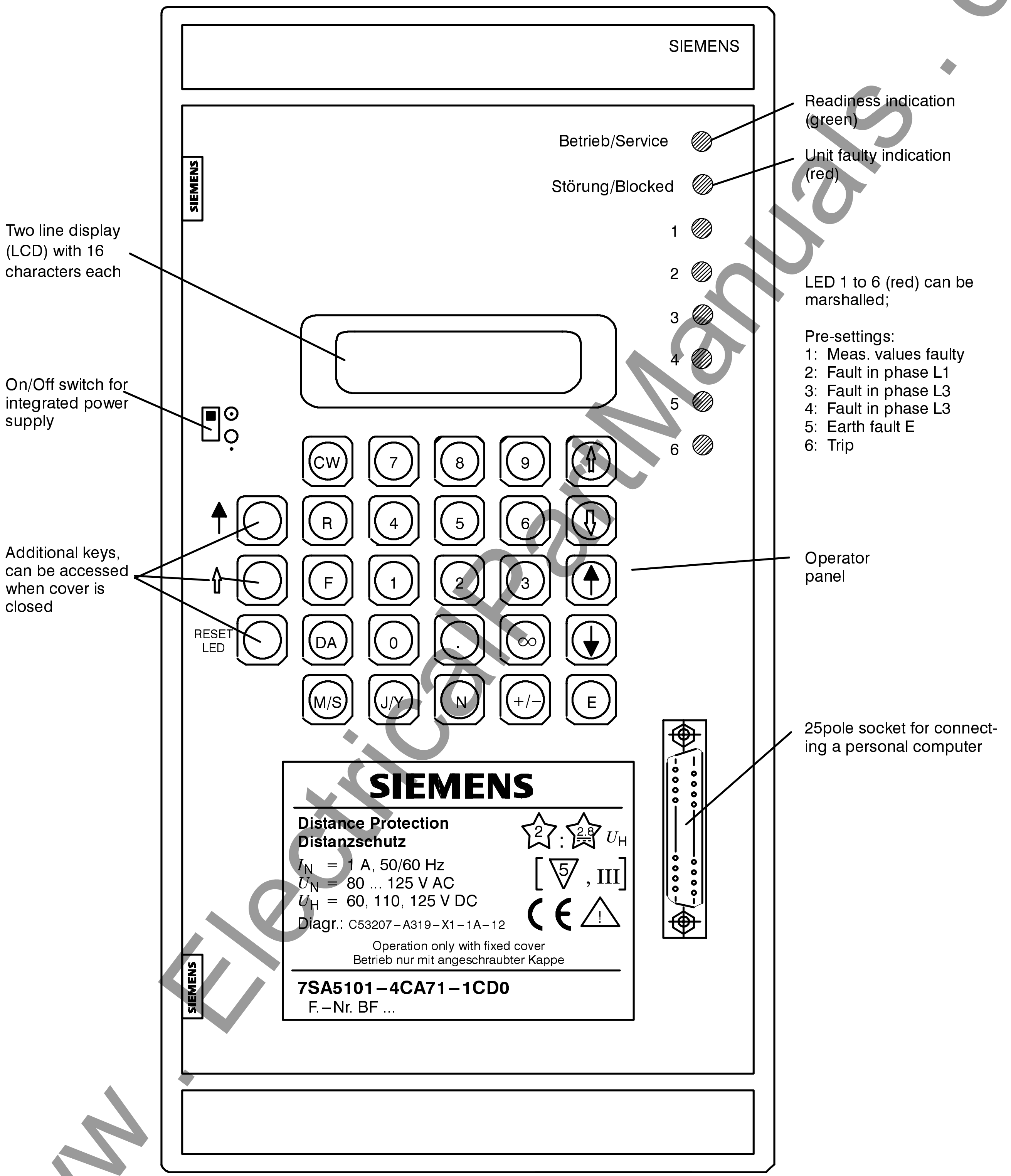


Figure 6.1 Front view of operating key board and display panel

6.3 Setting the functional parameters

6.3.1 Introduction

6.3.1.1 Parameterizing procedure

For setting the functional parameters it is necessary to enter the codeword (see 5.3.1). Without codeword entry, parameters can be read out but not be changed.

If the codeword is accepted, parameterizing can begin. In the following sections each address is illustrated in a box and is explained. There are three forms of display:

– Addresses without request for operator input

  The address is identified by the block number followed by 00 as sequence number (e.g. **11**00 for block **11**). Displayed text forms the heading of this block. No input is expected. By using keys ⇑ or ⇓ the next or the previous block can be selected. By using the keys ↑ or ↓ the first or last address within the block can be selected and paged.

– Addresses which require numerical input

  The display shows the four-digit address, i.e. block and sequence number (e.g. **1104** for block **11**, sequence number **4**). Behind the bar appears the meaning of the required parameter, in the second display line, the value of the parameter. When the relay is delivered a value has been preset. In the following sections, this value is shown. If this value is to be retained, no other input is necessary. One can page forwards or backwards within the block or to the next (or previous) block. If the value needs to be altered, it can be overwritten using the numerical keys and, if required, the decimal point and/or change sign (**+**/**–**) or, where appropriate, infinity sign ∞. The permissible setting range is given in the following text, next to the associated box. Entered values beyond this range will be rejected. The setting steps correspond to the last decimal place as shown in the setting box. Inputs with more decimal places than permitted will be truncated down to the permissible number. **The value must be confirmed with the entry key E!** The display then confirms the accepted value. The changed parameters are only saved after termination of parameterizing (refer below).

– Addresses which require text input

  The display shows the four-digit address, i.e. block and sequence number (e.g. **1102** for block **11**, sequence number **2**). Behind the bar appears the meaning of the required parameter, in the second display line, the applicable text. When the relay is delivered, a text has been preset. In the following sections, this text is shown. If it is to be retained, no other input is necessary. One can page forwards or backwards within the block or to the next (or previous) block. If the text needs to be altered, press the "No" key **N**. The next alternative text, also printed in the display boxes illustrated in the following sections, then appears. If the alternative text is not desired, the **N** key is pressed again, etc. The alternative which is chosen, **is confirmed with the entry key E.** The changed parameters are only saved after termination of parameterizing (refer below).

For each of the addresses, the possible parameters and text are given in the following sections. If the meaning of a parameter is not clear, it is usually best to leave it at the factory setting. The arrows ⇑ ⇓ or ↑↓ at the left hand side of the illustrated display boxes indicate the method of moving from block to block or within the block. Unused addresses are automatically passed over.

If the parameter address is known, then direct addressing is possible. This is achieved by depressing key **DA** followed by the four-digit address and subsequently pressing the enter key **E**. After direct addressing, paging by means of keys ⇑ ⇓ and keys ↑ ↓ is possible.

The setting procedure can be ended at any time by the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question "SAVE NEW SETTINGS?". Confirm with the "Yes" – key **Y** that the new settings shall become valid now. If you press the "No" – key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

If one tries to leave the setting range for the functional parameter blocks (i.e. address blocks 10 to 39) with keys ⇑ ⇓, the display shows the question “END OF CODEWORD OPERATION ?”. Press the “No”–key **N** to continue parameterizing. If you press the “Yes”–key **J/Y** instead, another question appears: “SAVE NEW SETTINGS ?”. Now you can confirm with **J/Y** or abort with **N**, as above.

After completion of the parameterizing process, the changed parameters which so far have only been stored in volatile memory, are then permanently stored in EEPROMs. The display confirms “NEW SETTINGS SAVED”. After pressing the key **M/S** followed by RESET LED, the indications of the quiescent state appear in the display.

6.3.1.2 Selectable parameter sets

Up to 4 different sets of parameters can be selected for the functional parameters, i.e. the addresses above 1000 and below 4000. These parameter sets can be switched over during operation, locally using the operator panel or via the operating interface using a personal computer, or also remotely using binary inputs.

If this facility is not used then it is sufficient to set the parameters for the preselected set. The rest of this section is of no importance. Otherwise, the parameter change-over facility must be configured as *EXIST* under address 7885 (refer to Section 5.4.2). The first parameter set is identified as set A, the other sets are B, C and D. Each of these sets is adjusted one after the other.

If the switch-over facility is to be used, first set all parameters for the normal status of parameter set A. Then switch over to parameter set B:

– Fist complete the parameterizing procedure for set A as described in Section 6.3.1.1.

– Press key combination **F 2**, i.e. first the function key **F** and then the number key **2**. All following inputs then refer to parameter set B.

All parameter sets can be accessed in a similar manner:

- Key combination **F 1**: access to parameter set **A**
- Key combination **F 2**: access to parameter set **B**
- Key combination **F 3**: access to parameter set **C**
- Key combination **F 4**: access to parameter set **D**

Input of the codeword is again necessary for the setting of a new selected parameter set. Without input of the codeword, the settings can only be read but not modified.

Since only a few parameters will be different in most applications, it is possible to copy previously stored parameter sets into another parameter set.

It is additionally possible to select the original settings, i.e. the settings preset on delivery, for a modified and stored parameter set. This is done by copying the “ORIG.SET” to the desired parameter set.

It is finally still possible to define the active parameter set, i.e. the parameter set which is valid for the functions and threshold values of the unit. See Section 6.5.4 for more details.

The parameter sets are processed in address block 85. The most simple manner to come to this block is using direct addressing:

– press direct address key **DA**,
– enter address, e.g. **8 5 0 0**,
– press enter key **E**.

The heading of the block for processing the parameter sets then appears.

It is possible to scroll through the individual addresses using the ↑ key. The copying facilities are summarized in Table 6.1.

```
⇑ 8 5 0 0 █ P A R A M E T E R
⇓ C H A N G E - O V E R
```

Beginning of the block “Parameter change-over”; processing of parameter sets

Addr.	Copy from	to
8510	ORIG.SET	SET A
8511	ORIG.SET	SET B
8512	ORIG.SET	SET C
8513	ORIG.SET	SET D
8514	SET A	SET B
8515	SET A	SET C
8516	SET A	SET D
8517	SET B	SET A
8518	SET B	SET C
8519	SET B	SET D
8520	SET C	SET A
8521	SET C	SET B
8522	SET C	SET D
8523	SET D	SET A
8524	SET D	SET B
8525	SET D	SET C

Table 6.1 Copying parameter sets

Following copying, only such parameters need be changed which are to be different from the source parameter set.

Parameterizing must be terminated for each parameter set as described in Section 6.3.1.1.

6.3.1.3 Setting of date and time

The date and time can be set if the the real time clock is available. Setting is carried out in block 81 which is reached by direct addressing **DA 8 1 0 0 E** or by paging with ⇑ and ⇓. Input of the codeword is required to change the data.

Selection of the individual addresses is by further scrolling using ↑ ↓ as shown below. Each modification must be confirmed with the enter key **E**.

The date and time are entered with dots as separator signs since the keyboard does not have a colon or slash (for American date).

The clock is synchronized at the moment when the enter key **E** is pressed following input of the complete time. The difference time facility (address 8104) enables exact setting of the time since the difference can be calculated prior to the input, and the synchronization of the clock does not depend on the moment when the enter key **E** is pressed.

```
⇑  8 1 0 0 █ S E T T I N G
⇓  R E A L   T I M E   C L O C K
```

Beginning of the block “Setting the real time clock” Continue with ↑.

```
↑  2 9 . 1 2 . 1 9 9 6
↓  1 9 : 3 9 : 1 6
```

At first, the actual date and time are displayed. Continue with ↑.

```
↕  8 1 0 2 █ D A T E
```

Enter the new date: 2 digits for day, 2 digits for month and 4 digits for year (including century); use the order as configured under address 7102 (Section 5.3.2), but always use a dot for separator:
DD.MM.YYYY or **MM.DD.YYYY**

```
↕  8 1 0 3 █ T I M E
```

Enter the new time: hours, minutes, seconds, each with 2 digits, separated by a dot:
HH.MM.SS

```
↕  8 1 0 4 █ D I F F .   T I M E
```

Using the difference time, the clock is set forwards by the entered time, or backwards using the **+/–** key. The format is the same as with the time setting above.

6.3.2 Initial displays − address blocks 0 and 10

When the relay is switched on, firstly the address 0 and the type identification of the relay appears. All Siemens relays have an MLFB (machine readable type number). When the device is operative and displays a quiescent message, any desired address can be reached e.g. by pressing the direct address key **DA** followed by the address number.

```
0 █ 7SA510    V3.***
7SA510**********
```

The relay introduces itself by giving its type number, the version of firmware with which it is equipped, and a hardware identifier. The second display line shows the complete ordering designation.

After address 1000, the functional parameters begin. Further address possibilities are listed under “Annunciations” and “Tests”.

```
 1000█
PARAMETERS
```

Commencement of functional parameter blocks

6.3.3 Power system data − address block 11

6.3.3.1 General data

The relay requests basic data of the power system and the switchgear.

```
 1100█
POWERSYSTEM DATA
```

Beginning of the block “Power system data”

```
 1101█CT STARPNT
TOWARDS LINE

TOWARDS BUSBAR
```

Current transformer polarity:
LINE – c.t. star-point towards line
BUSBAR – c.t. star-point towards busbar
This setting determines the measurement direction of the relay (forwards = line direction)

```
 1102█SYSTEMSTAR
SOLIDLY EARTHED

COMPENSATED

ISOLATED
```

System star-point condition:
Important for earth fault and double earth fault conditions

```
 1103█Un PRIMARY
110 kV
```

Voltage transformer primary voltage (line-to-line)
Smallest setting value: **1** kV
Largest setting value: **1200** kV

```
 1104█Un  SECOND.
100  V
```

Voltage transformer secondary voltage (line-to-line)
Smallest setting value: **80** V
Largest setting value: **125** V

```
 1105█In  PRIMARY
1000  A
```

Current transformer primary rated current (phases)
Smallest setting value: **10** A
Largest setting value: **5000** A

With address 1112, the device is instructed as to how the earth current input is connected. This information is important for the monitoring of measured values.

If the earth current is derived from the star point of the current transformer set (standard circuit arrangement, see also Appendix B, Figure B.2), then:

Address 1112 is set as Ie/Iph = 1.000

If the earth current is derived from a separate earth current transformer (e.g. summation c.t., see also Appendix B, Figure B.3), then:

Address 1112 is set as

$$Ie/Iph = \frac{\text{ratio of the earth current CT}}{\text{ratio of the phase current CT}}$$

Example:

Phase current transformers 400 A/5 A
Window type summation transformer 60 A/1 A

results in setting of address 1112

$$Ie/Iph = \frac{60/1}{400/5} = 0.750$$

```
 1112█Ie/Iph
1.000
```

Matching factor for earth current:
1 for connection in c.t. starpoint;

$$\frac{(window-type)\ earth\ c.t.\ ratio}{(phase)\ c.t.\ ratio}$$

for connection to separate earth current transformer

Smallest setting value: **0.001**
Largest setting value: **20.000**

6.3.3.2 Line data, general

General line data are those which are independent of reach of the distance zones and the grading plan. Matching of the earth impedance ratio is achieved by entering the resistance ratio R_E/R_L and the reactance ratio X_E/X_L. These are purely formally calculated and are not identical with real and imaginary parts of Z_E/Z_L. **No** complex calculation is necessary!

The setting parameters can be determined from the line data using the following formulae:

Resistance ratio

$$\frac{R_E}{R_L} = \frac{1}{3} \cdot \left(\frac{R_0}{R_1} - 1\right)$$

Reactance ratio

$$\frac{X_E}{X_L} = \frac{1}{3} \cdot \left(\frac{X_0}{X_1} - 1\right)$$

Whereby
- R_0 – Zero sequence line resistance
- X_0 – Zero sequence line reactance
- R_1 – Positive sequence line resistance
- X_1 – Positive sequence line reactance

It is unimportant whether total line values or values per unit length are used, since the ratios are independent of the line length.

Calculation Example

110 kV overhead line Alu/Steel 240/40 mm^2 with the line parameters

s (length) = 60 km

$R_1/s = 0.13\ \Omega/km$
$X_1/s = 0.39\ \Omega/km$ } Pos. seq. impedance

$R_0/s = 0.38\ \Omega/km$
$X_0/s = 1.15\ \Omega/km$ } Zero seq. impedance

Current transformers 600 A/5 A
Voltage transformers 110 kV/0.1 kV

For the earth impedance ratio we have:

$$\frac{R_E}{R_L} = \frac{1}{3} \cdot \left(\frac{R_0}{R_1} - 1\right)$$
$$= \frac{1}{3} \cdot \left(\frac{0.38\Omega/km}{0.13\Omega/km} - 1\right) = 0.64$$

$$\frac{X_E}{X_L} = \frac{1}{3} \cdot \left(\frac{X_0}{X_1} - 1\right)$$
$$= \frac{1}{3} \cdot \left(\frac{1.15\Omega/km}{0.39\Omega/km} - 1\right) = 0.65$$

Some additional data are requested for various protection functions. These have to be entered to the relay under the addresses 1122 and 1124.

The reactance per unit line length (address 1122) is entered as secondary value. This can be derived from the primary value using the formula

$$X_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X_{prim} \cdot \frac{I_N}{A}$$

Where N_{ct} – c.t. ratio
N_{vt} – v.t. ratio
I_N/A – rated current of the current transformers = rated current of the device

Finally, the line length is entered under address 1124. It is used for fault location.

```
  1 1 1 7 ▮ R E / R L
1 . 0 0
```

Matching of earth impedance, resistance ratio
Smallest setting value: **--7.00**
Largest setting value: **7.00**

```
  1 1 1 8 ▮ X E / X L
1 . 0 0
```

Matching of earth impedance, reactance ratio
Smallest setting value: **--7.00**
Largest setting value: **7.00**

```
  1 1 2 2 ▮ X   S E C
0 . 5 0 0   Ω / k m
```

Line reactance per unit line length, secondary, only for fault location (refer to Section 6.3.14)
Smallest setting value: **0.010** Ω/km
Largest setting value: **5.000** Ω/km

```
  1 1 2 4 ▮ L I N E L E N G T H
1 0 0 . 0   k m
```

Length of the total line, secondary, only for fault location (refer to Section 6.3.14)
Smallest setting value: **1.0** km
Largest setting value: **550.0** km

Note: When the line length is entered in miles instead of kilometers, and the line constants are entered in ohms per mile, then the relay will operate properly.

6.3.3.3 General device data

Under addresses 1130 and 1131, the minimum trip command duration can be set. This is then valid for all protection functions of the device which can issue a trip signal. Distinction can be made between the minimum trip command duration with current flow T−TRIP I> (address 1130) ($I > 0.1\ I_N$) and the duration without current flow T−TRIP I< (address 1131).

Under address 1135, the maximum close command duration can be set. This time is then valid for all functions of the device which can close the circuit breaker. It must be long enough to ensure reliable closure of the circuit breaker. The closing command will be interrupted at once on renewed trip of any of the protection functions.

Under addresses 1145 to 1150, some additional general device data are entered to the protection relay, to match it to the switch-gear conditions.

The parameter T−M/C−PROL (address 1145) is operative only after manual closing of the breaker. This time is decisive for those protection stages which shall operate only during manual closing (e.g. overreach zone of the distance protection).

The external stabilization time (address 1149) is a delay time by which external commands via binary inputs are delayed. Thus, it increases the dynamic noise immunity of the binary inputs.

```
 1130█ T-TRIP  I>
0.00  s
```

Minimum duration of **trip** command with current flow
Smallest setting value: **0.00** s
Largest setting value: **32.00** s

```
 1131█ T-TRIP  I<
0.15  s
```

Minimum duration of **trip** command without current flow
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

```
 1135█ T-CLOSE
1.00  s
```

Maximum duration of **close** command
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

```
 1145█ T-M/C-PROL
0.30 s
```

Prolongation time after manual closing, for which the associated protection stage shall operate
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

```
 1149█ T-EXT.STAB
0.01  s
```

Stabilization time (delay) for external trip command via binary input
Smallest setting value: **0.00** s
Largest setting value: **32.00** s

```
 1150█ FILTER
NORMAL
```

```
LONG
```

Filter for measured quantities

NORMAL filter

LONG filter for difficult measuring conditions

6.3.4 Settings for distance protection

Since the main function of 7SA510 is that of distance protection, it is assumed in the following that in setting the scope of the device (Section 5.4.2) the distance protection function has been set as *EXIST* (address 7812). If the response *NON–EXIST* has been set for the distance protection (for example, because only other functions shall be used) this section is irrelevant.

6.3.4.1 General settings -- address block 12

7SA510 comprises 5 distance zones and 7 time stages arranged as follows:

Independent distance stages:
zone Z1 delay T1
zone Z2 delay T2
zone Z3 delay T3

Controlled (overreaching) stages:
zone Z1B delay T1B
zone Z1L delay T1L

Final stages:
fault detection, directional delay T4
fault detection, non-directional delay T5

For Z1, Z2, and Z1B different delay times can be set for single-phase faults and multi-phase faults respectively.

In address block 12, the direction of the directional stage and the delay times T4 and T5 are set.

<u>*NOTE*</u>:
The direction which is set for the directional final stage (address 1202) is <u>not</u> valid for other directionally dependent functions of the fault detection functions, for example, for directional comparison when this is selected!

```
 1200█ DIST.PROT.
GENERAL SETTINGS
```

Beginning of the block
“Distance protection general settings”

```
 1201█ DIST.PROT.
ON
```

```
OFF
```

Distance protection is
ON switched on
or
OFF switched off

```
 1202█ DIR. FD&T4
FORWARDS
```

```
REVERSE
```

```
NON-DIRECTIONAL
```

Direction for directional trip with fault detection, which can be set
FORWARDS (line direction) or
REVERSE (busbar direction) or
NON–DIRECTIONAL (either direction)

```
 1203█ T4
0.90 s
```

Delay for T4 (fault detection directional trip)
Smallest setting value: **0.00 s**
Largest setting value: **32.00 s**
and ∞ (no directional trip)

```
 1204█ T5
1.20 s
```

Delay for T5 (fault detection non-directional trip)
Smallest setting value: **0.00 s**
Largest setting value: **32.00 s**
and ∞ (no non-directional trip)

For manual closure onto the short circuit, the distance protection can be set for various values of reach (address 1205). For *Z1 EFFECTIVE,* no special measures are taken. Possible measures are switch to overreach zone (instantaneous directional) *Z1B DIRECTIONAL* or overreach zone (instantaneous non−directional) *Z1B NON−DIRECT* or *FD EFFECTIVE,* i.e. fault detection instantaneous non-directional. Prerequisite is that the manual closing command is fed to the relay via a binary input from the discrepancy switch.

If the distance protection operates together with the integrated or an externally connected auto-reclose device, address 1216 determines which distance zone is valid before auto-reclosure. Normally, measurement for the RAR cycle takes place in the (extended) overreach zone Z1B. This can be changed by setting RAR −> Z1B to *NO*. Overreaching zone Z1B is not released by the RAR function in this case. Zone Z1 is effective continuously.

For DAR (further auto−reclose cycles), a separate distance zone Z1L is available. Release of this zone before a DAR cycle can be blocked by setting address 1218 DAR −>Z1L to *NO*. The DAR cycles can also be blocked by a binary input. One can select the stage that should be effective during blocking of the DAR cycles (address 1217): Normally, Z1 with T1 is effective in this case, this can be changed to Z1 with T1B.

If a line to be protected is composed of overhead line and cable sections, the controlled zones Z1B and Z1L can be used to distinguish between faults on the the overhead section and cable faults, to a certain degree. Reclosure can be blocked for cable faults using addresses 1221 and 1222. If, for example, a cable section is followed by an overhead line section, zone Z1B is set to cover the cable section and address 1221 is set such that reclosure is blocked for faults *WITHIN Z1B*. If further segregation is necessary (e.g. cable – overhead line – cable), distinction can be made by address 1222 in similar way. In all other cases, both addresses remain in position *NO*.

1205 MAN. CLOSE / Z1B DIRECTIONAL	Distance measuring range which is valid when the circuit breaker is closed manually: *Z1B DIRECTIONAL* i.e. the overreach zone, direc− tional as set in address 1414
Z1B NON-DIRECT.	*Z1B NON−DIRECT* i.e. the overreach zone, non− directional
FD EFFECTIVE	*FD EFFECTIVE* i.e. fault detection zone, non− directional
Z1 EFFECTIVE	*Z1 EFFECTIVE* i.e. the normal first zone: no special measures
1216 RAR -> Z1B / YES	Zone Z1B is effective with a “ready”-signal of an external auto-reclosure device *YES* or
NO	*NO*
1217 DAR BLOCK / Z1; T1	If DAR (2nd and further shots) is blocked, *Z1; T1* zone Z1 is valid with delay T1
Z1; T1B	*Z1; T1B* zone Z1 is valid with delay T1B
1218 DAR -> Z1L / YES	Zone Z1L is effective before DAR *YES* or
NO	*NO*

```
  1 2 2 1 █ B L K . A R   Z 1 B
N O
```

```
W I T H I N
```

```
O U T S I D E
```

Auto–reclosure is blocked for faults

NO	normal setting
WITHIN	zone Z1B
OUTSIDE	of zone Z1B

```
  1 2 2 2 █ B L K . A R   Z 1 L
N O
```

```
W I T H I N
```

```
O U T S I D E
```

Auto–reclosure ist blocked for faults

NO	normal setting
WITHIN	zone Z1L
OUTSIDE	of zone Z1L

6.3.4.2 Setting of the distance stages -- address blocks 13 and 14

The relevant parameters are set for each distance stage. The reactance X determines the reach of its associated zone. The resistance R forms the allowance for line and fault resistance. It can be set separately for phase-phase faults and for phase-earth faults to allow, for example, for earth faults with higher fault path resistance.

Measurement direction can be set individually for each zone. This allows free choice of forwards, reverse or non-directional stages, e.g. at transformers, generators or bus-bar couplers.

The delay times T1 and T2 can each be set individually and differently for single-phase faults and multi-phase faults. Thus one can, for example, make a setting for single phase faults higher than that of an associated differential earth fault protection (T1 1PHASE grater than T1 >1PHASE) or, set a shorter reserve time for multi-phase faults close to a power station (T2 >1PHASE less than T2 1PHASE). Different delay times for single- and multi-phase faults are possible for the overreach zone Z1B, too.

The independent zones Z1, Z2, Z3 operate independently from one another and independently of the overreach zones Z1B and Z1L.

It is recommended that a comprehensive grading plan should be made for the complete electrically connected network. It should be made before this entry series is attempted. This plan should contain the line lengths with their primary reactances X in Ω/phase. These reactances X are the basis for zone reach determination.

For the first zone Z1, one normally selects no delay time (i.e. T1 = 0.00 s) for the first 85 % of the protected line length. Over this distance the relay will then disconnect faults within its inherent operating time.

For each of the following stages the delay time is increased by one grading time unit. This grading time unit must be adequate to cover the circuit breaker operating time inclusive tolerance, the reset time of the protection devices and the tolerance of the delay times. Normally 0.3 s to 0.4 s is used. Reach is selected so that it covers up to 80 % of the equal time stage of the relay for the shortest following line section.

The values determined from the grading plan must be converted for the secondary side of current and voltage transformers. In general:

$$Z_{secondary} = \frac{\text{Current transformer ratio}}{\text{Voltage transformer ratio}} \cdot Z_{primary}$$

The secondary values given to the relay must be related to a current of 1 A. Thus the conversion formula for reach for any distance zone is:

$$X_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X_{prim} \cdot \frac{I_N}{A}$$

Where N_{ct} – c.t. ratio
N_{vt} – v.t. ratio
I_N/A – rated relay current in Ampere = secondary rated current of current transformers

Resistance setting R allows a margin for fault resistance, which appears as an in-phase resistance addition to the line impedance, at the point of fault. It comprises, for example, arc resistances, tower footing resistances or similar. The setting should take these fault resistances into account but not be set higher than absolutely necessary. An adequate difference from the operating impedance must be ensured, even under conditions of temporary overload. The resistance margin can be set separately for phase-phase faults and for phase-earth faults.

Calculation Example

110 kV overhead line Alu/Steel 240/40 mm^2 with the characteristics:

s (length) = 60 km

R_1/s = 0.13 Ω/km
X_1/s = 0.39 Ω/km
R_0/s = 0.38 Ω/km
X_0/s = 1.15 Ω/km

Current transformers 600 A/5 A
Voltage transformers 110 kV/0.1 kV

Maximum overload:
P_{max} = 130 MVA corresponding
I_{max} = 680 A

Figure 6.2 shows a sample network section with primary grading plan.

Which gives the line data:

X_a = 0.39 Ω/km · 60 km = 23.4 Ω
R_a = 0.13 Ω/km · 60 km = 7.8 Ω

X_b = 0.39 Ω/km · 30 km = 11.7 Ω
R_b = 0.13 Ω/km · 30 km = 3.9 Ω

X_c = 0.39 Ω/km · 40 km = 15.6 Ω
R_c = 0.13 Ω/km · 40 km = 5.2 Ω

Thus the following zone limits arise:

Zone 1 primary 85 % of line length

$$X1_{prim} = 0.85 \cdot X_a = 0.85 \cdot 23.4\Omega = 19.89\Omega$$

Zone 1 secondary

$$X1_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X1_{prim} \cdot \frac{I_N}{A} = \frac{600/5}{110/0.1} \cdot 19.89\Omega \cdot \frac{5A}{A} = 10.85\Omega$$

Zone 2 primary 80 % up to Z1 of the next line b

$$X2_{prim} = 0.8 \cdot (X_a + 0.85 \cdot X_b) = 0.8 \cdot (23.4\Omega + 0.85 \cdot 11.7\Omega) = 26.68\Omega$$

Zone 2 secondary

$$X2_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X2_{prim} \cdot \frac{I_N}{A} = \frac{600/5}{110/0.1} \cdot 26.68\Omega \cdot \frac{5A}{A} = 14.55\Omega$$

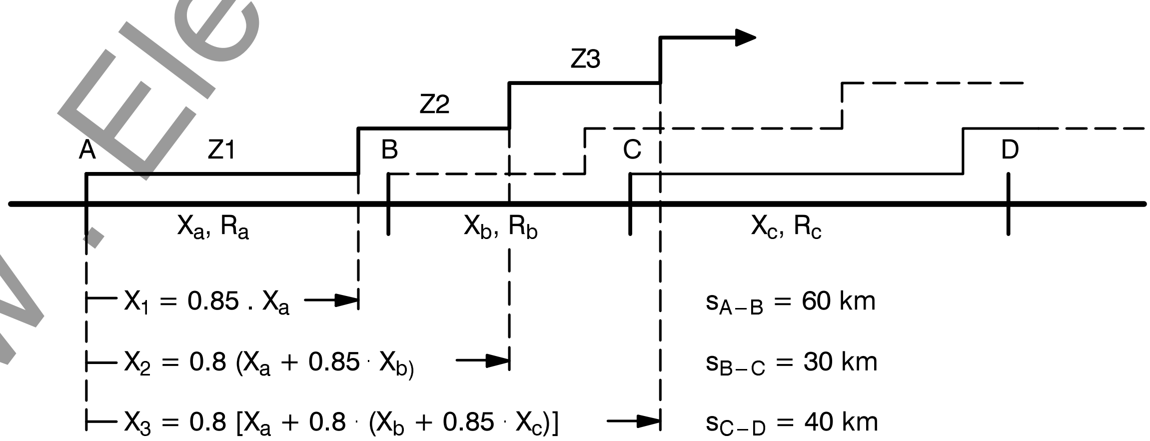


Figure 6.2 Grading plan related to above calculation example

Zone 3 primary 80 % up to Z2 of the next line b

$$X3_{prim} = 0.8 \cdot [X_a + 0.8 \cdot (X_b + 0.85 \cdot X_c)]$$
$$= 0.8 \cdot \left[23.4\Omega + 0.8 \cdot (11.7\Omega + 0.85 \cdot 15.6\Omega)\right]$$
$$= 34.69\Omega$$

Zone 3 secondary

$$X3_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X3_{prim} \cdot \frac{I_N}{A}$$
$$= \frac{600/5}{110/0.1} \cdot 34.69\Omega \cdot \frac{5A}{A} = 18.92\Omega$$

Resistance setting

For resistance setting in relation to overhead lines, consideration of the arc resistance is most important. In cable networks, an extensive arc is not possible; thus the effective resistance of the cable itself normally plays the more important role. With very short cable lengths, however, it must be ensured that the resistance of an arc at the terminals at the close-up cable end is covered by the resistance which is set for the first zone.

In this example, for phase-phase arcs, an arc voltage drop of max. 12 kV is assumed. With an assumed minimum short circuit current of 1000 A, this corresponds to 12 Ω primary. For the resistance setting of the first zone, this results in

$$R1_{prim} = R1_{line} + \frac{1}{2} \cdot R_{arc}$$
$$= 6.63\Omega + \frac{1}{2} \cdot 12\Omega = 12.63\Omega$$

$$R1_{sec} = \frac{N_{ct}}{N_{vt}} \cdot R1_{prim} \cdot \frac{I_N}{A}$$
$$= \frac{600/5}{110/0.1} \cdot 12.63\Omega \cdot \frac{5A}{A}$$
$$= 6.9\Omega$$

Only half of the arc resistance value was used, because it is additive to the *loop* impedance and only half should be added to the impedance *per phase*.

For earth faults, a separate resistance tolerance can be set. If an arc resistance of 9 Ω and a resistance of 25 Ω for the tower footing earth path are assumed, this then leads to

$$R1E_{prim} = R1_{line} + R_{arc} + R_{tower}$$
$$= 6.63\Omega + 9\Omega + 25\Omega$$
$$= 40.63\Omega$$

$$R1E_{sec} = \frac{N_{ct}}{N_{vt}} \cdot R1E_{prim} \cdot \frac{I_N}{A}$$
$$= \frac{600/5}{110/0.1} \cdot 40.63\Omega \cdot \frac{5A}{A}$$
$$= 22.2\Omega$$

This value gives an adequate clearance to the minimum load impedance. The power swing polygon can be ignored for the phase-earth faults, because the power swing detection works only with phase-phase measurement.

Independent zones Z1, Z2 and Z3 – address block 13

```
⇧  1300 DIST.PROT.
⇩ INDEPEND. ZONES
```

Beginning of block
“Distance protection, independent zones Z1, Z2 and Z3”

First zone Z1

```
  1301 R1
 1.25 Ω
```

Resistance for phase-phase
Smallest setting value: **0.05** Ω
Largest setting value: **65.00** Ω

```
 1 3 0 2 █ X 1
2 . 5 0   Ω
```

Reactance value (reach)
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1 3 0 3 █ R 1 E
2 . 5 0   Ω
```

Resistance for phase-earth
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1 3 0 4 █ D I R E C .  Z 1
F O R W A R D S
```

```
R E V E R S E
```

```
N O N - D I R E C T I O N A L
```

Direction for zone Z1: can be

FORWARDS (line direction) or

REVERSE (busbar direction)

NON−DIRECTIONAL (either direction)

```
 1 3 0 5 █ T 1  1 P H A S E
0 . 0 0   s
```

Delay for zone Z1, single-phase faults
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z1 for single-phase faults)

```
 1 3 0 6 █ T 1  > 1 P H A S E
0 . 0 0   s
```

Delay for zone Z1, multi-phase faults
Smallest setting value **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z1 for multi-phase faults)

Normally, addresses 1305 and 1306 are set to the same value.

Second zone Z2

```
 1 3 1 1 █ R 2
2 . 5 0   Ω
```

Resistance for phase-phase
Smallest setting value: **0.05** Ω
Largest setting value: **65.00** Ω

```
 1 3 1 2 █ X 2
5 . 0 0   Ω
```

Reactance value (reach)
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1 3 1 3 █ R 2 E
5 . 0 0   Ω
```

Resistance for phase-earth
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1314█ DIREC.  Z2
FORWARDS
```
```
REVERSE
```
```
NON-DIRECTIONAL
```

Direction for zone Z2: can be

FORWARDS	(line direction) or
REVERSE	(busbar direction)
NON–DIRECTIONAL	(either direction)

```
 1315█ T2  1PHASE
0.30  s
```

Delay for zone Z2, single-phase faults
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z2 for single-phase faults)

```
 1316█ T2  >1PHASE
0.30  s
```

Delay for zone Z2, multi-phase faults
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z2 for multi-phase faults)

Normally, addresses 1315 and 1316 are set to the same value.

Third zone Z3

```
 1321█ R3
5.00  Ω
```

Resistance for phase-phase
Smallest setting value: **0.05** Ω
Largest setting value: **65.00** Ω

```
 1322█ X3
10.00  Ω
```

Reactance value (reach)
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1323█ R3E
10.00  Ω
```

Resistance for phase-earth
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1324█ DIREC.  Z3
FORWARDS
```
```
REVERSE
```
```
NON-DIRECTIONAL
```

Direction for zone Z3: can be

FORWARDS	(line direction) or
REVERSE	(busbar direction)
NON–DIRECTIONAL	(either direction)

```
  1 3 2 5▮ T 3
0 . 6 0   s
```

Delay for zone Z3
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z3)

Controlled (overreach) zones Z1B and Z1L – address block 14

The two overreach zones Z1B and Z1L are controlled stages. They do not influence the normal zones Z1, Z2, Z3. There is, therefore, no switch-over, rather the overreach zones will be switched effective or non-effective by the appropriate criteria. If one of these stages is not required the corresponding settings are irrelevant.

Zone Z1B is effective in conjunction with rapid reclosing (first shot) and/or teleprotection modes. It can also be activated via a binary input circuit. It is generally set at at least 120 % of the line length.

The zone Z1L is used for multiple reclosing, after the second shot (DAR = "delayed auto-reclosure"). It can also be activated via a binary input circuit.

Both stages can also be used for selection between cable and overhead line sections in case of mixed lines (refer to Section 6.3.4.1 for more details). Each of these stages have their own delay time whereby, for Z1B, one can again distinguish between single-phase (T1B 1PHASE) and multi-phase faults (T1B >1PHAS).

Measurement direction can also be set individually for the overreach zone.

NOTE: The directions set for zone Z1B and Z1L apply in general for this stage, independent of the cause which leads to activation of one of these zones.

```
  1 4 0 0▮ D I S T . P R O T .
C O N T R O L L E D   Z O N E S
```

Beginning of block
"Distance protection, controlled zone Z1B"

Overreach zone Z1B (controlled by RAR, teleprotection signals or binary input)

```
  1 4 0 1▮ R 1 B
1 . 5 0   Ω
```

Resistance for phase-phase
Smallest setting value: **0.05** Ω
Largest setting value: **65.00** Ω

```
  1 4 0 2▮ X 1 B
3 . 0 0   Ω
```

Reactance value (reach)
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
  1 4 0 3▮ R 1 B E
3 . 0 0   Ω
```

Resistance for phase-earth
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1404█DIREC.  Z1B
FORWARDS
```
```
REVERSE
```
```
NON-DIRECTIONAL
```

Direction for zone Z1B: can be
FORWARDS (line direction) or
REVERSE (busbar direction)
NON–DIRECTIONAL (either direction)

```
 1405█T1B  1PHASE
0.00  s
```

Delay for zone Z1B, single-phase faults
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z1B for single-phase faults)

```
 1406█T1B  >1PHAS
0.00  s
```

Delay for zone Z1B, multi-phase faults
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z1B for multi-phase faults)

Normally, addresses 1405 and 1406 are set to the same value.

Overreach zone Z1L (controlled by DAR or binary input)

```
 1411█R1L
2.00  Ω
```

Resistance for phase–phase
Smallest setting value: **0.05** Ω
Largest setting value: **65.00** Ω

```
 1412█X1L
4.00  Ω
```

Reactance value (reach)
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1413█R1LE
4.00  Ω
```

Resistance for phase–earth
Smallest setting value: **0.05** Ω
Largest setting value: **130.00** Ω

```
 1414█DIREC.  Z1L
FORWARDS
```
```
REVERSE
```
```
NON-DIRECTIONAL
```

Direction for zone Z1L: can be
FORWARDS (line direction) or
REVERSE (busbar direction)
NON–DIRECTIONAL (either direction)

```
 1415█T1L
0.00  s
```

Delay for zone Z1L
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip in zone Z1L)

6.3.4.3 Selection of the fault detection program – address block 15

The distance protection relay has a variety of fault detection functions from which the optimum can be chosen for the system under consideration (refer to Section 2.3 Ordering data).

The possible fault detection methods are individually described in Section 4.2.1. If the device is equipped with more than one fault detector, selection has been made during configuration according Section 5.4.2 (address 7813). The following paragraphs show the parameters for all fault detection facilities. When paging through the display, only those addresses appear which are valid for the selected fault detection method(s).

```
1500 DIST.PROT.
FAULT DETEC.PROG
```

Beginning of the block “Distance protection, fault detection program”

```
1501 PROG. U/I
LE:Uphe/LL:Uphph
```

only with voltage controlled (U/I) fault detection: measurement control
U_{Ph-E} with detected earth fault
U_{Ph-Ph} without detected earth fault

```
LE:Uphph/LL:Uphp
```

U_{Ph-Ph} with detected earth fault
U_{Ph-Ph} without detected earth fault

```
LE:Uphe/LL:Uphe
```

U_{Ph-E} with detected earth fault
U_{Ph-E} without detected earth fault

```
LE:Uphe/LL:I>>
```

U_{Ph-E} with detected earth fault
$I>>$ without detected earth fault overcurrent pick-up only

NOTE: Measurement control with *LE:Uphph/LL:Uphph* excludes measurement of phase-to-earth loop; thus it is not used for systems with earthed starpoint unless a different protective relay or function is activated for earth faults.

```
1503 PROG. ZA
LE:Zphe/LL:Zphph
```

only for impedance fault detection
(fix impedance ZA): Measurement control
Z_{Ph-E} with detected earth fault
Z_{Ph-Ph} without detected earth fault

```
LE:Zphe/LL:I>>
```

Z_{Ph-E} with detected earth fault
$I>>$ without detected earth fault overcurrent pick-up only

6.3.4.4 General setting for fault detection – address block 16

```
  1 6 0 0█ D I S T . P R O T .
F A U L T   D E T E C T I O N
```

Beginning of the block “Fault detection for distance protection”

Parameters for **overcurrent detection** are set in address 1601 (for phase currents) and 1602 (for earth current). The determining factor for overcurrent setting is the maximum possible operating current. Pick-up under conditions of permissible overload must be excluded! The threshold value Iph>> (Address 1601) must therefore be set above the maximum anticipated (over-)load current (approx. 1.2 times). It must then be checked that the minimum short circuit current is above this limit. If that is not the case, a relay with voltage controlled (U/I) fault detection or impedance detection is necessary.

For the earth fault current, a separate setting value Ie> (Address 1602) is provided. In solidly earthed networks this would be set below the minimum expected earth fault current value. In isolated or compensated networks, the setting value for correct detection of double earth faults must be set below the minimum expected double earth fault current.

Calculation example

For the line used in the example in Section 6.3.4.2 the maximum operating current is 680 A with 600 A/5 A current transformers and the minimum short circuit current is assumed to be 1200 A. The following setting would therefore be used:

$$\frac{I \gg}{I_N} = \frac{I_{Lmax}}{I_N} \cdot 1.2 = \frac{680A}{600A} \cdot 1.2 = 1.36$$

This value lies adequately below the minimum short circuit current of 1200 A/600 A = 2 · I_N.

The condition for the minimum short circuit current is also valid for earth fault currents in solidly earthed networks, equally for double earth faults in either system.

```
  1 6 0 1█ I p h > >
1 . 8 0   I / I n
```

Overcurrent detection threshold value $I_{Ph}\gg$
Smallest setting value: **0.25** · I_N
Largest setting value: **4.00** · I_N

```
  1 6 0 2█ I e >
0 . 5 0   I / I n
```

Threshold value for earth current detection $I_E>$
Smallest setting value: **0.10** · I_N
Largest setting value: **1.00** · I_N

6.3.4.5 Setting for voltage controlled fault detection (U/I)

NOTE: This section applies only for models with voltage controlled fault detection facility (7SA510★–★★★★**2**– or –★★★★**3**–) and when this method has been selected (Section 5.4.2). Otherwise it can be passed over.

The meaning of the parameters can be gathered from the current/voltage characteristic shown in Figure 6.3. Iph> (address 1611) is the minimum operating current, the prerequisite for each phase pick-up. It must be set below the minimum presumed short-circuit current.

The voltage dependent branch can be set either for phase-to-earth voltages in addresses 1612 and 1613 or for phase-to-phase voltages under addresses 1614 and 1615. This depends on whether voltage control is selected with U_{phph} or with U_{phe}. The characteristic must be set such that it has a sufficient safety distance from the maximum operation current at minimum operation voltage. In cases of doubt one should check the pick-up conditions against the characteristic. With comprehensive networks, short-circuit calculations may be useful.

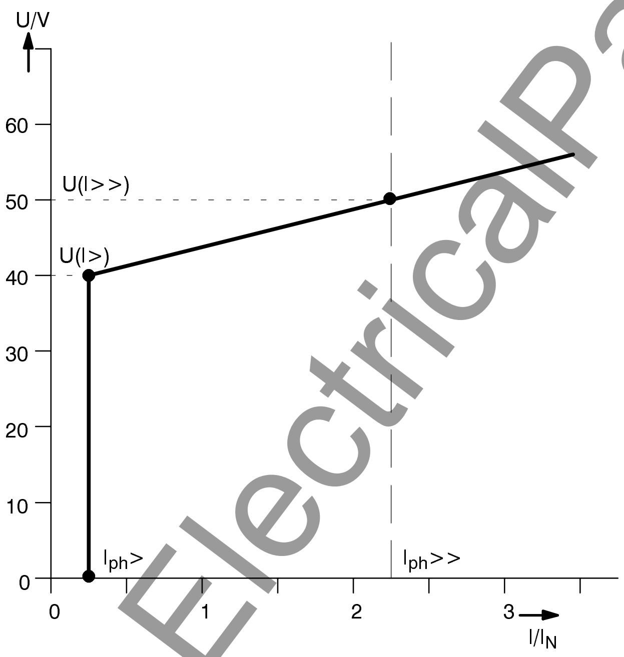


Figure 6.3 Voltage controlled fault detectors, U/I characteristic

In most cases, control with U_{Ph-E} for earth faults and U_{Ph-Ph} for earth-free faults is preferred in systems with **earthed** starpoint (address 1501 *LE:Uphe/LL:Uphph*). This ensures maximum sensitivity for all kinds of fault. A pre-requisite is, however, that the earth fault criteria are satisfied at the measuring point safely for all earth faults (refer to Section 4.2.1.1). Otherwise, control with U_{Ph-E} for all kinds of fault is reasonable (address 1501 *LE:Uphe/LL:Uphe*), which is less sensitive for earth-free short-circuits. In many cases this can be accepted because phase-to-phase faults are covered by the overcurrent fault detection functions I_{ph}>>.

The possibility to control with the voltage loops U_{Ph-E} only when an earth fault has been detected is advantageous in systems with a **low-impedance earthed** starpoint, i.e. with earth fault limiting aids (so-called resistance earthing). In these systems, only earth faults are to be detected by the voltage controlled fault detection. For phase-phase faults the high-set overcurrent fault detectors I_{ph}>> will pick up. (address 1501 *LE:Uphe/LL:I>>*).

In order to prevent faulty pick-up of the earth fault detector by the oscillation transients on occurrence of a simple earth fault in **isolated** or **compensated** (Petersen–coil) networks, earth fault detection can be delayed by the parameter TIe 1PHASE (address 1801, refer to Section 6.3.4.7). If the earth current could exceed the earth fault threshold even under steady-state conditions, TIe 1PHASE should be set to ∞: pick-up on one single-phase fault is then no more possible even when a high earth current will flow. Double earth faults will, nevertheless, be detected correctly and cleared in accordance with the double fault preference program (Section 6.3.4.7).

Additionally, it is possible to make voltage control with phase-to-phase voltages only (address 1501 *LE:Uphph/LL:Uphph*). The measured line loop in this case is independent of the earth fault detection; this method excludes pick-up on earth faults absolutely, however, correct double earth fault preference is not possible.

```
  1611█ Iph>
0.20  I/In
```

Minimum operating current for fault detection I_{ph}>
Smallest setting value: **0.10** · I_N
Largest setting value: **1.00** · I_N

```
 1612█Uphe(I>>)
48  V
```

Undervoltage pick-up value at Iph>> (address 1601) (Figure 6.3); phase-to-earth voltage
Smallest setting value: **20** V
Largest setting value: **70** V

```
 1613█Uphe(I>)
48  V
```

Undervoltage pick-up value at Iph> (address 1611) (Figure 6.3); phase-to-earth voltage
Smallest setting value: **20** V
Largest setting value: **70** V

```
 1614█Uphph(I>>)
80  V
```

Undervoltage pick-up value at Iph>> (address 1601) (Figure 6.3); phase-to-phase voltage
Smallest setting value: **40** V
Largest setting value: **130** V

```
 1615█Uphph(I>)
80  V
```

Undervoltage pick-up value at Iph> (address 1611) (Figure 6.3); phase-to-phase voltage
Smallest setting value: **40** V
Largest setting value: **130** V

6.3.4.6 Settings for impedance fault detection

NOTE: This section applies only for models with impedance detection facility (7SA510★–★★★★**2**–★★★★) and when this method has been selected (Section 5.4.2). Otherwise it can be passed over.

The impedance fault detection for phase-earth is supplemented by an overcurrent stage I_{ph}>> where pick-up of the overcurrent stage only leads to detection if the associated impedance loop has been eliminated (refer to Section 4.2.1.3). The respective parameters have been set in Section 6.3.4.4.

The meaning of the parameters can be gathered from the impedance characteristic shown in Figure 6.4. The bold dots identify the setting parameters which determine the geometry of the fault detection polygon. I_{ph}> is the minimum operating current, the prerequisite for each phase pick-up. It must be set below the minimum presumed short-circuit current.

Impedance detection should, with safety, be looked upon as the ultimate protection. Taking into account intermediate feeding for remote faults, a larger, rather than smaller threshold value should be chosen. If the line carries reactive power, the pick-up threshold must lie below the reactive power impedance, however.

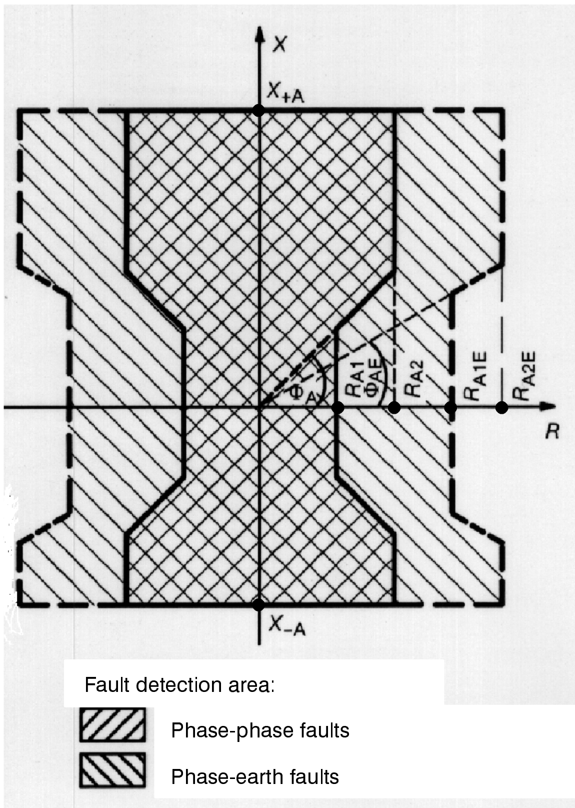


Figure 6.4 Impedance fault detection characteristic

Considering the calculation example in Section 6.3.4.2 we select approximately 2 times the value of the third zone. A calculation using primary values is superfluous in this consideration:

$$X{+}A_{sec} = \underline{\underline{38\,\Omega}}$$

For the reverse direction do not forget, that with overreach teleprotection procedures, a reverse fault must definitely be recognized if it lies within the overreach zone of the relay at the other line end. Normal setting values are approximately half those of the reach in the forwards direction.

$$X{-}A_{sec} = \underline{\underline{19\,\Omega}}$$

For the resistance setting there is a lower and an upper limit. The setting RA1 must still recognize arc faults within its tolerance range. Roughly, 2 or 3 times the value of the third zone applies here also.

For long overhead lines it must be considered that the setting in the resistive direction must have a sufficient safety margin from the minimum load impedance. The minimum load impedance occurs at maximum load current and minimum operating voltage. In this example, therefore

$$R_{Lprim} = \frac{U_{min}}{\sqrt{3} \cdot I_{Lmax}} = \frac{0.9 \cdot 110kV}{\sqrt{3} \cdot 680A}$$

$$= 84.06\Omega$$

or secondary

$$R_{Lsec} = \frac{N_{ct}}{N_{vt}} \cdot R_{Lprim} \cdot \frac{I_N}{A}$$

$$= \frac{600/5}{110/0.1} \cdot 84.06\Omega \cdot \frac{5A}{A}$$

$$= 45.85\Omega$$

A safety margin of at least 20 % should be maintained with respect to this value.

$$R_{max} = 0.8 \cdot 45.85\Omega = 36.6\Omega$$

When the power swing blocking function is used, this value must not be exceeded by the power swing polygon either, so the pick-up value in the R−direction must be set considerably smaller, in order to obtain adequate measuring clearance between the power swing polygon and the fault detection polygon (refer to Section 6.3.5)

In order to guarantee unequivocal criteria for discrimination between load operation and a short-circuit, in the case of long, high-loaded lines − in other words if above preconditions cannot be fulfilled − the characteristic can be set dependent on the phase angle: the R intersection RA2 (address 1625) then applies to phase angles above the value ANGLE PHIA (address 1628), the R intersection RA1 (address 1624) to phase angles below ANGLE PHIA. The safety margin from the minimum load impedance is necessary only for RA1. The angle ANGLE PHIA must be set higher than the maximum phase angle during load transport. Fundamentally, it is most important that the fault detection characteristic never exceeds the load impedance during operation.

For earth faults, a separate resistance tolerance and a separate limit angle ANG. PHIAE can be set (address 1629). Load impedance can be ignored for the phase-earth faults unless the pick-up value of the earth current detection (address1602) could be exceeded by zero sequence currents caused by asymmetries in currents.

The power swing detection uses phase-to-phase quantities. Thus, setting of the R−section for phase-earth measurement are irrelevant.

```
 1621▮ Iph>
0.20  I/In
```

Minimum current for impedance detection
Smallest setting value: **0.10** · I_N
Largest setting value: **4.00** · I_N

```
 1622▮ X+A
12.00  Ω
```

Reactance value (reach) forwards
Smallest setting value: **0.10** Ω
Largest setting value: **200.00** Ω

```
1623 X-A
2.50 Ω
```

Reactance value (reach) reverse
Smallest setting value: **0.10** Ω
Largest setting value: **200.00** Ω

```
1624 RA1
6.00 Ω
```

Resistance for phase-phase; phase angle below ANGLE PHIA (address 1628) (load area)
Smallest setting value: **0.10** Ω
Largest setting value: **200.00** Ω

```
1625 RA2
6.00 Ω
```

Resistance for phase-phase; phase angle above ANGLE PHIA (address 1628) (fault area)
Smallest setting value: **0.10** Ω
Largest setting value: **200.00** Ω

```
1626 RA1E
12.00 Ω
```

Resistance for phase-earth; phase angle below ANG. PHIAE (address 1629) **0.10** Ω
Smallest setting value: **200.00** Ω
Largest setting value:

```
1627 RA2E
12.00 Ω
```

Resistance for phase-earth; phase angle above ANG. PHIAE (address 1629)
Smallest setting value: **0.10** Ω
Largest setting value: **200.00** Ω

```
1628 ANGLE PHIA
45.0 °
```

Limit angle for phase-phase measurement, below which resistance intersection RA1 (address 1624) is valid (load area), above which resistance intersection RA2 (address 1625) is valid (fault area)
Smallest setting value: **30.0**°
Largest setting value: **80.0**°

```
1629 ANG. PHIAE
45.0 °
```

Limit angle for phase-earth measurement, below which resistance intersection RA1E (address 1626) is valid, above which resistance intersection RA2E (address 1627) is valid
Smallest setting value: **30.0**°
Largest setting value: **80.0**°

Note: Distinction between RA1 and RA2 can be made for use on long, heavy-loaded lines. In other cases both the parameters are to be set to the same value. Distinction between RA1E and RA2E is usually not necessary.

6.3.4.7 Settings for determination of the faulted loop – address blocks 17 and 18

The selection of valid short-circuited loops varies considerably, dependent upon whether the system starpoint is earthed, isolated or compensated (Petersen coil). Accordingly, the treatment of the system star-point has to be known before the device is put into operation (see Section 6.3.3.1; address 1102).

The parameter block 17 is important for networks with solidly earthed starpoint. With unearthed starpoint it is irrelevant and can be passed over.

Parameter block 18 is for isolated and compensated networks. For networks with earthed star-points it is irrelevant and can be passed over.

In **earthed networks**, an earth fault can be detected by earth current or displacement voltage (address 1701). Fault loop selection for double earth faults can be programmed under address 1703. Normally, the *PHASE–PHASE* loop will be selected. If high footing resistances are expected then *LAGGING PH–E* loop may be more favourable because the leading phase-earth loop tends to overreach. In some cases (fault resistance phase-phase larger than phase-earth) *LEADING PH–E* can be more favourable.

For three phase pick-up, the setting of address 1704 determines the type of loop which will be selected. 3PH FAULTS = *E/F CONTROL* means that if there is no earth fault detected then a phase-phase loop will be measured but with earth fault detection a phase loop phase-earth. The other possibilities *PH–PH ONLY* and *PH–E ONLY* are independent of the I_E pick-up.

Under address 1705, one can select whether, under conditions of a single phase pick-up without earth fault detection, a conductor-earth loop is selected. The setting 1PH FAULTS = *PHASE–EARTH* only makes sense in earthed networks when no current or only extremely low current can flow in the case of an earth fault. For impedance fault detection, this parameter is irrelevant because impedance fault detection always is related to a fault *loop*.

```
 1700 FAULT IN
EARTHED NETWORKS
```

Beginning of block
"Determination of the fault loop in solidly earthed networks"

```
 1701 Ue>
20 V
```

Displacement voltage (Ue = $\sqrt{3} \cdot U_0$) for earth fault detection in earthed systems.
Smallest setting value: **2** V
Largest setting value: **100** V
or ∞ (no earth fault detection based on displacement voltage measurement)

```
 1703 PHPHE FLTS
PHASE-PHASE ONLY
```

For double earth faults in earthed networks, measurement is carried out in

PHASE–PHASE loop *ONLY*

```
LEADING PH-E
```

*PH*ase–*E*arth loop of the *LEADING* phase

```
LAGGING PH-E
```

*PH*ase–*E*arth loop, of the *LAGGING* phase

```
 1704 3PH FAULTS
E/F CONTROL
```

With fault detection in all 3 phases

*E/F CONTROL*led – fault loop is selected dependent on earth fault detection

```
PHASE-PHASE ONLY
```

PHASE–PHASE ONLY – fault loop phase-to-phase is selected even with earth fault detection

```
PHASE-EARTH ONLY
```

PHASE–EARTH ONLY – fault loop phase-to-earth is selected even without earth fault detection

```
 1705█ 1PH FAULTS
PHASE-EARTH

PHASE-PHASE
```

with fault detection in one single phase

PHASE–EARTH – fault loop phase-to-earth is selected, even without earth fault detection

PHASE–PHASE – fault loop phase-to-phase is selected

In **isolated or compensated networks** it must be ensured that the preference under conditions of double (cross-country) earth faults is the same throughout the whole electrically connected network (address 1803). To prevent pick-up during the transient swings on inception of a single phase fault, I_E pick-up is delayed for single phase pick-up by setting TIe 1PHASE at 0.04 seconds (address 1801). In extended compensated networks this time should be increased. If it is set to ∞ no start of the distance protection takes place if only one phase picks up. If, however, a cross-country double earth fault occurs after detection of a simple earth fault, this is recognized by the relay and measured according to the selected double earth fault preference program. Single earth fault is recognized by the displacement voltage Ue> (address 1802); delay TIe 1PHASE is not effective thereafter: a further earth fault after occurrence of a single earth fault can only be a double earth fault.

```
 1800█ FAULT
NON-EARTHED NET
```

Beginning of block
"Determination of the fault loop in non-earthed (isolated or compensated) networks"

```
 1801█ TIe 1PHASE
0.04 s
```

Delay for I_E detection with single-phase pick-up in non-earthed systems
Smallest setting value: **0.04 s**
Largest setting value: **0.50 s**
and ∞ (I_E pick-up totally avoided)

```
 1802█ Ue>
40 V
```

Displacement voltage (Ue = $\sqrt{3} \cdot U_0$) for earth fault detection in non-earthed systems. *Note:* Address 1110 has no influence on this pick-up value
Smallest setting value: **10 V**
Largest setting value: **100 V**

```
 1803█ PHASE PREF
L3(L1) ACYCLIC

L1(L3) ACYCLIC
L2(L1) ACYCLIC
L1(L2) ACYCLIC
L3(L2) ACYCLIC
L2(L3) ACYCLIC
L3(L1) CYCLIC
L1(L3) CYCLIC
```

Phase preference for double (cross-country) earth faults. For isolated or compensated networks the preference sequence **must** be the same throughout the whole electrically interconnected network.

6.3.5 Settings for the power swing supplement – address block 20

NOTE: This section applies only for models with power swing option (model 7SA510★–★★★★★–★★★**1**/**3**). Otherwise it can be passed over. The power swing supplement only operates if it is configured (address 7820 POWER–SWING = *EXIST*, refer Section 5.4.2) and if the device has impedance fault detection.

Three possible programs can be selected for the power swing blocking function; in addition, a tripping function in the case of unstable power swings (asynchronism) can be programmed. For the detection of power swings, the following considerations are of importance (see also Section 4.3):

The distance between power swing polygon and fault detection polygon (phase-phase) should be as large as possible; the R–intersection is decisive. On the other hand, the power swing polygon must not extend into the operational impedance!

To set the rate of change of the impedance vector, both the maximum power swing frequency in the instant of entry of the impedance vector into the power swing polygon and the time required by 7SA510 for the detection of the power swing must be taken into consideration. Under the most difficult conditions, at least 35 ms should be allowed for the detection of a power swing.

```
 2000
POWER SWING
```

Beginning of block
"Power swing detection"

```
 2002 P/S PROGR.
BLOCK ALL
```

Functional program of the power swing supplement:
- blocking of all distance zones

```
BLOCK Z1 ONLY
```

- blocking of the first zone only

```
BLOCK ALL BUT Z1
```

- blocking of the higher (delayed) zones only, Z1 is released

```
OUT-OF-STEP TRIP
```

- trip in the event of unstable power swing (asynchronism), all zones are blocked

```
 2003 Delta R
5.00 Ω
```

Distance ΔR between power swing polygon and fault detection polygon (secondary, see 6.3.4.6), in Ω

Smallest setting value: **0.10** Ω

Largest setting value: **50.00** Ω

```
 2004 dR/dT
20 Ω/s
```

Rate of change of the power swing vector between the power swing polygon and fault detection polygon, in Ω/s, below which the power swing is detected.

Smallest setting value: **0** Ω/s

Largest setting value: **200** Ω/s

```
 2005 P/S T-ACT.
∞ s
```

Power swing action time:

The function can be limited to the time P/S T–ACT. With the setting ∞, the power swing function is effective until the impedance vector has left the power swing polygon again

Smallest setting value: **0.01** s

Largest setting value: **32.00** s

and ∞ (only after discontinuation of the power swing criterion)

6.3.6 Settings for teleprotection – address blocks 21 and 22

In programming of the scope of the functions (Section 5.4.2) one selects whether a permissive underreach transfer scheme (*UNDERREACH*) or a permissive overreaching transfer scheme (*OVERREACH*) shall be used for the teleprotection (address 7821). If the teleprotection is programmed as *NON–EXIST,* this Section is irrelevant.

The function of the various procedures is described in Section 4.4.

6.3.6.1 Underreach transfer schemes -- address block 21

For the underreach transfer schemes, the transmission signal prolongation T–SEND–PRL (address 2103) shall ensure that the transmission signal safely reaches the opposite line end, even when the signal from the transmitting line end is interrupted quickly and/or when the transmission time is relatively long. Similar considerations can apply for the received signal prolongation T–REC–PROL (address 2104). Delay of the first zone Z1 does not delay the transmission signal but an own time delay T–SEND–DEL (address 2106) is available.

```
2100 TELEPROTEC
PERM. UNDERREACH
```

Beginning of block "Teleprotection, permissive underreach transfer schemes"

```
2101 PUTT
ON
```

```
OFF
```

Permissive underreach transfer trip is

ON switched on

OFF switched off

```
2102 PUTT MODE
Z1B ACCELERATION
```

Mode selection of permissive underreach transfer trip:
Zone acceleration Z1B with T1B

```
FD ACCELERATION
```

Trip with fault detection non-directional (instantaneous)

```
2103 T-SEND-PRL
0.05 s
```

Prolongation of transmit signal with underreach modes

Smallest setting value: **0.01** s
Largest setting value: **32.00** s

```
2104 T-REC-PROL
0.00 s
```

Prolongation of received signal with underreach modes

Smallest setting value: **0.00** s
Largest setting value: **32.00** s

```
2106 T-SEND-DEL
0.00 s
```

Delay of transmission signal in permissive underreach modes (T1 is not decisive for transmission signal delay even if a delay is set)

Smallest setting value: **0,00** s
Largest setting value: **32,00** s

6.3.6.2 Overreach transfer schemes – address block 22

For the overreach transfer schemes it must be noted that the normal zones – particularly therefore also Z1 – operate independently. If the distance protection devices at the two line ends have significantly different command times (more than approximately 40 ms difference), the first zone with delay T1 shall be appropriately delayed (addresses 1305 and 1306) for the release procedures *Z1B RELEASE, FD DIREC RELEASE, Z1B UNBLOCK* and *FD UNBLOCK*.

For the blocking procedures *Z1B BLOCKING* and *REVERS INTERLOCK,* T1B (addresses 1405 and 1406) must be sufficiently delayed that the blocking signal is safely transmitted under conditions of external fault. For *PILOT WIRE COMP* a delay of T1B is equally necessary when significant differences are present between the pick-up and drop-off times of the devices at two line ends. Additionally, a sufficient time period must remain between fault detection pick-up and trip signal in zone Z1B so that the closed wire loop can safely be interrupted (by fault detection) and reclosed (by trip in Z1B). If necessary, T1B must be delayed for this case, too.

The transient blocking time T–TRANSBLO (address 2203) must be longer than the transmission time; in addition, the duration of heavy transient reactions at the inception and interruption of short circuits has to be taken into consideration.

The time T–WAIT (address 2204) is a waiting time for initiation of transient blocking: When the distance protection has detected a fault, the reception circuit (release) will be blocked if no reception signal has been received within this time; thereafter a reception signal can only be effective after the transient blocking time T–TRANSBLO (refer also to Section 4.4.11). If set to ∞, no blocking takes place for this case.

Prolongation of the transmission signal T–SEND–PRL (address 2206) is only effective during the release procedure when the relay has already issued a tripping command. This also guarantees release of the other line end when the short circuit is rapidly cleared by the independent zone Z1. In the blocking procedure *Z1B BLOCKING* the transmission signal is always prolonged by this time.

If a delay T1B is set for the overreach zone Z1B, this does not lead to delay of the transmit signal but transmission can be delayed by the time T–SEND DEL (address 2212).

```
 2200 TELEPROTEC
PERM. OVERREACH
```

Beginning of block "Teleprotection, permissive overreach transfer schemes"

```
 2201 POTT
ON
```

```
OFF
```

Permissive overreach transfer trip is

ON switched on

OFF switched off

```
 2202 POTT MODE
Z1B RELEASE
```

```
FD DIREC RELEASE
```

```
Z1B UNBLOCK
```

```
FD UNBLOCK
```

```
Z1B BLOCKING
```

```
PILOT WIRE COMP.
```

```
REVERS INTERLOCK
```

Mode selection of permissive overreach transfer trip:

Z1B RELEASE – permissive overreach with zone Z1B, release mode

FD DIREC RELEASE – directional comparison, release fault detection

Z1B UNBLOCK – Unblocking mode with zone Z1B

FD UNBLOCK – Unblocking mode with fault detection directional

Z1B BLOCKING – Blocking mode with zone Z1B

PILOT WIRE COMP. – Comparison Z1B via pilot wires

REVERS INTERLOCK – Reverse interlocking

```
  2203█ T-TRANSBLO
0.05  s
```

Transient blocking time (after external fault)
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

```
  2204█ T-WAIT
 ∞   s
```

Waiting time before transient blocking with missing reception signal
Smallest setting value: **0.01** s
Largest setting value: **32.00** s
or ∞, i.e. no transient blocking with missing reception
Attention! In blocking mode (address 2202 POTT MODE = *Z1B BLOCKING*), the waiting time must be set to the smallest value in order to ensure transient blocking after reception!

```
  2206█ T-SEND-PRL
0.05  s
```

Prolongation of the transmission signal; effective only with *Z1B BLOCKING* or after a trip signal has been issued
Smallest setting value **0.01** s
Largest setting value **32.00** s

```
  2210█ POTT  DirFD
FORWARDS
```

```
REVERSE
```

```
NON-DIRECTIONAL
```

Effective direction for directional POTT modes (*FD DIREC RELEASE* and *FD UNBLOCK*) (not relevant for the other POTT modes)

FORWARDS Normal application
REVERSE
NON−DIRECTIONAL } for special application only

```
  2212█ T-SEND  DEL
0.00  s
```

Delay of transmission signal in permissive overreach modes (T1B is not decisive for transmission signal delay even if a delay is set)
Smallest setting value: **0.00** s
Largest setting value: **32.00** s

For line ends with **weak** power **infeed** the echo function is reasonable when using overreach transfer schemes with release (permission) signals, so that the strong feeding line end can be released even when the weak infeed end does not pick up. For other transfer schemes the echo function is not effective; respective parameters are of no concern, then.

The echo delay time T−ECHO−DEL (address 2221) must be set to such a long duration that differing reaction times of the fault detectors of the protective relays at both line ends cannot result in a false echo signal in the case of external faults.

The echo impulse duration T−ECHO−IMP (address 2222) can be adjusted in accordance with the requirements of the network. It has to be long enough so that even with differing operating times of the protective devices at both line ends and of the transmission devices, recognition of the receive signal is guaranteed.

To avoid false echo signals after disconnection of the line, a blocking time for echo generation T−ECHO−BLO (address 2223) is set. This should include the echo delay time T−ECHO−DEL plus the echo impulse duration T−ECHO−IMP plus a safety margin of at least twice the transmission time.

```
  2 2 2 0█ E C H O
O N
```
```
O F F
```

The echo function for weak-infed line ends is

ON switched on

OFF switched off

```
  2 2 2 1█ T - E C H O - D E L
0 . 0 4   s
```

Echo delay time
Smallest setting value: **0.01** s
Largest setting value: **32.00** s
and ∞ (no echo signal when circuit breaker is closed)

```
  2 2 2 2█ T - E C H O - I M P
0 . 0 5   s
```

Duration of echo impulse
Smallest setting value: **0.02** s
Largest setting value: **32.00** s

```
  2 2 2 3█ T - E C H O - B L O
0 . 1 5   s
```

Echo blocking time
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

6.3.7 Settings for user definable logic functions – address block 23

Two user definable logical functions are available. They can operate if they are configured as EXIST under address 7823 during configuration of the scope of functions (refer to Section 5.4.2). Each function can be triggered by binary inputs and marshalled to binary outputs (LEDs, signal relays, trip relays). For pick-up and drop-off, delay times can be set in address block 23.

Note that the set times are pure delay times which do not include the inherent operating times of the binary inputs and outputs.

```
  2 3 0 0█ U S E R
L O G I C   F U N C T I O N S
```

Beginning of block
"User definable logical functions"

```
  2 3 0 2█ T - P I C K U P
1 0 . 0 0   s
```

Pick-up time delay for the first user definable logical function
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞, i.e. no start

```
  2 3 0 3█ T - D R O P   1
0 . 0 0   s
```

Drop-off time delay for the first user definable logical function
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞, i.e. drop-off only by reset signal

```
 2305█T-PICKUP 2
0.00 s
```

Pick-up time delay for the second user definable logical function
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞, i.e. no start

```
 2306█T-DROP 2
0.00 s
```

Drop-off time delay for the second user definable logical function
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞, i.e. drop-off only by reset signal

6.3.8 Settings for emergency overcurrent time protection – address block 26

If the measured voltage fails, e.g. because the v.t. protection m.c.b. has tripped, the relay can still be operated as a definite time overcurrent protection (emergency overcurrent function). A pre-condition is that the emergency protection has been configured under address 7826 as EMERG. O/C = *EXIST* (refer to Section 5.4.2).

The parameters of the overcurrent time protection are set in block 26. The pick-up value I> (address 2612) must be set above the maximum expected (over)load current (approximately 1.2 times). The pick-up value I>> (address 2602) allows a current grading. The corresponding delay times T−I> (address 2613) and T−I>> (address 2603) are set in such a way that they allow the highest possible degree of selectivity. In a ring network, for example, one can set up a deliberate break point, with rapid interruption, to allow for emergency cases (e.g. fault in the v.t. secondary circuit). The resultant radial networks can be protected in accordance with the conventional practice of grading of definite time overcurrent protection.

For earth faults, both the pick-up value IE> (address 2642) and the delay time T−IE> (address 2643) can be set separately. In this way, it is often possible to achieve a separate grading with shorter times for earth faults.

During emergency operation teleprotection communication is not possible.

If the protection system is required to operate exceptionally for a certain time period (e.g. because of missing voltage transformers), **only** as definite time overcurrent protection, the distance protection elements can be blocked by input of the external signal ”v.t. protective m.c.b. tripped”.

If parts of the overcurrent protection are not required at all, then the corresponding delay times can be set at ∞.

Addresses 2621 and 2651 determine which stages are effective if the circuit breaker is manually closed. A pre-requisite is, that the manual close command for the breaker is repeated via a binary input to the relay so that it is informed about manual closing of the breaker. *INEFFECTIVE* means that the stages operate according to the settings.

It is also possible to carry out auto-reclosure in the emergency overcurrent protection mode. This has to be entered into the device during configuration under address 7926 (refer to Section 5.4.3). In this case, the I>> stage with T−I>> is decisive for the auto-reclosure. Final disconnection is carried out via I> with T−I> delayed. I>> and I> should then be set to the same value; T−I>> is set undelayed (= 0).

Address 2623 determines whether the I>> stage in effective only in conjunction with auto-reclosure or whether it operates independently.

Note that the set times are pure delay times which do not include the inherent operating times.

```
2600 EMERGENCY
OVERCURRENT PROT
```

Beginning of block
"Emergency overcurrent time protection"

```
2601 EMERG. O/C
ON
```
```
OFF
```

Emergency overcurrent time protection is

ON switched on

OFF switched off

```
2602 I>>
2.00 I/In
```

High overcurrent detection value I>> for phase currents
Smallest setting value: **0.50** · I_N
Largest setting value: **9.99** · I_N

```
2603 T-I>>
0.30 s
```

Delay for I>> phase currents
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip with I>> phases)

```
2612 I>
1.00 I/In
```

Overcurrent detection value I> for phase currents
Smallest setting value: **0.10** · I_N
Largest setting value: **4.00** · I_N

```
2613 T-I>
0.50 s
```

Delay for I> phase currents
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip with I> phases)

```
2621 M/CLOSE PH
I>> UNDELAYED
```
```
I> UNDELAYED
```
```
INEFFECTIVE
```

Phase overcurrent stage which is effective during manual closing of the circuit breaker:

I>> i.e. I>> stage but without delay T−I>>

I> i.e. I> stage but without delay T−I>

INEFFECTIVE, i.e. phase current stages operate as parameterized

```
2623 RAR ZONE P
I>> WITH AR
```
```
I>> ALWAYS
```

AR-function operates with the I>>stage:

I>> WITH AR i.e. I>> is released only if AR is ready

I>> ALWAYS i.e. I>> stage operates always, independent of the AR function

```
2642 IE>
0.20 I/In
```

Overcurrent detection value I_E> for earth currents
Smallest setting value: **0.10** · I_N
Largest setting value: **4.00** · I_N

```
 2 6 4 3 █ T - I E >
0 . 3 0   s
```

Delay for $I_E>$ (earth current)
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip with I> earth)

```
 2 6 5 1 █ M / C L O S E   E
I E >   U N D E L A Y E D

I N E F F E C T I V E
```

Earth overcurrent time stage which is effective during manual close of the circuit breaker:

IE> UNDELAYED i.e. the $I_E>$ –stage but without delay

INEFFECTIVE earth current stage operates as parameterized even during manual closure

6.3.9 Settings for thermal overload protection – address block 27

The relay includes a thermal overload protection function (refer to Section 4.7). This can operate only when it is configured to THERMAL OL = *EXIST* under address 7827 during configuration of the device functions (refer to Section 5.4.2).

Cables are particularly endangered by overloads of longer duration. These overloads cannot and should not be detected by the short-circuit protection. A back-up stage of the distance protection, for example, must be set sufficiently high so as to only detect short-circuits. Only short delays are permitted for short-circuit protection. These short time delays, however, do not permit measures to unload the overloaded cable nor to utilize its (limited) overload capacity.

The protection relay 7SA510 includes an overload function with a thermal trip characteristic which can be matched to the overload capacity of the protected cable. This function is usually not required for overhead lines as the current carrying capacity of overhead lines is generally not defined.

The overload protection function can be set to be inoperative, to initiate alarms only or to initiate tripping (including alarm) (address 2701).

The rated current of the current transformers is used as the base current for the overload measurement. The setting factor k is determined by the ratio of the continuously permissible thermal current I_{max} to the rated current:

$$k = \frac{I_{max}}{xI_N}$$

The permissible continuous current depends on cross-section, insulation material, type of construction and method of installation of the cable, etc. In general, the magnitude of the current can be taken from widely available tables or otherwise is to be stated by the manufacturer.

The heating-up time constant τ depends on the cable data and the cable surroundings. If the time constant is not readily available, it can be calculated from the short-term overload capacity of the cable. Frequently, the 1 s current, i.e. the maximum permissible current for 1 s duration, is known or can be taken from tables. The time constant can then be calculated according to the following formula:

$$\text{Setting value } \tau[\text{min}] = \frac{1}{60} \cdot \left(\frac{\textit{permissible } 1 \textit{ s current}}{\textit{continuously permissible current}}\right)^2$$

If the short-time overload capacity is stated for a duration other than 1 s, then that short-term current is inserted into the above formula instead of the 1 s current. However, the result is then multiplied with the stated duration, i.e. in case of an 0.5 s current:

$$\frac{\mathbf{0.5}}{60} \cdot \left(\frac{\textit{permissible } \mathbf{0.5} \textit{ s current}}{\textit{continuously permissible current}}\right)^2$$

It should be noted that the result becomes more inaccurate the longer the stated duration of the current becomes.

```
 2700█THERMAL
OVERLOAD PROT.
```

Beginning of block "Thermal overload protection"

```
 2701█THERMAL OL
ALARM ONLY
```

```
ON
```

```
OFF
```

Thermal overload protection can be set to

issue *ALARM*s *ONLY* or

be switched *ON* i.e. trip and alarms or

be switched *OFF*

```
 2702█K-FACTOR
1.10
```

Setting value of k−factor = I_{max}/I_N
Setting range: **0.10** to **4.00**

```
2203█T-CONSTANT
100.0 min
```

Time constant τ
Setting range: **1.0** to **999.9** min

By setting a warning temperature rise (address 2704), an alarm can be output before the trip temperature rise is reached, so that, for example, by prompt load shedding tripping may be prevented.

A further current warning stage is available (address 2705). This can be set as a factor of the rated current and should be equal or less than the continuously admissible current. It can be used besides the temperature warning stage or instead of that. When setting $\Theta_{warn}/\Theta_{trip}$ to 100 %, the temperature warning is practically ineffective.

A choice can be made whether the temperature rise which is decisive for the threshold stages, is the maximum calculated temperature rise of the three conductors, the mean value of the calculated temperature rises of the three conductors, or the temperature rise calculated from the maximum current of the three conductors (address 2706).

```
 2704█Θ WARN
90 %
```

Thermal warning stage, in % of trip temperature rise $\Theta_{warn}/\Theta_{trip}$
Setting range: **50** % to **100** %

```
 2705█I WARN
1.00 I/In
```

Current warning stage; set as a multiple of I_N
Setting range: **0.10** · I_N to **4.00** · I_N

```
 2706█O/L CALCUL
Θ MAX
```

```
Θ MEAN
```

```
Θ FROM IMAX
```

Calculation method decisive for thermal stages

*max*imum of the *temperature* rises of the three conductors

mean value of the *temperature* rises of the three conductors

temperature rise calculated *from* the *max*imum conductor *current*

6.3.10 Settings for measured value monitoring − address block 29

The different monitoring functions of the protective relay are described in Section 4.13.4. They partly monitor the relay itself, partly the steady-state measured values of the transformer circuits.

The sensitivity of the measured value monitoring can be changed in block 29. The factory settings are sufficient in most cases. If particularly high operational asymmetries of the currents and/or voltages are expected, or if, during operation, one or more monitoring functions react sporadically, then sensitivity should be reduced.

NOTE: Prerequisite for correct function of the measured value monitors is the proper setting of the general power system data (Section 6.3.3.1), especially the parameter concerning earth current matching factor.

```
 2900█ MEAS.VALUE
SUPERVISION
```

Beginning of block
"Measured value supervision"

```
 2901█ SYM.Uthres
50 V
```

Voltage threshold (phase-phase) above which the symmetry monitoring is effective (see Figure 4.46)
Smallest setting value: **10** V
Largest setting value: **100** V

```
 2902█ SYM.Fact.U
0.75
```

Symmetry factor for the voltage symmetry = slope of the symmetry characteristic (see Figure 4.46)
Smallest setting value: **0.58**
Largest setting value: **0.95**

```
 2903█ SYM.Ithres
0.50 I/In
```

Current threshold above which the symmetry monitoring is effective (refer to Figure 4.45)
Smallest setting value: **0.10** $\cdot I_N$
Largest setting value: **1.00** $\cdot I_N$

```
 2904█ SYM.Fact.I
0.50
```

Symmetry factor for the current symmetry = slope of the symmetry characteristic (see Figure 4.45)
Smallest setting value: **0.10**
Largest setting value: **0.95**

```
 2905█ SUM.Ithres
0.10 I/In
```

Current threshold above which the summation monitoring (refer to Figure 4.44) reacts (absolute content, referred to I_N only)
Smallest setting value: **0.10**
Largest setting value: **2.00**

```
 2906█ SUM.Fact.I
0.10
```

Relative content (related to the maximum conductor current) for operation of the current summation monitoring (refer to Figure 4.44)
Smallest setting value: **0.00**
Largest setting value: **0.95**

```
 2 9 0 7 █ U M E A S   U <
6 0   V
```

Voltage threshold (phase-to-phase), below which the voltage failure monitor operates
Smallest setting value: **10** V
Largest setting value: **125** V

```
 2 9 0 8 █ U M E A S   I >
0 . 0 6   I / I n
```

Minimum current to detect a voltage failure
Smallest setting value: **0.06** · I_N
Largest setting value: **1.00** · I_N

The setting values of the fuse failure monitor (addresses 2911 and 2912) have to be chosen so that it picks-up reliably in the case of single phase voltage failure (criterion 3 x U_0), but on the other hand does not pick-up in the case of earth faults in an earthed network. I_E must therefore be set at a correspondingly sensitive level (below the smallest fault current in the case of earth faults). **The function "Fuse failure monitor" must not be chosen for lines in earthed networks, in which earth faults with small or zero earth currents can occur**, for example, when feeder transformers may not be earthed. In non-earthed networks, this fuse failure monitor is not meaningful and will be ignored by the 7SA510. The fuse failure monitor can be switched off under address 2910.

```
 2 9 1 0 █ F U S E - F A I L
O N

O F F
```

Fuse-failure monitor is

ON switched on

OFF switched off

```
 2 9 1 1 █ F F M   3 * U o >
3 5   V
```

Displacement voltage 3 · U_0, above which fuse failure should be detected
Smallest setting value: **30** V
Largest setting value: **100** V

```
 2 9 1 2 █ F F M   I e <
0 . 1 0   I / I n
```

Earth current, above which no fuse failure is assumed
Smallest setting value: **0.10** · I_N
Largest setting value: **1.00** · I_N

6.3.11 Settings for earth fault detection in systems with isolated or compensated star-point − address block 30

This section applies only for relay models with earth fault detection module (7SA510★−★★★★★−★★★**2**/**3**, see Section 2.3 Ordering data) and only when these are used in networks with isolated or compensated star-point. In other cases, this section can be passed over.

Earth fault detection is only possible if the respective configuration parameter (Section 5.4.2, address 7830) is set to *EXIST*. If the device is equipped with earth fault detector but supposed to operate in an earthed network, configuration parameter 7830 ISOL. E/F **must** be set to *NON−EXIST*.

Earth fault detection can be switched operative in address 3001. The preset option ALARM ONLY represents the normal case in which the earth fault is annunciated and its data listed in the earth fault report (refer also to Section 6.4.4). If the parameter EARTH-FAULT is switched *ON*, then trip command is issued provided all earth fault conditions, including fault direction, are fulfilled. This trip command can be assigned to a trip relay (refer also to Section 5.5.5).

The function "earth fault detection" comprises residual voltage detection, determination of the earth-faulted phase and the determination of the earth fault direction. The latter is only possible when the earth current is available to the relay.

The residual voltage Ue> initiates earth fault detection and is set in address 3002. Since, for earth faults in isolated or compensated networks, the full displacement voltage appears, the setting value is not critical; it should lie between 30 V an 60 V. Earth fault is detected and annunciated only when the displacement voltage has been stayed for the duration T−E/F (address 3010).

For phase determination Uph< (address 3003) is the criterion for the earth-faulted phase, when simultaneously the other two phase voltages have exceeded Uph> (address 3004). Accordingly, Uph< must be set lower than the minimum operational phase-earth voltage. This setting is, however, also not critical, 40 V (factory setting) should always be adequate. Uph> must lie above the maximum operational phase-earth voltage, but below the minimum operational phase-phase voltage, therefore, for example, 75 V at U_N = 100 V. The identification of the faulty phase is a further precondition for annunciation of an earth fault.

For determination of the direction of the earth fault, in principle, the threshold current (address 3005) should be set as high as possible to prevent faulty operation due to asymmetrical currents in the network and through the current transformers (particularly in Holmgreen connection). Dependent upon the treatment of the network star point, the magnitude of the capacitive earth fault current (for isolated networks) or the wattmetric residual current (for compensated networks) is important.

In **isolated networks** an earth fault in a cable will allow the total capacitive earth fault currents of the entire electrically connected network, with the exception of the faulted cable itself, to flow through the measuring point. It is normal to use half the value of this earth fault current as the threshold value.

Example: A 24 kV bus-bar feeds seven cable circuits. Each circuit has a current transformer set 300 A/1 A. The earth fault current is 2.5 A/km. The cables might be as follows:

Cable 1	3.0 km	7.5 A
Cable 2	5.0 km	12.5 A
Cable 3	2.6 km	6.5 A
Cable 4	5.0 km	12.5 A
Cable 5	3.4 km	8.5 A
Cable 6	3.4 km	8.5 A
Cable 7	2.6 km	6.5 A
Total	25.0 km	62.5 A

With an earth fault on cable 2, 62.5 A − 12.5 A = 50 A earth fault current will flow through the measuring point, since 12.5 A flows direct from cable 2 into the fault. Since that cable is amongst the longest, this is the most unfavourable case (smallest earth fault current flows through the measuring point). On the secondary side, flows:

$$50\,A/300 = 0.167\,A.$$

The relay should be set at approximately half this value, e.g. 0.080 A.

In **compensated networks** directional determination is made more difficult since a much larger reactive current of capacitive or inductive character is superimposed on the critical wattmetric current. The total earth current available to the relay can therefore, dependent upon the network configuration and location of the compensation coil, assume very different values in magnitude and phase angle. The relay, however, must evaluate only the real component of the earth fault current, that is, $I_E \cdot \cos\varphi$. This demands extremely high accuracy, particularly with regard to phase angle accuracy of all the instrument transformers. Also, the relay should not be set unnecessarily sensitive. When used in compensated networks therefore, reliable directional determination is only expected when core balanced or window-type summation transformers are used. Here also, use the thumb rule: setting at half the expected measured current, whereby only the residual wattmetric current is applicable. This residual wattmetric current is provided principally by the losses in the Petersen coil.

Example: The same network, as in the previous example, is considered to be compensated by a Petersen coil. The coil is matched to the total network. The compensation current is thus 62.5 A. The losses should be 4 %. For earth fault directional determination, window-type current transformers 60 A/1 A are fitted.

Since the residual wattmetric current is derived principally from the coil losses, it is, independent of earth fault location, approximately the same:

4 % of 62.5 A = 2.5 A.

This real current is superimposed by a reactive current which can amount to up to 62.5 A for earth faults near the Petersen coil! On the secondary side we have

2.5 A/60 = 0.0417 A.

As setting value 0.020 A is selected.

The high reactive current component in compensated networks and the unavoidable air gap of the window-type current transformers often make compensation of the angle error of the current transformer necessary. This is possible through addresses 3006 to 3009. The max. angle error F1 of the c.t. with its associated current I1 as well as another c.t. operating point I2/F2 above which the angle error remains practically constant, are entered, for the actually connected burden. The relay then approximates, with adequate accuracy, to the characteristic of the transformer. In isolated networks this angle error compensation is not necessary.

```
 3000 █ EARTHFAULT
NON-EARTHED NET
```

Beginning of block
"Earth fault detection in non-earthed system"

```
 3001 █ EARTHFAULT
ALARM ONLY
```

```
ON
```

```
OFF
```

Earth fault detection in non-earthed systems is required to give ALARM ONLY (no trip)

ON switched on and will trip

OFF switched off

```
 3002 █ Ue>
40 V
```

Threshold value for displacement voltage Ue>
(= $\sqrt{3} \cdot U_0$)
Smallest setting value: **10** V
Largest setting value: **100** V

```
 3003 █ Uph<
40 V
```

Phase-earth voltage of a faulted phase which will be certainly undershot under earth fault conditions
Smallest setting value: **10** V
Largest setting value: **100** V

```
  3 0 0 4█ U p h >
7 5   V
```

Phase-earth voltage of healthy phases which will certainly be exeeded under earth fault conditions
Smallest setting value: **10** V
Largest setting value: **100** V

```
  3 0 0 5█ I e >
0 . 0 5 0   A
```

Threshold value for directional determination
For isolated network: capacitive earth fault current
For compensated network: ohmic (wattmetric) earth fault residual current
Smallest setting value: **0.003** A
Largest setting value: **1.000** A

```
  3 0 0 6█ C T   E R R .   I 1
0 . 0 5 0   A
```

Secondary current for max. error angle of current transformer
Smallest setting value **0.003** A
Largest sefting value **1.600** A

```
  3 0 0 7█ C T   E R R .   F 1
0 . 0   °
```

Error angle of current transformer at I1
Smallest setting value: **0.0** deg
Largest setting value: **5.0** deg

```
  3 0 0 8█ C T   E R R .   I 2
1 . 0 0 0   A
```

Secondary current above which the angle error is practically constant
Smallest setting value: **0.003** A
Largest setting value: **1.600** A

```
  3 0 0 9█ C T   E R R .   F 2
0 . 0   °
```

Error angle of current transformer at I2
Smallest setting value: **0.0** deg
Largest setting value: **5.0** deg

```
  3 0 1 0█ T - E / F
1 . 0   s
```

Duration of displacement voltage after which earth fault is detected and annunciated; this delay is also valid for annunciations when the earth fault conditions change (e.g. alteration of direction)
Smallest setting value: **0.0** s
Largest setting value: **320.0** s

6.3.12 Settings for high-resistance earth fault protection − address blocks 31 to 33

If the device is equipped with protection for high-resistance earth faults in an earthed network (type 7SA510★−★★★★★−★★★**2**/**3**, see Section 2.3 Ordering data), the following possibilities are available for the detection of high-resistance earth faults:

- **directional** definite time overcurrent protection with non-directional back-up stage,
- directional definite time overcurrent protection with **directional comparison** and non-directional back-up stage,
- **non-directional** overcurrent protection with inverse time characteristic.

In 7SA510, one of these three possibilities can be programmed or earth fault protection can be made ineffective (see Section 5.4.2).

6.3.12.1 Directional earth fault protection (definite time) − address block 31

For directional overcurrent time protection with non-directional back-up stage the parameters are set in address block 31. The pick-up value **Ie>** (address 3103) should be set somewhat below the minimum expected earth fault current. The set value of the earth voltage Ue> (address 3104) shall not be exceeded by operational asymmetry of the voltages. Ue means the voltage calculated by the formula

$$Ue = (U_{L1} + U_{L2} + U_{L3}) / \sqrt{3}.$$

The directional dependent tripping time T−DIRECT (address 3106) is independent of directional comparison and received signal. The direction set under address 3107 is decisive for the directional stage. Normally, the line direction is set as *FORWARDS* direction.

The non-directional back-up stage T−NON−DIR (address 3108) also operates when no directional determination is possible because the measured voltage is too small, or if the voltage transformer protective m.c.b. has tripped out. It thus also performs the emergency function for earth fault protection as well as a back-up stage.

```
⇧  3100█ EARTHFAULT
⇩ DIREC/NON-DIREC
```

Beginning of block
"Earth fault directional definite time protection with non-directional back-up stage"

```
  3101█ E/F  D.T.
 ON
 OFF
```

Earth fault definite time protection is

ON switched on

OFF switched off

```
  3103█ Ie>
 0.20  I/In
```

Pick-up value for earth current detection
(0,75 x Ie> for transmit signal)
Smallest setting value: **0.10** I/I_N
Largest setting value: **4.00** I/I_N

```
  3104█ Ue>
 5.0  V
```

Minimum voltage for directional discrimination
Smallest setting value: **1.0** V
Largest setting value: **10.0** V

```
  3106█ T-DIRECT.
 0.90  s
```

Delay time for directional trip
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no directional trip)

```
  3107█ DIRECTION
FORWARDS
```

```
REVERSE
```

```
NON-DIRECTIONAL
```

Direction for directional stage; can be set to trip

FORWARDS	in line direction
REVERSE	in busbar direction
NON–DIRECTIONAL	in either direction

```
  3108█ T-NON-DIR.
1.20 s
```

Delay time for non-directional back-up stage
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no directional trip)

```
  3109█ T-BLOCK
0.01 s
```

Time during which earth-fault protection is blocked after distance protection has reset; when a second external protection relay with single-pole AR is present, this time must be longer than a single-pole auto-reclose cycle
Smallest setting: **0.00** s
Largest setting value: **320.00** s

6.3.12.2 Directional comparison earth fault protection – address block 32

If the earth fault directional protection is extended by directional comparison, the parameters are set in address block 32, in addition to those of address block 31 (Section 6.3.12.1).

The directional comparison can be switch *ON* and *OFF* under address 3201. The functions according to address block 31 (Section 6.3.12.1) operate independently. But, when the earth fault protection is switched off under address 3101 (Section 6.3.12.1) the directional comparison earth fault protection is ineffective, too.

Transmission signal and trip will be delayed by the delay time time T–DELAY (address 3202). This allows compensation for different reaction times of the devices at the two line ends.

The transient blocking time (address 3203) must be longer than the transmission time; in addition, the duration of heavy transient reactions at the inception and interruption of short circuits has to be taken into consideration.

The time T–WAIT (address 3204) is a waiting time for initiation of transient blocking: When the earth fault protection has detected a fault, the reception circuit (release) will be blocked if no reception signal has been received within this time; thereafter a reception signal can only be effective after the transient blocking time T–TRANSBLO (refer also to Section 4.9.2). If set to ∞, no blocking takes place for this case.

For lines with one **weak-infeed** or non-infeed end, the echo function is reasonable. So the strong feeding line end can be released even when the weak-infeed end does not pick up. The echo function can be set effective or not under address 3210.

The echo delay time T–ECHO–DEL (address 3211) must be set to such a long duration that differing reaction times of the fault detectors of the protective relays at both line ends cannot result in a false echo signal in the case of external faults.

The echo impulse duration T–ECHO–IMP (address 3212) can be adjusted in accordance with the requirements of the network. It has to be long enough so that even with differing operating times of the protective devices at both line ends and of the transmission devices, recognition of the receive signal is guaranteed.

To avoid false echo signals after disconnection of the line, a blocking time for echo generation T–ECHO–BLO (address 3213) is set. This should include the echo delay time T–ECHO–DEL plus the echo impulse duration T–ECHO–IMP plus twice the transmission time plus a safety margin.

3200 EARTHFAULT
DIREC.COMPARISON

Beginning of block
”Earth fault directional comparison”

3201 E/F COMPAR
ON

OFF

Directional comparison for earth fault definite time protection is

ON switched on

OFF switched off

3202 T-DELAY
0.00 s

Delay time for transmission and trip on reception for directional comparison
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no transmission, no trip)

3203 T-TRANSBLO
0.05 s

Transient blocking time (after external fault)
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

3204 T-WAIT
∞ s

Waiting time before transient blocking with missing reception signal
Smallest setting value: **0,01** s
Largest setting value: **32,00** s
or ∞, i.e. no transient blocking with missing reception

3210 E/F ECHO
ON

OFF

Echo function for directional comparison earth fault protection is

ON switched on

OFF switched off

3211 T-ECHO-DEL
0.04 s

Echo delay time when circuit breaker is closed
Smallest setting value: **0.01** s
Largest setting value: **32.00** s
and ∞ (no echo signal when circuit breaker is closed)

3212 T-ECHO-IMP
0.05 s

Duration of echo impulse
Smallest setting value: **0.02** s
Largest setting value: **32.00** s

3213 T-ECHO-BLO
0.15 s

Echo blocking time
Smallest setting value: **0.01** s
Largest setting value: **32.00** s

6.3.12.3 Non-directional earth fault protection (inverse time) – address block 33

Instead of the above mentioned functions, a non-directional earth fault protection can be set. A choice of three characteristics is given: normal inverse, very inverse and extreme inverse. Ie> shall be set below the minimum expected earth fault current, at 75 % or less since, according to IEC 60255–3, the protection shall **not** operate for currents up to 1.05 times the setting value and the characteristics are defined only from 2 times the setting value onwards. In any event, 7SA510 already trips for currents above approximately 1.2 times the setting value in accordance with the formulae valid for the characteristics (Figure 3.3, Section 3.8).

When setting the time T–Ie> (address 3304) one must consider that the setting value corresponds to 10 times the time factor of the tripping time formula, e.g.

T–Ie> = 10s
for normal inverse TM = 1, thus

t_{trip} = 10s tripping time at 2 times the set value Ie>

```
3300 EARTHFAULT
NON-DIRECTIONAL
```

Beginning of block
"Earth fault non-directional inverse time overcurrent protection"

```
3301 E/F I.T.
ON
```
```
OFF
```

Non-directional inverse time earth fault protection is

ON switched on

OFF switched off

```
3302 E/F CHARAC
NORMAL INVERSE
```
```
VERY INVERSE
```
```
EXTREMELY INVERS
```

Trip time characteristic for the non-directional inverse time overcurrent protection according IEC 60255–3 or BS 142

NORMAL INVERSE time characteristic (type A)

VERY INVERSE time characteristic (type B)

EXTREMELY INVERSe time characteristic (type C)

```
3303 Ie>
0.20 I/In
```

Pick-up value for earth current detection
Smallest setting value: **0.10** I/I_N
Largest setting value: **4.00** I/I_N

```
3304 T-Ie>
0.50 s
```

Delay time corresponds 10 x TM
Smallest setting value: **0.00** s
Largest setting value: **32.00** s
and ∞ (no trip by Ie>)

```
3305 T-BLOCK
0.01 s
```

Time during which earth-fault protection is blocked after distance protection has reset; when a second external protection relay with single-pole AR is present, this time must be longer than a single-pole auto-reclose cycle
Smallest setting value: **0.01** s
Largest setting value: **320.00** s

6.3.13 Settings for automatic reclosure – address block 34

NOTE: This section is valid only for models with integrated auto-reclose function (7SA510⋆–⋆⋆⋆⋆⋆–⋆⋆**F**⋆). Otherwise it can be passed over. Auto-reclose function is effective only if configured as *EXIST* under address 7834 (refer to Section 5.4.2).

When no auto-reclosure is to be carried out on the feeder which is protected by the distance protection relay (e.g. cables, transformers, motors, etc.), then the internal AR function must be configured as *NON–EXIST* in address 7834 (refer to Section 5.4.2). The AR function is then not effective at all, i.e. 7SA510 does not process the AR function. No corresponding annunciations are given, binary inputs for auto-reclosure are ignored. All parameters in block 34 are irrelevant and unavailable.

With the internal AR function, generally distinction is made between the first AR-cycle, identified in the following with RAR (rapid auto-reclosure), and further AR-cycles with multi-shot auto-reclosure, identified in the following with DAR (delayed auto-reclosure). The above identifications are regardless whether the dead times are really ”rapid” or ”delayed”. Setting address 3401 to 3419 are common for all types of auto-reclosure.

Most of the short-circuit protection functions of 7SA510 have several stages which operate independent on each other, e.g. for the distance protection stages, time delay and direction can be selected for each stage individually and independently. Therefore reclosure is normally blocked if a protection trips on a fault detected in reverse direction. Accordingly address 3402 is preset to AR BLO REV = *YES*.

When switching manually on a dead fault, it is normally desired that the short-circuit protection trips instantaneously, and the AR function is blocked. Thus, address 3403 should remain in position MC BLOCK = *YES*.

The reclaim time T–RECLAIM (address 3405) is the time period after which the network fault is supposed to be terminated after a successful auto-reclose cycle. A renewed trip of any protection function within this time increments the AR counter (when multi-shot AR is used) so that the next AR cycle starts; if no further AR is allowed the last AR is treated as unsuccessful.

The lock-out time T–LOCK (address 3406) is the time period during which after an unsuccessful auto-reclosure further reclosures by 7SA510 are blocked. If the manual close command is led via the 7SA510 then this will be blocked also. This time must be longer than the renewed readiness for operation of the circuit breaker unless the CB is supervised in the relay (see below, address 3415). If this time is set to ∞, all breaker close commands via 7SA510 are locked. In this case switching can be unlocked only when the binary input ”`>AR Reset`” (FNo `2704`) is energized.

The set time for T–BLOCK MC (address 3407) must cover the time for safe closing and opening of the circuit breaker (0.5 s to 1 s). If any of the protection functions of 7SA510 detects a fault within this time, three-pole definitive trip command is issued and reclosure is blocked provided MC BLOCK (address 3403, see above) is switched to *YES*.

The duration of the closing command has already been set when setting the general parameters of the device (address 1135, Section 6.3.3.3).

A prerequisite for initiation of the AR function is that the circuit breaker is ready for at least one trip–close cycle when any short-circuit protection function trips. This information has to be given to the relay via the binary input ”`>CB ready`” (FNo `2730`). In case such information is not available from the CB circuit, interrogation of ”`>CB ready`” can be suppressed by setting the parameter CB? 1 TRIP = *NO* (i.e. CB interrogation 1st trip, address 3412); otherwise reclosure would not be possible at all.

Additionally it is possible to interrogate readiness of the circuit breaker before each further reclose command or before every other reclose command. Setting is made in address 3413:

CB? CLOSE = *CB? NEVER*; interrogation is not made or only at the moment of the first trip command as parameterized under address 3412,

CB? CLOSE= *CB? WITH EACH AR*; interrogation is made before each reclose command,

CB? CLOSE = *CB? WITH 2nd AR*; interrogation is made before every other reclose command, i.e. before the 2nd, 4th, etc.; every trip–close cycle is valid regardless whether it is RAR or DAR.

In order to monitor the regeneration time of the circuit breaker a special circuit breaker supervision time T–CB–SUPV can be set under address 3415. This time should be set slightly above the regeneration time of the breaker after a trip–close cycle. If the circuit breaker is not yet ready after this time, reclosure is suppressed.

Finally, address 3419 determines for which reclose cycles synchronism or voltages shall be checked. In the cases which are parameterized in this address, reclosure is blocked as long as the conditions as set for an external synchronism-check device are not fulfilled. The relay must be informed about synchronism conditions via a binary input.

```
3400 AUTO-
RECLOSE FUNCTION
```

Beginning of block "Auto-reclose functions"

```
3401 AR FUNCT
ON
```

```
OFF
```

Auto-reclose function is

ON switched on

OFF switched off

```
3402 AR BLO REV
YES
```

```
NO
```

AR will be blocked when a fault in reverse direction is tripped (for all short-circuit protection functions which can operate directional)

normal setting: *YES*

```
3403 MC BLOCK
YES
```

```
NO
```

Blocking of reclosing after manual close of the circuit breaker

normal setting: *YES*

```
3405 T-RECLAIM
3.00 s
```

Reclaim time after successful AR cycle
Smallest setting value: **0.50** s
Largest setting value: **320.00** s

```
3406 T-LOCK
3.00 s
```

Lock-out time after unsuccessful AR; any close command is blocked
Smallest setting value: **0.50** s
Largest setting value: **320.00** s
and ∞ (locked until ">AR Reset" via binary input)

```
3407 T-BLOCK MC
1.00 s
```

Reclaim time after manual closing of circuit breaker
Smallest setting value: **0.50** s
Largest setting value: **320.00** s

```
  3412▌CB?  1.TRIP
YES
```
```
NO
```

CB ready interrogation at the first trip command

YES – normal setting

NO – only if there is no possibility to interrogate CB readiness

```
  3413▌CB?  CLOSE
CB?  NEVER
```
```
CB?  WITH  EACH  AR
```
```
CB?  WITH  2nd  AR
```

CB ready interrogation before reclosing

NEVER	no CB ready interrogation before reclosing
WITH EACH AR	CB ready interrogation before each reclosing
WITH EACH 2nd AR	CB ready interrogation before 2nd, 4th, 6th, etc. reclosing (RAR or DAR)

```
  3415▌T-CB-SUPV
3.00  s
```

CB supervision time within which CB must be ready
Smallest setting value: **0.01** s
Largest setting value: **320.00** s

```
  3419▌SYN-REQUST
BEFORE  3POLE  AR
```
```
ONLY  BEFORE  DAR
```
```
BEFORE  2nd  DAR
```
```
NEVER
```

Request for synchronizm check (if external synchro-check device is available) is made

– before every reclose after three-pole tripping;

– only before reclose during DAR

– only before reclose during DAR from the 2nd DAR shot on

– no request for synchro-check

For RAR (first auto–reclose cycle), addresses 3424 and 2425 are decisive.

When setting the action time RAR T–ACT (address 3424), it must be ensured that this time is at least as long as the command time of the protective relay, including any possible signal transmission times, but smaller than the delay T2 of the second distance zone (usually 0.2 s).

The setting of the dead time RAR T–3POL (address 3425) depends on the application. For longer lines, the dead time should be long enough to ensure that the fault arc is extinguished and the air surrounding the arc is de-ionized, so that auto-reclosure can be successful (0.6 s to 1.0 s). For double-end fed lines, the stability of the network is the more important consideration. Since the disconnected line can no longer produce any synchronizing power, only a short dead time is permitted in such cases. Conventional values lie between 0.3 s and 0.6 s. For radial networks, a longer time may often be tolerated.

```
  3424▌RAR  T-ACT.
0.20  s
```

Action time for RAR (first AR-shot) (if trip signal is given after this time, AR is blocked)
Smallest setting value: **0.01** s
Largest setting value: **320.00** s
and ∞

```
  3425▌RAR  T-3POL
0.50  s
```

Dead time for first three–pole (RAR) cycle
Smallest setting value: **0.01** s
Largest setting value: **320.00** s

For DAR (further auto–reclose cycles), several programs are possible (address 3442). DAR can be excluded (DAR PROG = *NO DAR*). DAR can be permitted also if no RAR has been preceded (DAR PROG = *DAR WITHOUT RAR*). DAR can be permitted only after an unsuccessful RAR (DAR PROG = *DAR AFTER RAR*).

Multiple auto–reclosure with longer three-pole dead times are only permitted in networks in which no stability problems are to be expected (for example, due to a high degree of meshing), or in radial networks.

The number of DARs can be set in address 3444 DAR No.3PH.

For DAR, a separate action time DAR T–ACT can be set (address 3445).

Different dead times can be set for the first, second and third trip–close cycle. The dead time for the first cycle (address 3446) is only valid if the DAR cycle is really the first cycle (i.e. RAR is suppressed). For the second (address 3447) and third (address 3448) cycle, a RAR counts only if it has occurred. Further cycles are treated like the third cycle.

```
3442 DAR PROG.
NO DAR
```

```
DAR WITHOUT RAR
```

```
DAR AFTER RAR
```

Auto–reclose program for DAR cycles

NO DAR no delayed AR

DAR WITHOUT RAR DAR will be carried out also when no RAR has preceded

DAR AFTER RAR DAR will be carried out only after an unsuccessful RAR cycle

```
3444 DAR No.3PH
1
```

Number of permissible DAR cycles (the RAR is not included in this number) or without preceding RAR
Smallest setting value: **0**
Largest setting value: **9**

```
3445 DAR T-ACT.
0.20 s
```

Action time for DAR (further AR-shots) (if trip signal is given after this time, AR is blocked)
Smallest setting value: **0.01** s
Largest setting value: **320.00** s
and ∞

```
3446 DAR T3POL1
0.80 s
```

Dead time forthe first AR cycle if it is a DAR cycle
Smallest setting value: **0.01** s
Largest setting value: **1800.00** s

```
3447 DAR T3POL2
0.80 s
```

Dead time for the second AR cycle
Smallest setting value: **0.01** s
Largest setting value: **1800.00** s

```
3448 DAR T3POL3
0.80 s
```

Dead time for further AR cycles
Smallest setting value: **0.01** s
Largest setting value: **1800.00** s

6.3.14 Settings for fault location – address block 38

Distance to fault will be calculated as long as FAULT LOCAT. = *EXIST* has been set in address 7838 during configuration (see Section 5.4.2).

Normally, fault location calculation is initiated at the instant when a tripping command is issued. It can, however, also be started on fault detection drop-off (address 3802) if, for example, another protection device clears the fault. Additionally, fault location can be initiated by an external command via a binary input (FNo `1106`, refer to Section 5.5.2), provided, the protection has picked up.

To calculate the distance in kilometers, the device requires the reactance value in Ω/km as a secondary value, referred to 1 A. Conversion from primary to secondary value is made by using the same formula as for the distance setting (Section 6.3.4.2). If one puts in the reactance value of the line in Ω/km for X_{prim} one obtains the required setting value X SEC (address 1122).

For correct output of the distance to fault in % of line length, the total line length in km must also be input (address 1124). If the reactance X SEC is entered in Ω/mile and the LINE LENGTH entered in miles, the result of fault calculation would be read in miles instead of kilometers.

<u>Example:</u>

For the example given in section 6.3.4.2 we obtain:

$$X_{prim} = 0.39\Omega/km$$

$$X_{sec} = \frac{N_{ct}}{N_{vt}} \cdot X_{prim} \cdot \frac{I_N}{A}$$

$$= \frac{600/5}{110/0.1} \cdot 0.39\Omega/km \cdot \frac{5A}{A}$$

$$= 0.213\Omega/km$$

$$Length = 60km$$

If, for example, a fault reactance of 2.29 Ω primary is calculated, this example gives us the fault location data

$Xpri = 2.29\ \Omega$
$d = 5.86\ km$
$d = 9.78\ \%$

```
  3 8 0 0 █
F A U L T   L O C A T I O N
```

Beginning of block ”Fault location”

```
  3 8 0 2 █ S T A R T
D R O P - O F F   o r   T R I P
```

```
T R I P   C O M M A N D
```

Start-to-measure of fault location is initiated

- by *DROP–OFF* of the fault detector or by *TRIP* command
- only by *TRIP COMMAND*

6.4 Annunciations

6.4.1 Introduction

After a network fault, annunciations and messages provide a survey of important fault data and the function of the relay, and serve for checking sequences of functional steps during testing and commissioning. Further, they provide information about the condition of measured data and the relay itself during normal operation.

To read out recorded annunciations, no codeword input is necessary.

The annunciations generated in the relay are presented in various ways:

– LED indications in the front plate of the relay (Figure 6.1),

– Binary outputs (output relays) via the connections of the relay,

– Indications in the display on the front plate or on the screen of a personal computer, via the operating interface,

– Transmission via the system interface to local or remote control facilities (if available).

Most of these annunciations can be relatively freely allocated to the LEDs and binary outputs (see Section 5.5). Also, within specific limitations, group and multiple indications can be formed.

To call up annunciations on the operator panel, the following possibilities exist:

– Block paging with the keys ⇑ forwards or ⇓ backwards up to address 5000,

– Direct selection with address code, using key **DA**, address **5 0 0 0** and execute with key **E**,

– Press key **M/S** (M stands for ”messages”, S for ”signals”); then the address 5000 appears automatically as the beginning of the annunciation blocks.

For configuration of the transfer of annunciations via the serial interfaces, the necessary data are entered in address block 72 (see Section 5.3.3).

The annunciations are arranged as follows:

Block 51 Operational annunciations; these are messages which can appear during the operation of the relay: information about condition of relay functions, measurement data etc.

Block 52 Event annunciations for the last fault; pick-up, trip, AR, expired times, calculated distance, or similar. As defined, a network fault begins with pick-up of any fault detector. If auto-reclosure is carried out, the network fault ends after expiry of the last reclaim time; thus an AR-shot (or all shots) occupy only one fault data store. Within a network fault, several fault events can occur, from pick-up of any fault detection until drop-off.

Block 53 Event annunciations for the previous network fault, as block 52.

Block 54 Event annunciations for the last but two network fault, as block 52.

Block 55 Annunciations of an earth fault report (models with earth fault detection in non-earthed systems only).

Block 56 Annunciations for CB operation statistics, that is counters for first AR (RAR), second or further AR (DAR) and tripping commands, together with accumulated short-circuit currents of each breaker pole.

Block 57 Indication of operational measured values (currents, voltages, powers, frequency).

Block 58 Indication of earth fault values (models with earth fault detection in non-earthed systems only).

Block 59 Indication of measured values of the thermal overload protection.

```
⇑ 5 0 0 0 █
⇓ A N N U N C I A T I O N S
```

Commencement of ”annunciation blocks”

A comprehensive list of the possible annunciations and output functions with the associated function number FNo is given in Appendix C. It is also indicated to which device each annunciation can be routed.

6.4.2 Operational annunciations – address block 51

Operational and status annunciations contain information which the unit provides during operation and about the operation. They begin at address 5100. Important events and status changes are chronologically listed, starting with the most recent message. Time information is shown in hours and minutes. Up to 50 operational indications can be stored. If more occur, the oldest are erased in sequence.

Faults in the network are only indicated as ”`Syst. Flt`” together with the sequence number of the fault. Detailed information about the history of the fault is contained in blocks ”Fault annunciations”, refer to Section 6.4.3.

If the device is equipped with earth fault detection for non-earthed systems, an earth fault is indicated with ”`E/F Det`”; detailed information can be found in the earth fault report (refer to Section 6.4.4).

The input of the codeword is not required.

After selection of the address 5100 (by direct selection with **DA 5 1 0 0 E** and/or paging with ⇑ or ⇓ and further scrolling ↑ or ↓) the operational annunciations appear. The boxes below show all available operational annunciations. In each specific case, of course, only the associated annunciations appear in the display. The annunciations which are indicated by a leading ”>” sign, represent the direct confirmation of the binary inputs.

Next to the boxes below, the abbreviated forms are explained. It is indicated whether an event is announced on occurrence (**C** = ”**C**oming”) or a status is announced ”**C**oming” and ”**G**oing” (**C**/**G**).

The first listed message is, as example, assigned with date and time in the first line; the second line shows the beginning of a condition with the character **C** to indicate that this condition occurred at the displayed time.

⇑⇓ `5100█OPERATIONAL` `ANNUNCIATIONS`	Beginning of the block ”Operational annunciations”
↑↓ `19.12.96  17:02` `Emer. Mode :C`	1st line: Date and time of the event or status change 2nd line: Annunciation text, in the example **C**oming

If the real time clock is not available the date is replaced by ⋆⋆.⋆⋆.⋆⋆, the time is given as relative time from the last re-start of the processor system.

Direct response from binary inputs:

`>Start FltRec`	Fault recording started via binary input (C)
`>Annunc. 1`	User definable annunciation No 1 received via binary input (C/G)
`>Annunc. 2`	User definable annunciation No 2 received via binary input (C/G)
`>Annunc. 3`	User definable annunciation No 3 received via binary input (C/G)
`>Annunc. 4`	User definable annunciation No 4 received via binary input (C/G)
`>CloseCmd.Blo`	Block all closing commands (C/G)

>VT mcb Trip	Voltage transformer secondary m.c.b. (feeder v.t.) tripped (C/G)
>RAR Release	Release RAR stages from external AR device (C/G)
>DAR Release	Release DAR stage from external AR device (C/G)
>Start FltLoc	Start fault locator via binary input (C/G)
>E/F Recept	Carrier signal for directional comparison earth fault protection received (C)
>E/F Rec.Fail	Carrier reception for directional comparison earth fault protection faulty (C/G)
>I>> block	Block I>> stage of emergency overcurrent protection from an external device (C/G)
>AR block	Block auto-reclosure statically via binary input (C/G)
>AR reset	Reset auto-reclosure function from external via binary input (C)
>RAR block	Block complete RAR via binary input (C/G)
>DAR block	Block complete DAR via binary input (C/G)
>Start AR	Starting signal from external protection for internal AR (C)
>Trip 3p AR	Three-pole trip signal from external protection for internal AR (C)
>DAR aft. RAR	DAR permitted only after unsuccessful RAR (C/G)
>Extens. Z1B	Switch distance reach to extended zone Z1B from external signal (C/G)
>Extens. Z1L	Switch distance reach to extended zone Z1L from external signal (C/G)
>Dis. Recept	Carrier signal for teleprotection with distance protection received (C)
>Dis.RecFail	Carrier reception for teleprotection with distance protection faulty (C/G)
>Ext.Trip blk	Block external trip function (C/G)
>Ext.Trp.L123	Trigger external trip function three-pole (C)
>Ext.Trp.woAR	Trigger external trip function three-pole without reclosure (C/G)
>User T1Start	Start user definable timer T1 (C/G)
>User T1Reset	Reset user definable timer T1 (C)
>User T2Start	Start user definable timer T2 (C/G)
>User T2Reset	Reset user definable timer T2 (C)

General operational annunciations of the protection device:

Dev.operative	Device operative (C/G)
Prot. operat.	At least one protection function is operative (C/G)
Initial start	Initial start of the processor system (C)
LED reset	Stored LED indications reset (C)
LogMeasBlock	Messages and measured values via the system interface are blocked (C/G)
Test mode	Messages and measured value via the system interface are marked with "Test operation" (C/G)
Param.running	Parameters are being set (C/G)
Param. Set A	Parameter set A is active (C/G)
Param. Set B	Parameter set B is active (C/G)
Param. Set C	Parameter set C is active (C/G)
Param. Set D	Parameter set D is active (C/G)
Syst.Flt	Network system fault (C/G), detailed information in the fault annunciations
E/F Det.	Earth fault detected (in non-earthed system) (C/G, detailed information in the earth fault report)
Manual Close	Manual close command registered (impulse) (C)
CB in Test	Circuit breaker test is in progress (C/G)
Flt.RecDatDel	Fault recording data deleted (C)
Flt.Rec.viaBI	Fault recording triggered via binary input (C)
Flt.Rec.viaKB	Fault recording triggered via the front keyboard (C)
Flt.Rec.viaPC	Fault recording triggered via operating (PC) interface (C)

Annunciations of monitoring functions:

Wrong SW-vers	Software version of the device is wrong (C)
Wrong dev. ID	Device identification number is wrong (C)
Annunc. lost	Annunciations lost (buffer overflow) (C)
Annu. PC lost	Annunciations for operating (PC) interface lost (C)
Oper.Ann.Inva	Operational annunciations invalid (C/G)
Flt.Ann.Inval	Fault annunciations invalid (C/G)
E/F.Prot Inva	Earth fault report (for non-earthed systems) invalid (C/G)
Stat.Buff.Inv	Buffer for operation statistics invalid (C/G)
LED Buff.Inva	Buffer for stored LEDs invalid (C/G)
VDEW-StateInv	VDEW state (IEC 60870–5–103) invalid (C/G)
Chs Error	Check-sum error detected (C/G)
Chs A Error	Check-sum error detected for parameter set A: no operation possible with this set (C/G)
Chs B Error	Check-sum error detected for parameter set B: no operation possible with this set (C/G)
Chs C Error	Check-sum error detected for parameter set C: no operation possible with this set (C/G)
Chs D Error	Check-sum error detected for parameter set D: no operation possible with this set (C/G)
Failure 24V	Failure in internal supply voltage 24 V (C/G))
Failure 15V	Failure in internal supply voltage 15 V (C/G))
Failure 5V	Failure in internal supply voltage 5 V (C/G))
Failure 0V	Failure in offset voltage 0 V (C/G)
Failure I/O 1	Failure on input/output module (C/G)
Fail. TripRel	Failure in internal trip relay circuit (C/G)
LSA disrupted	LSA-link disrupted (system interface) (C/G)

`Failure ΣI`	Failure detected by current plausibility monitor ΣI (C/G)
`Failure Isymm`	Failure detected by current symmetry monitor (C/G)
`Failure Usymm`	Failure detected by voltage symmetry monitor (C/G)
`Failure Umeas`	Loss of measured voltages (C/G)
`FFM pick-up`	Fuse-failure monitor picked up (undelayed annunciation) (C/G)
`Fuse-Failure`	Fuse-failure monitor operated (delayed annunciation, approx. 10 s) (C/G)
`Fail.PhaseSeq`	Failure detected by phase sequence monitor (C/G)

Operational annunciation of distance protection and teleprotection features:

`Dist. off`	Distance protection is switched off (C/G)
`Dist. blocked`	Distance protection is blocked (C/G)
`Emer. mode`	Emergency overcurrent time mode is running (C/G)
`>Extens. Z1B`	Release zone extension stage Z1B (C/G)
`>Extens. Z1L`	Release zone extension stage Z1L (C/G)
`Dis.Tele.off`	Teleprotection function with distance protection is switched off (C/G))
`>Dis. Recept`	Carrier signal for teleprotection with distance protection received (C)
`Dis.RecFail`	Reception signal for teleprotection with distance protection is faulty (C/G)
`Dis.POTT Echo`	Echo signal for teleprotection with distance protection transmitted (C)

Operational annunciations of power swing supplement:

`Power Swing`	Power swing detected (C/G)
`O/S Trip`	Out-of-step trip signal issued (C)

Operational annunciations of user definable logic functions and external trip function:

`>User T1Start`	Start user definable timer T1 (C/G)
`>User T1Reset`	Reset user definable timer T1 (C)
`User output 1`	Output of user definable timer T1 (C/G)
`>User T2Start`	Start user definable timer T2 (C/G)
`>User T2Reset`	Reset user definable timer T2 (C)
`User output 2`	Output of user definable timer T2 (C/G)
`>Ext.Trip blk`	Block external trip function (C/G)
`>Ext.Trp.L123`	Trigger external trip function three-pole (C)
`>Ext.Trp.woAR`	Trigger external trip function three–pole without reclosure (C/G)

Operational annunciations of emergency overcurrent time protection:

`Emer. off`	Emergency overcurrent time protection is switched off (C/G)
`Emer. block`	Emergency overcurrent time protection is blocked (C/G)
`Emer. mode`	Emergency overcurrent time mode is running (C/G)
`>I>> block`	Block I>> stage of emergency overcurrent time protection from an external device (C/G)

Operational annunciations of thermal overload protection:

`O/L Prot. off`	Thermal overload protection is switched off (C/G)
`O/L blocked`	Thermal overload protection is blocked (C/G)
`O/L Warn I`	Thermal overload protection: current warning stage (C/G)
`O/L Warn Θ`	Thermal overload protection: thermal warning stage (C/G)
`O/L Pickup Θ`	Thermal overload protection: pick-up of thermal trip stage (C/G)

Operational annunciations of earth fault detection for non-earthed systems:

E/F Det. off	Earth fault detection is switched off (C/G)
E/F Det.block	Earth fault detection is blocked (C/G)

Detailed information about the earth fault are given in the earth fault report (address block 55), refer Section 6.4.4.

Operational annunciations of high-resistance earth fault protection in earthed systems:

E/F Prot. off	Earth fault protection is switched off (C/G)
E/F blocked	Earth fault protection is blocked (C/G)
E/F Dir off	Earth fault directional comparison is switched off (C/G)
>E/F Recept	Carrier signal for directional comparison earth fault protection received (C)
>E/F Rec.Fail	Carrier reception for directional comparison earth fault protection faulty (C/G)
E/F Echo	Echo signal for directional comparison transmitted (C)

Operational annunciation of the internal auto-reclose function:

AR off	Auto-reclose function is switched off (C/G)
AR inoperativ	Auto-reclose function inoperative, i.e, cannot be initiated (C/G)
>AR block	Block auto–reclosure statically via binary input (C/G)
>AR reset	Reset auto-reclosure function from external via binary input (C)
>RAR block	Block complete RAR via binary input (C/G)
>DAR block	Block complete DAR via binary input (C/G)
>Start AR	Starting signal from external protection for internal AR (C)
>Trip 3p AR	Three-pole trip signal from external protection for internal AR (C)
>DAR aft. RAR	DAR permitted only after unsuccessful RAR (C/G)
AR Close Cmd.	Reclose command from auto-reclose function issued (C)

Operational annunciations of fault location:

`>Start FltLoc`	Start fault locator via binary input (C/G)

Operational annunciations from the circuit breaker test function:

`CB in Test`	Circuit breaker test in progress (C/G)
`CB Test 3p`	Trip three-pole by internal circuit breaker test function (C)

Further messages:

`Table overflow`	If more messages have been received the last valid message is *Table overflow*.
`End of table`	If not all memory places are used the last message is *End of table*.

6.4.3 Fault annunciations – address blocks 52 to 54

The annunciations which occurred during the last three network faults can be read off on the front panel or via the operating interface. The indications are recorded in the sequence from the youngest to the oldest under addresses 5200, 5300 and 5400. When a further fault occurs, the data relating to the oldest are erased. Each fault data buffer can contain up to 80 annunciations.

Input of the codeword is not required.

To call up the **last** fault data, one goes to address 5200 either by direct address **DA 5 2 0 0 E** or by paging with the keys ⇑ or ⇓. With the keys ↑ or ↓ one can page the individual annunciations forwards or backwards. Each annunciation is assigned with a sequence item number.

For these purposes, the term "system fault" means the period from short circuit inception up to final clearance. If auto–reclose occurs, then the "system fault" is finished on expiry of the last reclaim or lock–out time, that is, after successful or unsuccessful AR. Thus the total fault clearance procedure inclusive AR–cycles occupies only one fault annunciation store. Within one system fault, several fault events can have occurred, i.e. from pick–up of any protection function until drop–off of the last pick–up of a protection function.

In the following clarification, all the available fault annunciations are indicated. In the case of a specific fault, of course, only the associated annunciations appear in the display. At first, an example is given for a system fault, and explained.

```
⇑ 5200█LAST
⇓ FAULT
```

Beginning of the block "Fault annunciations of the last system fault"

```
↑ 001█02.11.96
↓ Syst.Flt  21
```

under item 1, the date of the system fault is indicated, in the second line the consecutive number of the system fault

```
↑ 002█16:54:14.397
↓ Fault          :C
```

under item 2, the time of the beginning of the fault is given; time resolution is 1 ms

```
↑ 003█0  ms
↓ Dist.Flt.L1E  :C
```

The following items indicate all fault annunciations which have occurred from fault detection until drop-off of the device, in chronological sequence. These annunciations are tagged with the relative time in milliseconds, starting with the fault detection.

```
↑ 004█6  ms
↓ Dis.Trip  3p  :C
```

```
↑ 005█115  ms
↓ Dev. Drop-off:C
```

```
↑ 006█115  ms
↓ FL  Loop  L1E
```

For fault location, the conductor loop is given, from which the fault location has been derived. Fault distance is displayed in Ohms primary, in Ohms secondary, in kilometers and in percentage line length, calculated from the parameters which have been set for line and transformer data (refer to Section 6.3.3).

If the per unit line reactance has been parameterized in Ω/mile instead of Ω/km (address 1122) then the fault distance is to be read in miles.

```
↑ 007█
↓ d      =16.0  km
```

```
↑ 008█
↓ d [%] =63  %
```

etc.

General fault annunciations of the device:

`Syst.Flt`	System fault with consecutive number
`Fault`	Beginning of fault
`Flt.Buff.Over`	Fault annunciations lost (buffer overflow)
`>RAR Release`	Release RAR stages from external AR device when occurred during a fault
`>DAR Release`	Release DAR stage from external AR device when occurred during a fault
`Dev.Trip rev.`	Trip on fault in reverse (bus-bar) direction
`IL1/In=`	Interrupted fault current of phase L1
`IL2/In=`	Interrupted fault current of phase L2
`IL3/In=`	Interrupted fault current of phase L3
`Device Trip`	The general trip command of the device is annunciated **G**oing, i.e. reset of the trip is indicated
`Dev. Drop-off`	Drop-off of the device, general

Fault annunciations of distance protection:

`DisZ1B AR blk`	Auto-reclosure blocked by fault in zone Z1B
`DisZ1L AR blk`	Auto-reclosure blocked by fault in zone Z1L
`Dist.Flt.L1`	Fault detection distance protection, phase L1
`Dist.Flt.L1E`	Fault detection distance protection, phase L1–E
`Dist.Flt.L2`	Fault detection distance protection, phase L2
`Dist.Flt.L2E`	Fault detection distance protection, phase L2–E
`Dist.Flt.L12`	Fault detection distance protection, phases L1–L2
`Dist.Flt.L12E`	Fault detection distance protection, phases L1–L2–E
`Dist.Flt.L3`	Fault detection distance protection, phase L3
`Dist.Flt.L3E`	Fault detection distance protection, phase L3–E
`Dist.Flt.L13`	Fault detection distance protection, phases L1–L3

Dist.Flt.L13E	Fault detection distance protection, phases L1–L3–E
Dist.Flt.L23	Fault detection distance protection, phases L2–L3
Dist.Flt.L23E	Fault detection distance protection, phases L2–L3–E
Dist.Flt.L123	Fault detection distance protection, phases L1–L2–L3
Dist.Flt.123E	Fault detection distance protection, phases L1–L2–L3–E
Loop L1-E f	In line loop L1–E a fault in forward direction is detected
Loop L2-E f	In line loop L2–E a fault in forward direction is detected
Loop L3-E f	In line loop L3–E a fault in forward direction is detected
Loop L1-2 f	In line loop L1–L2 a fault in forward direction is detected
Loop L2-3 f	In line loop L2–L3 a fault in forward direction is detected
Loop L3-1 f	In line loop L3–L1 a fault in forward direction is detected
Loop L1-E r	In line loop L1–E a fault in reverse direction is detected
Loop L2-E r	In line loop L2–E a fault in reverse direction is detected
Loop L3-E r	In line loop L3–E a fault in reverse direction is detected
Loop L1-2 r	In line loop L1–L2 a fault in reverse direction is detected
Loop L2-3 r	In line loop L2–L3 a fault in reverse direction is detected
Loop L3-1 r	In line loop L3–L1 a fault in reverse direction is detected
Dis.Trip 3p	Trip three-pole by distance protection
>Dist. Recept	Carrier signal for teleprotection with distance protection received
Dis. Send	Carrier send signal for teleprotection with distance protection transmitted
Dis.TransBlo	Transient blocking function of teleprotection with distance protection has operated

Fault annunciation of power swing supplement:

O/S Trip	Out-of-step trip signal issued

Fault annunciations of user definable logic functions and external trip function:

>User T1Start	Start user definable timer T1 during fault
>User T1Reset	Reset user definable timer T1 during fault
User output 1	Output of user definable timer T1 during fault
>User T2Start	Start user definable timer T2 during fault
>User T2Reset	Reset user definable timer T2 during fault
User output 2	Output of user definable timer T2 during fault
Ext.Trip 3p	Trip by external trip function three-pole
Ext.Trip woAR	Trip by external trip function three-pole without reclosure

Fault annunciations of emergency overcurrent time protection:

Emer. Flt E	Earth fault detection of emergency overcurrent time protection
Emer. Flt L1	Fault detection emergency overcurrent time protection, phase L1
Emer. Flt L1E	Fault detection emergency overcurrent time protection, phase L1 – earth
Emer. Flt L2	Fault detection emergency overcurrent time protection, phase L2
Emer. Flt L2E	Fault detection emergency overcurrent time protection, phase L2 – earth
Emer. Flt L12	Fault detection emergency overcurrent time protection, phases L1 – L2
Emer.Flt L12E	Fault detection emergency overcurrent time protection, phases L1 – L2 – earth
Emer. Flt L3	Fault detection emergency overcurrent time protection, phase L3
Emer. Flt L3E	Fault detection emergency overcurrent time protection, phase L3 – earth
Emer. Flt L13	Fault detection emergency overcurrent time protection, phases L1 – L3
Emer.Flt L13E	Fault detection emergency overcurrent time protection, phases L1 – L3 – earth
Emer. Flt L23	Fault detection emergency overcurrent time protection, phases L2 – L3
Emer.Flt L23E	Fault detection emergency overcurrent time protection, phases L2 – L3 – earth
Emer.Flt L123	Fault detection emergency overcurrent time protection, phases L1 – L2 – L3

`Emer.Flt 123E`	Fault detection emergency overcurrent time protection, phases L1 – L2 – L3 – earth
`Emer. I>>`	Fault detection emergency overcurrent protection on high phase current stage I>>
`Emer. I>`	Fault detection emergency overcurrent protection on phase overcurrent stage I>
`Emer. IE>`	Fault detection emergency overcurrent protection on earth overcurrent stage I_E>
`Emer.Trip 3p`	Trip three-pole by emergency overcurrent time protection

Fault annunciation of thermal overload protection:

`O/L Trip`	Trip by thermal overload protection

Fault annunciation of earth fault detection in non-earthed systems:

Note: These annunciation occur only in the fault annunciations when the high-sensitivity earth fault protection is configured to trip on earth fault (address 3001 EARTH FAULT = *ON*, refer also to Section 6.3.11). Otherwise, the annunciations are stored only in the earth fault report (refer to Section 6.4.4).

`E/F Detection`	Earth fault detection in non-earthed systems
`E/F Det. Trip`	Trip by earth fault detection in non-earthed systems

Fault annunciations of high-resistance earth fault protection in earthed systems:

`E/F blocked`	Earth fault protection blocked (when during fault)
`E/F Flt75%Ie>`	Fault detection earth fault protection 75 % I_E> stage (valid for directional determination and transmission)
`E/F Flt Ie<->`	Fault detection earth fault protection non-directional
`E/F Flt Ie ->`	Fault detection earth fault protection directional
`E/F Trip`	Trip by earth fault protection
`E/F Send`	Directional comparison earth fault protection, carrier signal transmitted
`>E/F Recept`	Directional comparison earth fault protection, carrier signal received
`E/F TransBloc`	Transient blocking function of directional earth fault protection has operated

Fault annunciations of internal auto−reclose function:

`AR in prog.`	Auto−-eclose cycle in progress
`RAR T-3p run.`	Dead time of three-pole RAR is running
`DAR T-3p1 run`	Dead time of first three-pole DAR is running
`DAR T-3p2 run`	Dead time of second three-pole DAR is running
`DAR T-3p3 run`	Dead time of third or further three-pole DAR is running
`AR block.dyn.`	AR function dynamically blocked (by internal cause)
`AR Close Cmd.`	Reclose command from auto-reclose function issued

Fault annunciations of fault location:

`Fault Locat.`	Fault location data, the line loop is indicated from which fault data have been calculated
`Rpri = Ω`	Calculated primary fault resistance in ohms, based on the parameterized rated values (addresses 1103 to 1105, refer to Section 6.3.3.1)
`Xpri = Ω`	Calculated primary fault reactance in ohms, based on the parameterized rated values (addresses 1103 to 1105, refer to Section 6.3.3.1)
`Rsec = Ω`	Calculated secondary fault resistance in ohms, based on 1 A
`Xsec = Ω`	Calculated secondary fault reactance in ohms, based on 1 A
`d = km`	Calculated fault distance in kilometers, based on the parameterized rated values (addresses 1103 to 1105, refer to Section 6.3.3.1) and the line data as parameterized under addresses 1122 and 1124 (refer to Section 6.3.3.2)
`d[%] = %`	Calculated fault distance in % of line length, based on the parameterized rated values (addresses 1103 to 1105, refer to Section 6.3.3.1) and the line data as parameterized under addresses 1122 and 1124 (refer to Section 6.3.3.2)

Further messages:

`Table empty`	means that no fault event has been recorded
`Table overflow`	means that other fault data have occurred, however, memory is full
`Table superceded`	a new fault event has occurred during read-out: page on with ↑ or ↓; the display shows the first annunciation in the actualized order
`End of table`	If not all memory places are used the last message is `End of table`.

The data of the **second to last** system fault can be found under address 5300. The available annunciations are the same as for the last fault.

```
⇧ 5300█ 2nd TO LAST
⇩ FAULT
```

Beginning of the block ”Fault annunciations of the second to last system fault”

etc.

The data of the **third to last** system fault can be found under address 5400. The available annunciations are the same as for the last fault.

```
⇧ 5400█ 3rd TO LAST
⇩ FAULT
```

Beginning of the block ”Fault annunciations of the third to last system fault”

etc.

6.4.4 Data of earth faults in non-earthed systems – address block 55

For earth faults in isolated or compensated networks a special earth fault data store is available under address 5500. Up to 80 messages can be stored for each of the last three earth faults. Input of the codeword is not required.

The earth fault reports can be called up by direct addressing, using **DA 5 5 0 0 E** or by paging with the keys ⇑ or ⇓ to the address 5500. With the keys ↑ or ↓ one can page forwards or backwards within the indications.

In the following list, the available earth fault annunciations are attached to the box with main heading. In a specific case, of course, only the associated indications appear in the display.

⇑⇓ `5500 ISOLATED` / `EARTH FLT DATA`	Beginning of block ”Earth fault event data for non-earthed system”
↑↓ `001 27.10.96` / `E/F Det. 18`	under item No. 1, the date and the sequence number of the earth fault are displayed
↑↓ `002 10:43:57` / `E/F Detection :C`	Item No. 2 shows the time of commencement of the earth fault
	The following items show the earth fault data
`E/F Detec. L1`	Earth fault detected in phase L1
`E/F Detec. L2`	Earth fault detected in phase L2
`E/F Detec. L3`	Earth fault detected in phase L3
`E/F forwards`	Earth fault in forward direction
`E/F reverse`	Earth fault in reverse direction
`E/F undefined`	Earth fault direction undefined (e.g. current too small
`Iea 18 mA`	Active component of earth fault current
`Ier 126 mA`	reactive component of earth fault current
`E/F Det. Trip`	Trip on earth fault (only when earth fault detection is configured to trip)
`E/F Buff.Over`	Earth fault annunciations lost (buffer overflow)
`Table empty`	means that no earth fault has been recorded (yet)

Reports of further earth faults begin with item number 101 and 201, e.g.:

↑↓ `101 19.07.96` / `E/F Det. 17`	under Item No. 101, the date of another earth fault can be displayed, followed by the respective data

6.4.5 Circuit breaker operation statistics – address block 56

The number of trip commands initiated by the relay is counted. Also, the number of auto-reclose attempts is counted, separately for RAR (first shot) and DAR (further shots). Additionally, the interrupted currents are stated for each individual pole and given under the fault annunciations (refer to Section 6.4.3) following each trip command. These currents are accumulated and stored. Counter status and stores are secured against auxiliary voltage failure and can be read off in address block 56. The address can be reached by direct addressing **DA 5 6 0 0 E** or by paging with the keys ⇑ or ⇓ until address 5600 is reached. The counters can be called up using the key ↑ for forwards paging or ↓ for backwards paging.

Entry of the codeword is not required for read-off of counter states.

⇑⇓
```
5 6 0 0 █ C B   O P E R A T .
S T A T I S T I C S
```
Beginning of the block "Circuit breaker operation statistics"

↑↓
```
5 6 0 2 █ A R   3 p o l e =
1 8
```
Number of auto-reclose attempts, 1st AR cycle (RAR) e.g. 18

Page on with key ↑ to get further counter states:

↑
```
5 6 0 3 █ D A R   3 p o l =
```
Number of auto-reclose attempts, further AR cycles (DAR)

↑
```
5 6 0 4 █ T R I P   N o   =
```
Number of trip commands issued by the relay

↑
```
5 6 0 7 █ Σ I L 1 / I n =
```
Accumulated interrupted currents for CB pole L1

↑
```
5 6 0 8 █ Σ I L 2 / I n =
```
Accumulated interrupted currents for CB pole L2

↑
```
5 6 0 9 █ Σ I L 3 / I n =
```
Accumulated interrupted currents for CB pole L3

The maximum values of the counters are:

– *RAR 3pole, DAR 3pole*	9 digits
– *Trip No*	9 digits
– *ΣIL1/In*, *ΣIL2/In*, *ΣIL3/In*	7 digits plus 1 decimal digit

The counters can be reset to 0 in block 82 (see Section 6.5.2).

6.4.6 Read-out of operational measured values – address blocks 57 and 59

The steady state r.m.s. operating values can be read out at any time in address block 57. The address can be called up directly using **DA 5 7 0 0 E** or by paging with ⇑ or ⇓. The individual measured values can be found by further paging with ↑ or ↓. Entry of the codeword is not necessary. The values will be updated in approximately 1 to 5 seconds intervals.

The data are displayed in absolute primary values and in percent of the rated device values. To ensure correct primary values, the rated data must be entered to the device under address block 11 as described in Section 6.3.3.1.

In the following example, some typical values have been inserted. In practice the actual values appear.

⇑⇓
```
5700 OPERATIONAL
MEASURED VALUES
```

Beginning of the block "Operational measured values"

Use ↑ key to move to the next address with the next measured value.

↑↓
```
5701 MEAS.VALUE
IL1  = 460  A
```

Page on with the ↑ key to read off the next address with the next measured value, or page back with ↓.

↑↓
```
5702 MEAS.VALUE
IL2  = 485  A
```

One address is available for each measured value. The values can be reached also by direct addressing using key **DA** followed by the address number and execute with **E**.

↑↓
```
5703 MEAS.VALUE
IL3  = 473  A
```

The primary values (addresses 5701 to 5711) are based on the primary rated values as parameterized under addresses 1103 (for U_N) and 1105 (for I_N) (refer to Section 6.3.3.1).

↑↓
```
5704 MEAS.VALUE
UL1E= 64.5  kV
```

↑↓
```
5705 MEAS.VALUE
UL2E= 63.9  kV
```

↑↓
```
5706 MEAS.VALUE
UL3E= 64.3  kV
```

↑↓
```
5707 MEAS.VALUE
UL12= 110.2  kV
```

```
5708█MEAS.VALUE
UL23= 111.0 kV
```

```
5709█MEAS.VALUE
UL31= 111.5 kV
```

```
5710█MEAS.VALUE
Pa= 79.1 MW
```

```
5711█MEAS.VALUE
Pr= 44.8 MVAr
```

```
5712█MEAS.VALUE
f [%] = 99.9 %
```

The percentage is referred to rated frequency 50 Hz or 60 Hz as parameterized under address 7899 (refer to Section 5.4.2)

```
5713█MEAS.VALUE
IL1[%]= 76.6 %
```

The percentage is referred to rated current

```
5714█MEAS.VALUE
IL2[%]= 80.8 %
```

```
5715█MEAS.VALUE
IL3[%]= 78.8 %
```

```
5716█MEAS.VALUE
UL1E[%]= 101.6 %
```

The percentage is referred to rated voltage divided by $\sqrt{3}$

```
5717█MEAS.VALUE
UL2E[%]= 100.6 %
```

```
5718█MEAS.VALUE
UL3E[%]= 101.2 %
```

```
5719▌MEAS.VALUE
UL12[%]=  100.2 %
```

The percentage is referred to rated voltage

```
5720▌MEAS.VALUE
UL23[%]=  100.9 %
```

```
5721▌MEAS.VALUE
UL31[%]=  101.3 %
```

```
5722▌MEAS.VALUE
Pa[%]=  69.1  %
```

The percentage is referred to rated apparent power $\sqrt{3} \cdot U_N \cdot I_N$

```
5723▌MEAS.VALUE
Pr[%]=  39.2  %
```

The calculated temperature rise for the overload protection can be read out in address block 59. The address can be called up directly using **DA 5900 E** or by paging with ⇑ or ⇓. The individual measured values can be found by further paging with ↑ or ↓. Entry of the codeword is not necessary.

The values are available as long as the thermal overload protection is configured as THERMAL OL = *EXIST* (address 7827) and switched on (address 2701). Page on with the ↑ key to read off the next address with the next measured value, or page back with ↓.

```
5901▌MEAS.VALUE
Θ/ΘtripL1=  49  %
```

The calculated temperature rises of the individual phases are not presented if the measuring method Θ with Imax has been selected (address 2706)

```
5902▌MEAS.VALUE
Θ/ΘtripL2=  54  %
```

```
5903▌MEAS.VALUE
Θ/ΘtripL3=  51  %
```

```
5904▌MEAS.VALUE
Θ/Θtrip  = 54  %
```

The percentage is referred to the trip temperature rise according to the measurement method as selected in address 2706

6.4.7 Read-out of earth fault measured values in non-earthed systems − address block 58

The measured values during an earth fault can be read out in address block 58. The address can be directly called up using **DA 5 8 0 0 E** or by paging with keys ⇑ or ⇓. The individual values can be found then by further paging with ↑ or ↓. Entry of the codeword is not necessary. The values are recorded only if the relay is equipped with the earth fault detection function and when this is configured to *EXIST*.

The displayed values are: the active component Iea and the reactive component Ier of the earth current, as primary values and as secondary values at the relay terminals. Pre-requisite for correct output of the current values is that the rated data are correctly parameterized in address block 11 (refer to Section 6.3.3.1).

In the following example, some typical values have been inserted. In practice the actual values appear.

⇑⇓
```
5800█ISOL.  E/F
MEASURED  VALUES
```

Beginning of the block "Measured values of earth fault detection in non-earthed systems"

↑↓
```
5801█MEAS.VALUE
Iea  =  0.0  A
```

Use ↑ key to display the next address with the next measured value, or use ↓ key for the previous address.

Each measured value is assigned to one address; each address, alternatively, can be reached by direct addressing, using key **DA** followed by the address number.

The primary values (addresses 5801 and 5802) are based on the primary rated values as parameterized under addresses 1112 and 1105 (refer to Section 6.3.3.1).

↑↓
```
5802█MEAS.VALUE
Ier  =  1.2  A
```

↑↓
```
5803█MEAS.VALUE
Iea[mA]=  0.5  mA
```

↑↓
```
5804█MEAS.VALUE
Ier[mA]=  20.0  mA
```

6.5 Operational control facilities

During operation of the protection relay it may be desired to intervene in functions or annunciations manually or from system criteria. 7SA510 comprises facilities, e.g. to re-adjust the real time clock, to erase stored informations and event counters, to switch on or off partial functions under specific conditions, or to change over preselected sets of function parameters. The scope of operational control facilities depends on the ordered scope of functions of the device (refer to Section 2.3 Ordering data).

The functions can be controlled from the operating panel on the front of the device, via the operating and system interface as well as via binary inputs.

In order to control functions via binary inputs it is necessary that the binary inputs have been marshalled to the corresponding switching functions during installation of the device and that they have been connected (refer to Section 5.5.2 Marshalling of the binary inputs).

The control facilities begin with address block 8000. This address is reached

– by block paging with the keys ⇑ forwards or ⇓ backwards up to address 8000, or
– by direct selection with address code, using key **DA**, address **8 0 0 0** and execute with key **E.**

```
8000█ DEVICE
CONTROL
```

Beginning of the block "Device control"

6.5.1 Adjusting and synchronizing the real time clock – address block 81

The date and time can be adjusted at any time during operation as long as the real time clock is operative. Setting is carried out in block 81 which is reached by direct addressing **DA 8 1 0 0 E** or by paging with ⇑ and ⇓. Input of the codeword is required to change the data.

Selection of the individual addresses is by further scrolling using ↑ ↓ as shown below. Each modification must be confirmed with the enter key **E**.

```
8100█ SETTING
REAL TIME CLOCK
```

Beginning of the block "Setting the real time clock". Continue with ↑.

```
25.10.1996
15:54:42
```

At first, the actual date and time are displayed. Continue with ↑.

```
8102█ DATE
```

Enter the new date: 2 digits for day, 2 digits for month and 4 digits for year (including century); use the order as configured under address 7102 (Section 5.3.2), but always use a dot for separator:
DD.MM.YYYY or **MM.DD.YYYY**

```
8103█ TIME
```

Enter the new time: hours, minutes, seconds, each with 2 digits, separated by a dot:
HH.MM.SS

```
8104█ DIFF. TIME
```

Using the difference time, the clock is set forwards by the entered time, or backwards using the **+/–** key. The format is the same as with the time setting above.

6.5.2 Erasing stored annunciations and counters – address block 82

The statistical indications (Section 6.4.5, address block 56) are stored in EEPROMs in the device. They are not therefore erased if the auxiliary power supply fails. Additionally, annunciations and the status of the LED memories are stored in NV–RAMs and thus saved provided the back-up battery is operational. These stores can be cleared in block 82. Block 82 is called up by paging with the keys ⇑ or ⇓ or directly by keying in the code **DA 8 2 0 0 E**. With the exception of resetting the LED indications (address 8201), codeword entry is necessary to erase the stored items. Reset is separate for the different groups of counters, memories and annunciations. One reaches the individual items by paging ↑ ↓. Erasure requires confirmation with the key **J/Y**. The display then confirms the erasure. If erasure is not required, press key **N** or simply page on.

```
8200
RESET
```

Beginning of block "Reset"

```
8201 RESET
LED ?
```

Request whether the LED memories should be reset

```
8202 RESET
OPERAT.ANNUNC. ?
```

Request whether the operational annunciation buffer store should be erased

```
8203 RESET
FAULT ANNUNC. ?
```

Request whether the fault annunciation buffer and fault recording stores should be erased

```
8204 RESET
COUNTERS ?
```

Request whether the CB operation counters should be set to zero

```
8205 RESET
TOTAL Isc ?
```

Request whether the total of switched short-circuit currents should be set to zero

```
8206 RESET
E/F ANNUNC. ?
```

Request whether the earth fault report buffer store (for earth faults in non-earthed systems) should be erased

During erasure of the stores (which may take some time) the display shows TASK IN PROGRESS. After erasure the relay acknowledges erasure, e.g.

```
8202 RESET
EXECUTED
```

6.5.3 Information to LSA during test operation – address block 83

When the relay is connected to a central storage device or localized substation automation system and the protocol according VDEW/ZVEI (IEC 60870–5–103) is used, then the informations which are transmitted to the central computing system can be influenced.

The standardized protocol allows all annunciations, messages, and measured values to be tagged with the origin ”test operation”, which occur while the relay is tested. Thus, these messages can be distinguished from those which occur during real operation. Additionally, it is possible to block all annunciations, messages and measured values to LSA during test operation.

This features can be accomplished via binary inputs or using the integrated operating keyboard or via the operating (PC) interface.

In order to accomplish switch-over via binary inputs, the respective inputs must have been assigned during marshalling (refer to Section 5.5.2). The following input functions are suitable:

FNo `15` `>Sys-Test` for tagging the messages and measured values with the origin ”Test operation”,

FNo `16` `>Sys-MM-block` for blocking all messages and measured values.

In order to carry out switch-over by the operator, entry of the codeword is necessary (refer to Section 5.3.1). For this purpose, address block 83 is available provided the VDEW/ZVEI protocol (IEC 60870–5–103) has been chosen during configuration of the serial system interface (Section 5.3.3, address 7221 and/or 7222 *VDEW COMPATIBLE* or *VDEW EXTENDED*). The block is called up by paging with the keys ⇑ or ⇓ or directly by keying in the code **DA 8 3 0 0 E**. Use key ↑ to scroll to address 8301. By pressing the ”No”–key **N** the positions of this switch are changed. The desired position must be confirmed with the enter key **E**.

As with every settings of the device for which codeword input is necessary, codeword operation must be terminated. This is done by using the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question ”SAVE NEW SETTINGS?”. Confirm with the ”Yes”–key **J/Y** that the new settings shall become valid now. If you press the ”No”–key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

```
8300 SYS-VDEW
ANNUNC.-MEAS.VAL
```

Beginning of block ”Annunciations and measured values for the system interface with VDEW/ZVEI compatible protocol (IEC 60870–5–103)”

```
8301 SYS TEST
OFF
```

```
ON
```

Only for VDEW/ZVEI compatible protocol (IEC 60870–5–103):

in *ON* position, the VDEW/ZVEI–compatible annunciations (IEC 60870–5–103) are assigned with the origin ”test operation”

```
8302 SYS BLOCK
OFF
```

```
ON
```

Only for VDEW/ZVEI compatible protocol (IEC 60870–5–103):

in *ON* position, no annunciations and measured values are transmitted to the system interface

Do not forget to switch the addresses back to *OFF* after having finished test operations!

6.5.4 Selection of parameter sets – address block 85

Up to 4 different sets of parameters can be selected for the functional parameters, i.e. the addresses above 1000 and below 4000. These parameter sets can be switched over during operation, locally using the operator panel or via the operating interface using a personal computer, or also remotely using binary inputs or the system interface.

The first parameter set is identified as set A, the other sets are B, C and D. Each of these sets has been set during parameterizing (Section 6.3.1.2) provided the switch-over facility is used.

6.5.4.1 Read-out of settings of a parameter set

In order to **look up** the settings of a parameter set **in the display** it is sufficient to go to any address of the function parameters (i.e. addresses above 1000 and below 4000), either by direct addressing using key **DA**, entering the four-figure address code and terminating with enter key **E**, or by paging through the display with ⇑ or ⇓. You can switch-over to look up a different parameter set, e.g.

– Press key combination **F 2**, i.e. first the function key **F** and then the number key **2**. All displayed parameters now refer to parameter set B.

The parameter set is indicated in the display by a leading character (A to D) before the address number indicating the parameter identification.

The corresponding procedure is used for the other parameter sets:

- Key combination **F 1**: access to parameter set **A**
- Key combination **F 2**: access to parameter set **B**
- Key combination **F 3**: access to parameter set **C**
- Key combination **F 4**: access to parameter set **D**

The relay operates always with the active parameter set even during read-out of the parameters of any desired parameter set. The change-over procedure described here is, therefore, only valid for **read-out** of parameters **in the display**.

6.5.4.2 Change-over of the active parameter set from the operating panel

For **change over to a different parameter set**, i.e. if a different set shall be activated, the address block 85 is to be used. For this, codeword entry is required.

The block for processing parameter sets is reached by pressing the direct address key **DA** followed by the address **8 5 0 0** and enter key **E** or by paging through the display with ⇑ or ⇓. The heading of the block will appear:

```
⇑  8500▮PARAMETER
⇓  CHANGE-OVER
```

Beginning of the block ”Parameter change-over”: processing of parameter sets

It is possible to scroll through the individual addresses using the ↑ key or to scroll backwards with ↓.

Address 8501 shows the actually active parameter set with which the relay operates.

In order to switch-over to a different parameter set scroll on with ↑ to address 8503. Using the ”No”–key **N** you can change to any desired parameter set; alternatively, you can decide that the parameter sets are to be switched over from binary inputs, or via the system interface. If the desired set or possibility appears in the display, press the enter key **E**.

As with every settings of the device for which codeword input is necessary, codeword operation must be terminated. This is done by using the key combination **F E**, i.e. depressing the function key **F** followed by the entry key **E**. The display shows the question ”SAVE NEW SETTINGS?”. Confirm with the ”Yes”–key **Y** that the new settings shall become valid now. If you press the ”No”–key **N** instead, codeword operation will be aborted, i.e. all alterations which have been changed since the last codeword entry are lost. Thus, erroneous alterations can be made ineffective.

```
8501 ACTIV PARAM
SET A
```

Address 8501 shows the actually active parameter set

```
8503 ACTIVATION
SET A
```

```
SET B
```

```
SET C
```

```
SET D
```

```
SET BY BIN.INPUT
```

```
SET BY LSA CONTR
```

Use the "No"–key **N** to page through the alternative possibilities. The desired possibility is selected by pressing the enter key **E**.

If you select *SET BY BIN.INPUT*, then the parameter set can be changed over via binary inputs (see Section 6.5.4.3)
If you select *SET BY LSA CONTR*, then the parameter set can be changed over via the system interface

6.5.4.3 Change-over of the active parameter set via binary inputs

If change-over of parameter sets is intended to be carried out via binary inputs, the following is to be heeded:

– Locally (i.e. from the operator panel or from PC via the operating interface), ACTIVATION must be switched to *SET BY BIN.INPUT* (refer to Section 6.5.4.2).

– 2 logical binary inputs are available for control of the 4 parameter sets. These binary inputs are designated "`>ParamSelec.1`" and "`>Param Selec.2`" (FNo 7 and 8).

– The logical binary inputs must be allocated to 2 physical input modules (refer to Section 5.5.2) in order to allow control. An input is treated as not energized when it is not assigned to any physical input.

– The control input signals must be continuously present as long as the selected parameter set shall be active.

The active parameter sets are assigned to the logical binary inputs as shown in Table 6.2.

A simplified connection example is shown in Figure 6.5. Of course, the binary inputs must be declared in normally open ("NO") mode.

Binary input ParamSelec.1	Binary input ParamSelec.2	causes active set
no	no	Set A
yes	no	Set B
no	yes	Set C
yes	yes	Set D

no = input not energized
yes = input energized

Table 6.2 Parameter selection via binary input

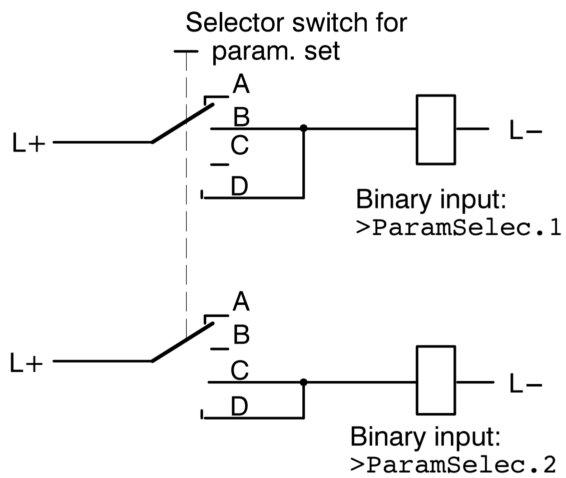


Figure 6.5 Connection scheme for parameter change-over via binary inputs

6.6 Testing and commissioning

6.6.1 General

Prerequisite for commissioning is the completion of the preparation procedures detailed in Chapter 5.

Warning

Hazardous voltages are present in this electrical equipment during operation. Non-observance of the safety rules can result in severe personal injury or property damage.

Only qualified personnel shall work on and around this equipment after becoming thoroughly familiar with all warnings and safety notices of this manual as well as with the applicable safety regulations.

Particular attention must be drawn to the following:

- The earthing screw of the device must be connected solidly to the protective earth conductor before any other connection is made.
- Hazardous voltages can be present on all circuits and components connected to the supply voltage or to the measuring and test quantities.
- Hazardous voltages can be present in the device even after disconnection of the supply voltage (storage capacitors!).
- The limit values given in the Technical data (Section 3.1) must not be exceeded at all, not even during testing and commissioning.

When testing the unit with a secondary injection test set, it must be ensured that no other measured values are connected and that the tripping leads to the circuit breaker trip-coils have been interrupted.

DANGER!

Secondary connections of the current transformers must be short-circuited before the current leads to the relay are interrupted!
If a test switch is installed which automatically short-circuits the current transformer secondary leads, it is sufficient to set this switch to the "Test" position. The short-circuit switch must be checked beforehand (refer to Section 5.2.6).

It is recommended that the actual settings for the relay be used for the testing procedure. If these values are not (yet) available, test the relay with the factory settings. In the following description of the test sequence the preset settings are assumed unless otherwise noted; for different setting values formulae are given, where necessary.

For the functional test a three-phase symmetrical voltage source with individually adjustable voltage outputs, together with a three-phase symmetrical current source with individually adjustable currents, should be available. For checking the distance zones, AR, teleprotection and back-up overcurrent, a single-phase current source is sufficient, but this is not adequate for a correct functional check of the measured value monitoring systems and power swing detector. Phase displacement between test current I_P and test voltage U_P should preferably be continuously adjustable but at least settings of 90° and 0° shall be available.

If unsymmetrical currents and voltages occur during the tests it is likely that the asymmetry monitoring will frequently operate. This is of no concern because the condition of steady-state measured values is monitored and, under normal operating conditions, these are symmetrical; under short circuit conditions these monitoring systems are not effective. Additionally, unsymmetrical voltages may cause the fuse failure monitor to operate. This switches the distance protection out of service so that distance measurement is not possible! If this happens, this monitoring must either be made ineffective during the test (by switching it *OFF* under Address 2910) or it must be ensured that during all tests without earth current detection no residual voltage occurs.

NOTE! The accuracy which can be achieved during testing depends on the accuracy of the testing equipment. The accuracy values specified in the Technical data can only be reproduced under the reference conditions set down in IEC 60255 resp. VDE 0435/part 303 and with the use of precision measuring instruments. The tests are therefore to be looked upon purely as functional tests.

During all the tests it is important to ensure that the correct command (trip) contacts close, that the proper indications appear at the LEDs and the output relays for remote signalling. If the relay is connected to a central memory device via the serial interface, correct communication between the relay and the master station must be checked.

After tests which cause LED indications to appear, these should be reset, at least once by each of the possible methods: the reset button on the front plate and via the remote reset relay (see connection diagrams, Appendix A). If the reset functions have been tested, resetting the stored indications is no more necessary as they are erased automatically with each new pick-up of the relay and replaced by the new annunciations.

6.6.2 Testing the overcurrent fault detection stage and emergency overcurrent time protection

Apply symmetrical rated voltages to all three phases to avoid immediate trip after pick-up.

Testing can be performed with single-phase, two-phase or three-phase test current without difficulties.

Setting parameter Iph>> (address 1601) is decisive for the phase currents. For setting values up to 4 x I_N, the current can be increased gradually in any phase until the stage picks up.

Caution!

Test currents larger than 4 times I_N may overload and damage the relay if applied continuously (refer to Section 3.1.1 for overload capability). Observe a cooling down period!

For tests currents above 4 x I_N measurement shall be performed dynamically. It should be ensured that the relay picks up at 1.1 times setting value and does not pick up at 0.9 times setting value. The reset value should lie at 95% of the pick-up value.

When, for test current phase-earth, the set value for Iph>> (factory setting 1.8 x I_N) is exceeded the pick-up indication for I_E> (LED 5 at factory setting) and pick-up indication appears for the tested phase (LED 2 for L1 or LED 3 for L2 or LED 4 for L3 at factory setting). When testing phase-phase, pick-up indication appears for the associated phases.

Final times are normally tested at 2 x setting value. Dependent upon polarity of the voltage, directional final time T4 or non-directional final time T5 will apply (address 1203 or 1204; consider also address 1202 for directional trip). It must be noted that the set times are pure delay times; operating times of the measurement functions are not included.

Put voltage transformer m.c.b. in tripped position. Repeat time measurement for one phase. Now, the delay time for emergency back-up operation is applicable: T–I> (address 2613), T–I>> (address 2603), T–IE> (address 2643). A prerequisite is that the function EMERG. O/C = *EXIST* is selected under address 7826 in the scope of functions (Section 5.4.2) and this function is switched *ON* under address 2601.

6.6.3 Testing the voltage controlled fault detection U/I (if fitted)

Close voltage transformer mcb.

Testing can be performed with single-phase, two-phase or three-phase test current without difficulties.

Set test voltage to 0 V.

Slowly increase test current of one phase until the fault detector picks up:

- When the test current exceeds the setting value (address 1611, 0.2 times I_N when delivered), pick-up annunciation occurs for the associated phase(s): "`Dist.Flt. L1`" and LED 2 when delivered for phase L1; for a different phase accordingly (LED 3 for L2, LED 4 for L3).

Switch off test current.

The voltage dependent branch of the pick-up characteristic is shown in Figure 6.6. When delivered the slope of the voltage dependent branch is 0.

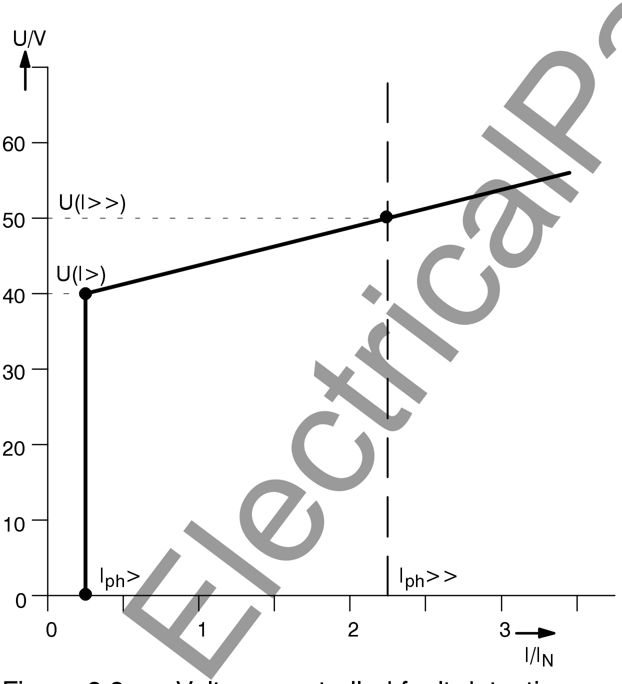


Figure 6.6 Voltage controlled fault detection, U/I characteristic

If voltage control is carried out with U_{Ph-E}, set test voltage of the tested phase to approximately the rated phase-to-earth voltage; set test current of the same phase to twice the setting value Iph> (address 1611). The phase-to-earth voltage is decisive for pick-up.

Slowly decrease voltage until the fault detector picks up:

- When the test voltage goes below the set value of address 1612/1613 (48 V at delivery) pick-up annunciation occurs for the associated phase: "`Dist.Flt. L1`" and LED 2 at delivery for phase L1; for a different phase accordingly ("`Dist.Flt. L2`" and LED 3 for L2, "`Dist. Flt. L3`" and LED 4 for L3).

If voltage control is carried out with U_{Ph-Ph}, set test voltage of the tested loop to approximately the rated voltage; set test current of both the phases to twice the setting value Iph> (address 1611); phase relationship of test voltage and test current is irrelevant. The phase-to-phase voltage is decisive for pick–up.

Slowly decrease voltage until the fault detector picks up:

- When the test voltage gets smaller than the set value of address 1614/1615 (80 V at delivery) pick-up annunciation occurs for both the associated phases: "`Dist.Flt.L12`" and LED 2 and LED 3 at delivery for phase loop L1–L2; for a different loop accordingly "`Dist.Flt.L23`" and LED 3 and LED 4 for phase loop L2–L3, "`Dist.Flt.L13`" and LED 2 and LED 4 for phase loop L1–L3).

The procedure described above is valid for the preset values of Uphe(I>>) (address 1612), Uphe(I>) (address 1613), Uphph(I>>) (address 1614) and Uphph(I>) (address 1615). In this case the slope of the voltage dependent branch of the pick-up characteristic is 0, i.e. Uphe(I>>) = Uphe(I>) and Uphph(I>>) = Uphph(I>).

If the voltage dependent branch is inclined, the expected pick-up value of the voltage can be calculated according the following formula, provided the test current is 2 times the setting value of Iph>:

Pick-up value *U*

$$= U(I>) + [U(I \gg) - U(I>)] \cdot \frac{Iph>}{Iph \gg - Iph>}$$

where:

U(I>) is the setting value Uphe(I>) (address 1613) with U_{ph-e} control but Uphph(I>) (address1615) with U_{ph-ph} control,

U(I>>) is the setting value Uphe(I>>) (address 1612) with U_{ph-e} control but Uphph(I>>) (address 1614) with U_{ph-ph} control.

6.6.4 Testing the impedance fault detection (if fitted)

Close voltage transformer m.c.b.

Always apply three-phase test voltage; ensure clockwise phase rotation!

Feed a test current $I_P = 2 \cdot I_N$ into the loop under test. If the test voltage would exceed rated voltage when the threshold is reached, reduce test current, but only so far that operation of minimum current detection Iph> (address 1621) is guaranteed. The test current must be kept constant during a test!

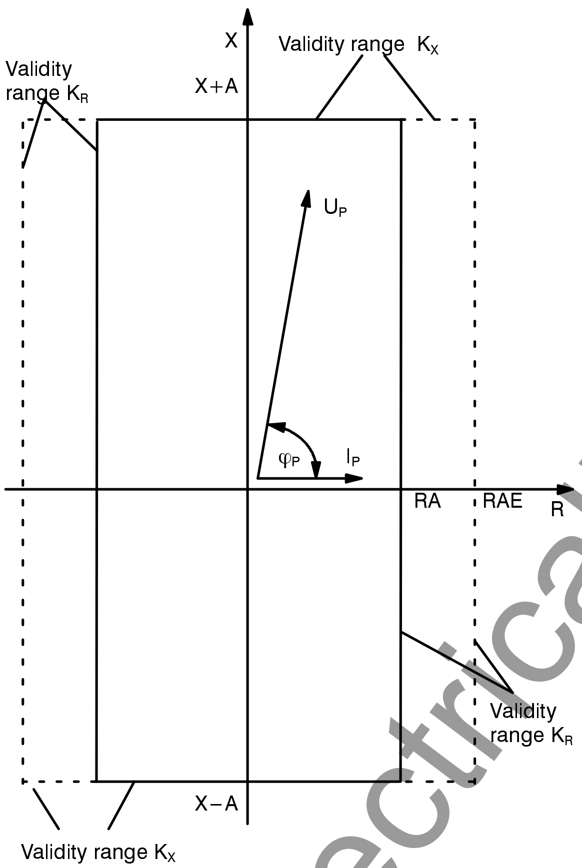


Figure 6.7 Impedance fault detection characteristic

Determine the threshold point by slow reduction of the voltage. Check indicators and outputs. Since the fault detection polygon is made up of straight lines (Figure 6.7) different formulae must be used for the threshold voltages dependent upon the intersections of these lines. The general formulae are:

– For the reactance intersections (X−reach)

$$U_P/V = \mathbf{K_X} \cdot X_{\pm A} \cdot I_P/I_N$$

– For the resistance intersections (R−limitation)

$$U_P/V = \mathbf{K_R} \cdot R_A \cdot I_P/I_N$$

where I_P – test current
I_N – rated current of relay
U_P – test voltage at threshold
$X_{\pm A}$ – setting value X+A for X−axis positive or setting value X−A for X−axis negative
R_A – setting value RA or RAE, for +R−axis positive, for −R−axis negative
K_X – factor for X intersection according Table 6.4
K_R – factor for R intersection according Table 6.4

For phase-to-earth testing, the test current is applied to one phase and the earth current path. Test voltage is the phase-to-earth voltage.

For testing phase-to-phase the current must flow through the tested phases in opposite directions. Test voltage is the phase-to-phase voltage. It is essential to ensure absolute symmetry of the two phase voltages, otherwise error will occur!

For three-phase testing, it is reasonable to measure one phase-to-earth voltage and the associated phase current. For the factory set values and I_P/I_N = 2 the resultant voltages will be as Table 6.3.

with fault type	φ_P = 0°	φ_P = 90°	φ_P = 180°	φ_P = 270° = − 90°
3−phase	U_P = 12 V	U_P = 24 V	U_P = 12 V	U_P = 5 V
2−phase	U_P = 24 V	U_P = 48 V	U_P = 24 V	U_P = 10 V
1−phase	U_P = 48 V	U_P = 48 V	U_P = 48 V	U_P = 10 V

Table 6.3 Test voltages U_P with test current $I_P = 2 \cdot I_N$ and presetting

with fault type	K_X		K_R	
	$\varphi_P = 90°/270°$	general	$\varphi_P = 0°/180°$	general
3–phase	1	$\frac{1}{\sin \varphi_P}$	1	$\frac{1}{\cos \varphi_P}$
2–phase	2	$\frac{2}{\sin \varphi_P}$	2	$\frac{2}{\cos \varphi_P}$
1–phase	$1 + X_E/X_L$	$\frac{1 + X_E/X_L}{\sin \varphi_P}$	$1 + R_E/R_L$	$\frac{1 + R_E/R_L}{\cos \varphi_P}$

Table 6.4 Test factors K_X and K_R for individual settings

If different values have been set for RA1 (address 1624) and RA2 (address 1625) then RA1 is valid for phase angles between –PHI A and +PHI A (address 1628), and between the complement angles 180° – PHI A and 180° + PHI A. For other phase angles, setting value RA2 is decisive.

If different values have been set for RA1E (address 1626) and RA2E (address 1627) then RA1E is valid for phase angles between –PHI AE and +PHI AE (address 1629), and between the complement angles 180° – PHI AE and 180° + PHI AE. For different phase angles, setting value RA2E is decisive.

Table 6.4 gives the factors K_X and K_R for your own settings, for test angles $\varphi_P = 90°$ and 0°, and the generally applicable formulae.

6.6.5 Testing the distance zones

Always apply three-phase test voltage; ensure clockwise phase rotation. Keep the voltage(s) in the untested phase(s) at approximately rated value.

Feed a test current $I_P = 2 \cdot I_N$ into the loop under test. If the test voltage would exceed rated voltage when the threshold is reached, reduce test current, but only so far that operation of the overcurrent detection (address 1601) or of the minimum current detection, $I_{Ph}>$ is guaranteed (address 1611 or 1621). The test current must be kept constant during a test!

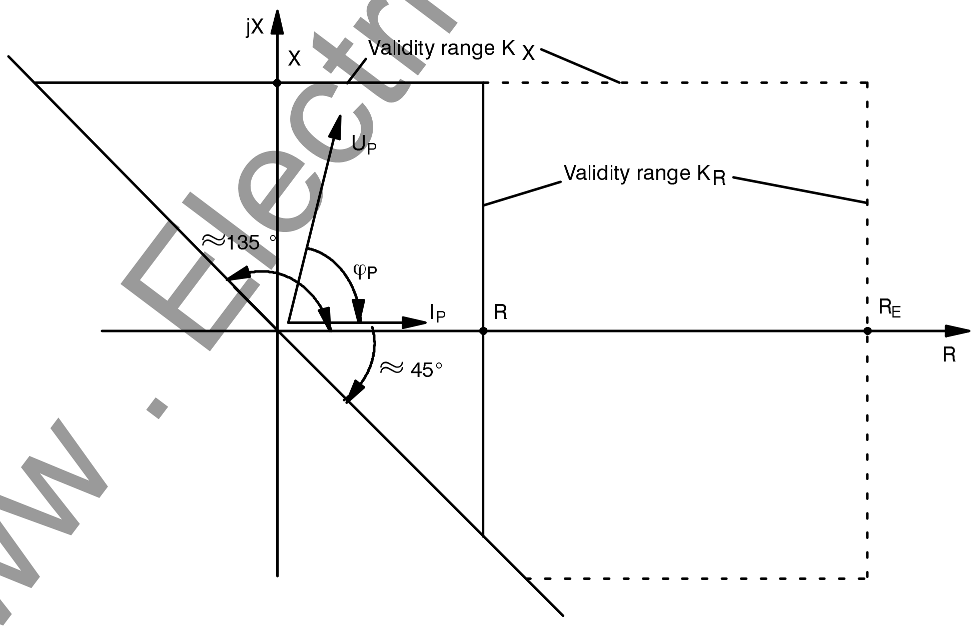


Figure 6.8 Distance zone characteristics

Determine the threshold point by slow reduction of the voltage. Check indicators and outputs. Since the tripping polygon is made up of straight lines (Figure 6.8), different formulae must be used for the threshold voltages dependent upon the intersection of these lines. The general formulae are:

– For the reactance intersections (X–reach)

$U_P/V = \mathbf{K_X} \cdot X_{Zone} \cdot I_P/I_N$

– For the resistance intersections (R–limitation)

$U_P/V = \mathbf{K_R} \cdot R_{Zone} \cdot I_P/I_N$

where I_P – test current
I_N – rated current of relay
U_P – test voltage at threshold
X_{Zone} – setting value X of the distance zone to be checked
R_{Zone} – setting value R or RE of the distance zone to be checked
K_X – factor for X intersection according Table 6.4
K_R – factor for R intersection according Table 6.4

For phase-to-earth testing, the the test current is applied to one phase and the earth current path. Test voltage is the phase-to-earth voltage.

For testing phase-to-phase the test current must flow through the tested phases in opposite directions. Test voltage is the phase-to-phase voltage. It is essential to ensure absolute symmetry of the two phase voltages, otherwise error will occur!

For three-phase testing, it is reasonable to measure one phase-to-earth voltage and the associated phase current. For the factory set values and I_P/I_N = 2 the resultant voltages will be as Tables 6.5 to 6.9.

Table 6.4 gives the factors K_X and K_R for your own settings, for test angles φ_P = 0° and 90°, and the generally applicable formulae.

Zone Z3	φ_P = 0°	φ_P = 90°
3–phase	U_P = 10 V	U_P = 20 V
2–phase	U_P = 20 V	U_P = 40 V
1–phase	U_P = 40 V	U_P = 40 V

Table 6.5 Test voltages U_P for zone Z3 at $I_P = 2 \cdot I_N$ and pre-setting

Zone Z2	φ_P = 0°	φ_P = 90°
3–phase	U_P = 5 V	U_P = 10 V
2–phase	U_P = 10 V	U_P = 20 V
1–phase	U_P = 20 V	U_P = 20 V

Table 6.6 Test voltages U_P for zone Z2 at $I_P = 2 \cdot I_N$ and pre-setting

Zone Z1	φ_P = 0°	φ_P = 90°
3–phase	U_P = 2.5 V	U_P = 5 V
2–phase	U_P = 5 V	U_P = 10 V
1–phase	U_P = 10 V	U_P = 10 V

Table 6.7 Test voltages U_P for zone Z1 at $I_P = 2 \cdot I_N$ and pre-setting

Overreach zone Z1B can only be checked under steady-state conditions, when an input relay has been allocated to the input function ">`Extens. Z1B`" and is energized (FNo `3611`, not allocated at delivery).

Zone Z1B	φ_P = 0°	φ_P = 90°
3–phase	U_P = 3 V	U_P = 6 V
2–phase	U_P = 6 V	U_P = 12 V
1–phase	U_P = 12 V	U_P = 12 V

Table 6.8 Test voltages U_P for zone Z1B at $I_P = 2 \cdot I_N$ and pre-setting

Overreach zone Z1L can only be checked under-steady-state conditions, when an input relay has been allocated to the input function ">`Extens. Z1L`" and is energized (FNo `3612`, not allocated at delivery).

Zone Z1L	φ_P = 0°	φ_P = 90°
3–phase	U_P = 4 V	U_P = 8 V
2–phase	U_P = 8 V	U_P = 16 V
1–phase	U_P = 16 V	U_P = 16 V

Table 6.9 Test voltages U_P for zone Z1L at $I_P = 2 \cdot I_N$ and pre-setting

6.6.6 Testing the grading times

For each time stage at least one additional dynamic test should be made to check the correct signalling of the time stages. For this purpose a short circuit approximately in the middle of two zones would be simulated.

When measuring the response times, do not forget that the programmed values are delay times. The inherent measurement and trip time of the relay is additional.

6.6.7 Testing the signal transmission functions

When programming the scope of the functions of the relay (Section 5.4.2.) it is decided whether the distance protection operates with intertrip facility or comparison protection, or if no teleprotection will be used (address 7821). When using a teleprotection feature, transmission and receiver circuits must be checked.

Communication between the devices and the carrier channel will be checked during commissioning with primary values (see Section 6.7.5).

6.6.7.1 Permissive underreach procedures

Simulate a short circuit in zone Z1. For the duration of the command, respectively extended by transmission signal prolongation T−SEND−PRL (address 2103) the transmission signal appears.

With permissive underreach transfer trip in zone Z1B (address 2102 PUTT MODE = *Z1B ACCELERATION)* simulate a short circuit in Z1B, but beyond Z1. Tripping results immediately the received signal ”`>Dis. Recept`” (FNo `4004`) appears (respectively in T1B) or, without received signal, first in a delayed stage.

For the condition permissive underreach transfer trip by fault detection (address 2102 = *FD ACCELERATION)* the relay must trip immediately upon receipt of the signal ”`>Dis. Recept`” (FNo `4004`), as long as it has already picked up.

6.6.7.2 Permissive overreach procedures

The transmission signal is checked by simulation of a short circuit in the applicable zone:

– With the release procedures POTT MODE = *Z1B RELEASE* or *Z1B UNBLOCK* (address 2202), a short circuit is simulated in Z1B;

– with POTT MODE = *FD DIREC RELEASE* or *FD UNBLOCK*, fault detection in the forward direction is simulated;

– with the blocking procedure *POTT MODE = Z1B BLOCKING* or *PILOT WIRE COMP,* a short circuit in the reverse direction is simulated.

In all these cases, the transmitting relay closes its working contact.

Similarly, to check the receiver circuit , a short circuit is simulated and simultaneously an external binary input ”`>Dis. Recept`” (FNo `4004`) is energized, as follows:

– with POTT MODE = *Z1B RELEASE* or *Z1B UNBLOCK* (address 2202), a short circuit in Z1B but beyond Z1: immediate trip results (respectively T1B);

– with POTT MODE = *FD DIREC RELEASE* or *FD UNBLOCK* within the fault detection zone, beyond Z1B: immediate trip results;

– with POTT MODE = *Z1B BLOCK* or *PILOT WIRE COMP* or *REVERSE INTERLOCK*, within Z1B but beyond Z1: tripping can only occur in a higher stage.

6.6.8 Testing the user definable logic functions

The operation of the user definable logic functions is widely dependent of the application. The input condition have to be produced in accordance with the intended function, and the output conditions must be checked.

When measuring the delay times, it must be noted that the set time (pick-up and/or drop-off) delays do not include the inherent time of the input and output modules; these are additional.

6.6.9 Testing the thermal overload protection function

The overload function can only be tested if it has been configured as THERMAL OL = *EXIST* (address 7827, refer to Section 5.4.2) and parameterized as operative, under address 2701.

The basis current for the detection of overload is always the rated current of the device. Overload data are calculated for each individual phase. If the tests are performed with three-phase currents no further conditions are to be considered. When testing with a single-phase current it must be noted, that the average value differs from the expected result when Θ_{mean} has been set for the operation mode under address 2706 (refer to Section 6.3.9).

When applying a test current

$$k \cdot I_N$$

tripping must not occur. After an appropriate time (approximately 5 x τ) a steady-state temperature rise according to the following relationship is established:

$$\frac{\Theta}{\Theta_{trip}} = \frac{1}{k^2}$$

This value can be read out in address block 59 for each phase.

To check the time constant, the current input is simply subjected to 1.6 x the pick-up value, i. e.

$$1.6 \times k \times I_N.$$

Tripping will then be initiated after a time interval which corresponds to half the time constant.

It is also possible to check the trip characteristic (Figure 3.1). It must be noted, that before each measurement, the temperature rise must be reduced to zero. This can be achieved by either de-activating and re-activating the overload function (address 2701) or by observing a current free period of at least 5 x τ.

Caution!

Test currents larger than 4 times I_N may overload and damage the relay if applied continuously (refer to Section 3.1.1 for overload capability). Observe a cooling down period!

If testing with preload is performed, then it must be ensured that a condition of thermal equilibrium has been established before time measurement commences. This is the case, when the preload has been applied constantly for a period of at least 5 x τ.

6.6.10 Testing the earth fault detection function (for non-earthed systems, if fitted)

Testing of the earth fault protection is not completely possible with conventional test sets, since the simulation of an earth fault requires a complete displacement of the voltage triangle. The correct relationship and polarity of the measuring transformer connections, essential for proper earth fault detection, can only be tested when primary load current is available during commissioning (see Section 6.7.3).

6.6.11 Testing the high-resistance earth fault protection for earthed systems (if fitted)

This protective function – when fitted – can be programmed as directional earth fault protection with or without directional comparison and with non-directional back-up or as non-directional inverse time overcurrent (address 7831, see Section 5.4.2.).

Before testing the earth fault protection, the distance protection shall be switched off (address 1201 DIST. PROT = *OFF*), so that it will not pick up (pick-up of the distance protection blocks the earth fault protection!).

If the directional earth fault protection (definite time overcurrent) is selected, then firstly, its non-directional back-up stage is checked by slowly raising the current of one phase .

Caution!

Test currents larger than 4 times I_N may overload and damage the relay if applied continuously (refer to Section 3.1.1 for overload capability). Observe a cooling down period!

After passing the value 75 % of the set value Ie> (address 3103) the annunciation ”E/F Flt75 % Ie>” appears (FNo 1341, not allocated in the factory setting) and after passing the set value, the annunciation ”E/F Flt Ie<->” (FNo 1342, not allocated in the factory setting).

After expiry of the time T–NON–DIR (address 3108) the annunciation ”E/F T<->” (FNo 1353, not allocated in the factory setting) and trip ”E/F Trip” (FNo 1361) appear.

To test the directional stage a residual voltage is necessary. A single-phase voltage will be applied to the phase into which the current is fed. It must be remembered that current and voltage in that same phase must be in phase opposition so, that the relay trips in the ”forwards” direction (annunciation ”E/F T->”, FNo 1352, not allocated in the factory setting).

If directional comparison is also carried out, the transmission circuit can be simultaneously checked: transmitting relay ”E/F Send” (FNo 1384, not allocated in factory setting).

To check the receiver circuit, a single-phase fault in the forwards direction is similarly simulated, simultaneously with external input of the binary signal ”>E/F Recept” (FNo 1316) is applied.

For non-directional earth fault protection one working point on the inverse time characteristic (see Figure 3.3) is checked, normally at 2 times the set value Ie> (address 3303). Pick-up indication ”E/F Flt Ie<->” (FNo 1342, at approximately 1.1 times set value, not allocated in the factory setting), trip after time delay expiry ”E/F Trip” (FNo 1361, allocated in the factory setting to the three tripping relays).

Caution!

Test currents larger than 4 times I_N may overload and damage the relay if applied continuously (refer to Section 3.1.1 for overload capability). Observe a cooling down period!

Switch distance protection on (address 1201 DIST.PROT = *ON*)**!**

6.6.12 Testing the internal auto-reclose functions (if fitted)

The internal AR function can be tested provided it is configured under address 7834 as INTERNAL AR = *EXIST* (refer to Section 5.4.2) and switched to AR FUNCT = *ON* (Address 3401).

To check the control of the overreach zone properly, the teleprotection function should be switched to PUTT = *OFF* (address 2101) or POTT = *OFF* (address 2201), and address 7921 must be set AR w/o TELE = *YES*.

The binary input "circuit breaker ready" must be simulated unless an open circuit contact has been programmed for this purpose (FNo `2730` "`>CB ready`", refer also to Section 5.5.2). If the circuit breaker is not ready before beginning of a test, a reclose attempt must not result; clearance of short circuits beyond Z1 is delayed by T2 or in a later stage.

Reclosing is even blocked when – at the moment of AR initiation (trip command) – the circuit breaker is signalled to be open, i.e. the breaker auxiliary contact is marshalled to a binary input (FNo `354`) and this input indicates an open breaker. For security reasons, automatic *re*closure shall only be carried out when the *closed* ciircuit breaker has been opened before.

A single-phase or two-phase short circuit should be simulated within Z1, and beyond Z1 but within Z1B, each time once with successful and once with unsuccessful AR. Check the proper reaction of the relay. For multi-shot AR (DAR), zone Z1L is decisive from the second shot on.

Note that each new test can begin only after the reclaim time or lock-out time for the previous test has expired; otherwise an auto-reclose cannot result: Annunciation "`AR not ready`" (FNo `2784`.

When multi-shot auto-reclosure is used, the sequence according to the desired programs and number of reclose attempts is to be checked.

6.7 Commissioning using primary tests

All secondary testing sets and equipment must be removed. Reconnect current and voltage transformers. For testing with primary values the line must be energized.

⚠ Warning

Primary tests shall be performed only by qualified personnel which is trained in commissioning of protection systems and familiar with the operation of the protected object as well as the rules and regulations (switching, earthing, etc.)

6.7.1 Current, voltage and phase sequence checks

Connections to current and voltage transformers are checked with primary values. For this purpose a load current of at least 10 % of the rated current is necessary. If the measuring circuit connections are correct, none of the measured value monitoring systems in the relay will operate. If a fault indication appears, the possible causes can be found in the operational annunciations (Address 5100).

For current sum errors, the matching factors (Section 6.3.3.1) should be checked.

If the symmetry monitoring appears, it is possible that asymmetry is in fact present on the line. If this is a normal operational condition, the corresponding monitoring function should be set at a less sensitive value (Section 6.3.10).

The phase rotation must be clockwise, otherwise the indication ”`Fail.PhaseSeq`” will appear. Check and correct the phase relationships in the measuring circuits. If the network has counter-clockwise rotation, two phases must be interchanged. This phase exchange must be taken into account in the setting for double earth fault preference (in isolated or compensated networks, address 1803, Section 6.3.4.7) or for double earth fault treatment (in earthed networks, address 1703, Section 6.3.4.7) and, when appropriate, in the allocation of the individual phase pick-up indications (Section 5.5.2 to 5.5.5).

Currents and voltages can be read off on the display in the front or via the operating interface in block 57 and compared with the actual measured values.

Switch off voltage transformer secondary miniature circuit breaker. of the feeder voltage. Check that the voltages indicated in the operational measured values (address block 57) are near 0. Small voltage values can be tolerated.

Check that the relay has recognized the position of the m.c.b.: The message ”`VT mcb Trip C`” must be given in the operational annunciations in address block 51.

Switch the m.c.b. on. The above message must occur in address block 51 again, but with the ’Going” index, e.g. ”`VT mcb Trip G`”.

Should one of the messages not be given under the operational annunciation then check the connection of the voltage transformer secondary circuits, and check correct marshalling of the binary inputs from the auxiliary contacts of the m.c.b. (refer to Section 5.5.2).

If the indices ”`C`” for ”Coming” and ”`G`” for ”Going” are interchanged, check and correct the contact mode of the binary inputs (”`NO`” or ”`NC`” contact) in accordance with Section 5.5.2.

6.7.2 Direction check with load current

Correct connections of current and voltage transformers are checked using load current over the protected line. The line must be energized and must carry a load current of at least 10 % of the rated current; this shall be ohmic or ohmic-inductive. The direction of the load current must be known. In cases of doubt, interconnected or ring networks must be isolated.

Initiation of the test is made via operator keyboard or personal computer. Tests are listed from address 4000, the directional test in address 4200.

The address is reached:

– directly with key **DA** followed by address number **4 2 0 0** and finally operation of the enter key **E** or

– by paging through the blocks with ⇑ or ⇓ until address 4200 is reached.

```
⇑  4 0 0 0 █
⇓  T E S T S
```

Beginning of block ”Tests”

```
⇑  4 2 0 0 █ D I R E C T I O N
⇓  I M P E D A N C E S
```

Block ”Directional tests and impedances”

When the address 4200 appears in the display, the directional test of the individual measurement loops is selected with the key ↑. For confirmation of the directional test, the ”Yes” – key **J/Y** is used; this starts the directional test. The selected measurement loop carries out a directional check and indicates the result on the display:

```
⇑  4 2 0 1 █ D I R E C .   T E S T
⇓  L 1 E   ?
```

Make directional test L1 – E? Confirm with **J/Y**

```
F o r w a r d   D i r
```

Load flow forwards
or

```
R e v e r s e   D i r
```

load flow backwards
or

```
u n d e f i n e d
```

directional determination not possible
(e.g. current too small)

The load direction must be indicated correctly. The next address shows the active and reactive component of the load impedance. The load impedances allow determination of the position of the load impedance vector in the R/X diagram (Figure 6.9).

```
↑  4 2 0 2 █ I M P E D A N C E S
↓  L 1 E   ?
```

After confirmation with the ”Yes” – key **J/Y** the load impedance will be calculated and displayed:

```
R r    =                 Ω
X r    =                 Ω
```

Continue with ↑.

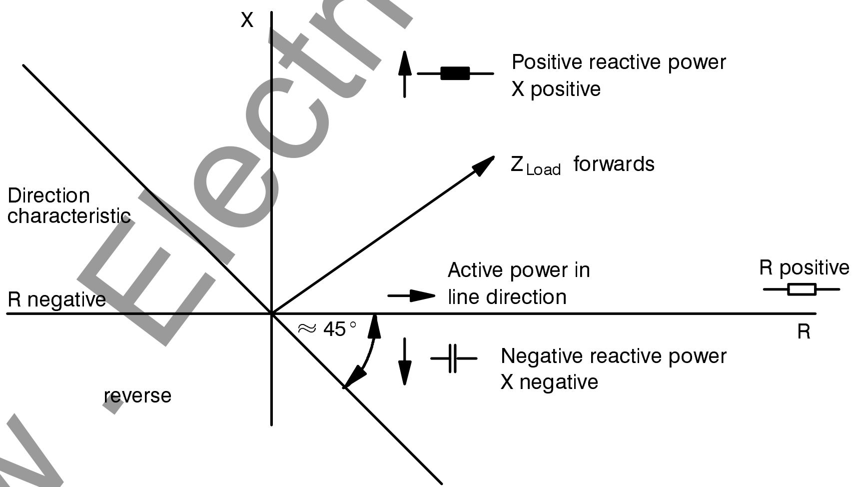
The same applies for the other loops: addresses 4203 and 4204 for L2−E, addresses 4205 and 4206 for L3−E, addresses 4207 and 4208 for L1−L2, addresses 4209 and 4210 for L2−L3, addresses 4211 and 4212 for L3−L1, e.g.

```
4 2 1 1 █ D I R E C .   T E S T
L 3 L 1   ?
```

```
4 2 1 2 █ I M P E D A N C E S
L 3 L 1   ?
```

All six measurement loops must indicate the correct direction of the load flow. If all directions are wrong, the polarity of the measuring transformers and the programmed polarity (address 1101, Section 6.3.3.1) do not agree with each other. Check the polarity and program correctly. If the directions given in the display differ from each other, the individual phases in the current or voltage transformer connections are interchanged, or the phase relationship is not correct. Check the connections.

If the load is capacitive, caused for example by underexcited generators or charging currents, borderline cases can occur with respect to the directional characteristics which will lead to undefined or inconsistent directional information. By means of the load impedance calculation the position of the load impedance vector can be determined (see Figure 6.9).



$$Z_{Load} = \frac{P_{active}}{I^2} + j\,\frac{P_{reactive}}{I^2} \quad [\text{Ohm}]$$

Figure 6.9 Load impedance vector

6.7.3 Earth fault checks for non-earthed systems (if used)

The primary current test allows determination of the correct polarity of transformer connections for the earth fault direction determination.

DANGER!

Operations in primary area must only be performed with plant sections voltage-free and earthed!

The most reliable test is to apply a primary earth fault. The procedure is as follows:

– Disconnect the line and earth at both ends; the line must remain disconnected at the remote end throughout the whole test.

– Apply a bolted single phase earth bridge to the line. On overhead lines, this can be done at any convenient point, but in any case behind the current transformers (looked at from the direction of the bus-bar of the circuit under test). For cables, the earth should be applied at the remote end (termination).

– Open the line earthing switches.

– Close the circuit breaker at the line end to be tested.

– Check the directional indication given (appropriately allocated LED).

– In the earth fault report on the operator terminal (address 5500, see also Section 6.4.4) the earth faulted phase and the line direction, i.e. ”E/F forwards” (FNo 1276) will be indicated. Active and reactive current are equally indicated: for isolated networks the reactive current, for resonant earthed networks the active current is critical. If the display indicates ”E/F reverse” (FNo 1277) then there is a crossed connection in the earth circuit of voltage or current transformers. If the display shows ”E/F undefined” (FNo 1278 the earth fault current is probably too small.

– Disconnect the line and earth it; remove the bolted earth connection.

– The test is thus completed.

6.7.4 Direction check for directional earth fault protection (if used)

The primary current test allows determination of the correct polarity of transformer connections for the earth fault direction protection. If this function is not fitted, or if it is set as EARTH FAULT = *NON EXIST* (address 7831), or if the non-directional earth current option is used (address 7831 EARTH FAULT = *INVERSE TIME*, then this directional check becomes superfluous. The distance protection shall be switched off (address 1201), so that it will not interfere with the earth fault protection.

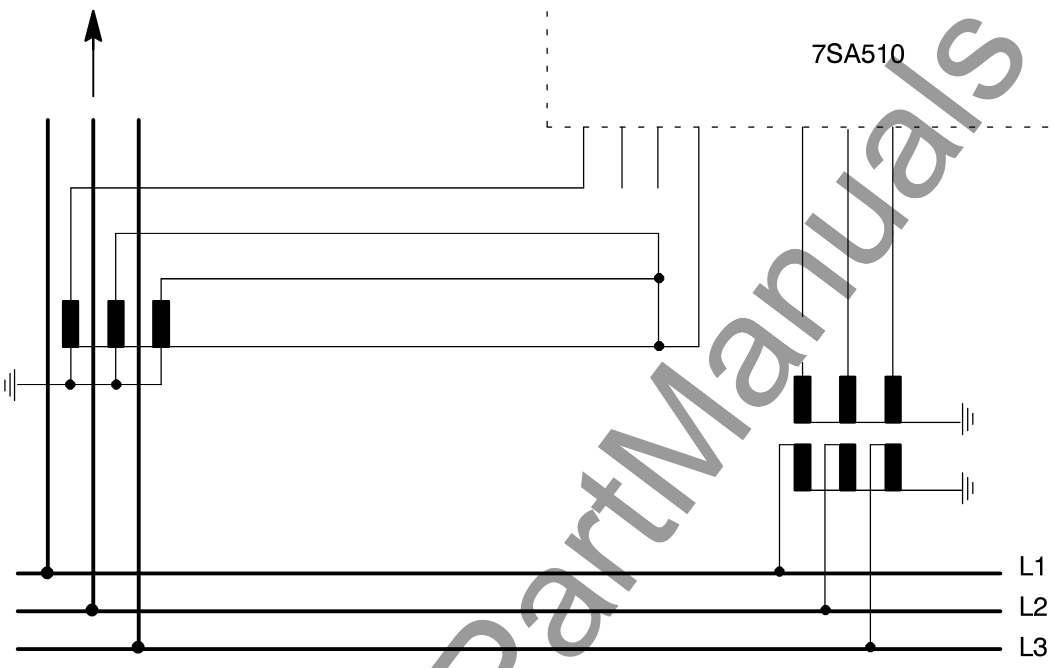


Figure 6.10 Earth fault direction test with Holmgreen connection

The trip circuits should be made inoperative as the relay will issue a trip command during this test. Furthermore, it must be noted, that during all such simulations which do not represent exactly the practical conditions, asymmetry of the measured values can cause the measured value monitors to operate. These annunciations should then be ignored.

DANGER!

All precautionary measures must be observed when working on the instrument transformers! Secondary connections of the current transformers must be short-circuited before any current leads to the relay are interrupted!

The displacement voltage will be derived by interrupting a voltage transformer phase on the secondary side (e.g. L1, see Figure 6.10). In the current circuit, only the current from the current transformer corresponding to the phase in which the voltage is missing, will be used. If the line is carrying active and inductive power in line direction, practically the same relationships apply for the relay as with an earth fault in the line direction.

Check the directional indication. In the fault event report on the display panel (address 5200, see also Section 6.4.3) at least the following fault annunciations must be indicated: "E/F Flt75%Ie>" (FNo 1341), "E/F Flt Ie ->" (FNo 1343) and "E/F Trip" (FNo 1361). Should directional trip annunciation be missing, then a crossed connection is present in either the current or voltage transformer connections. If no pick-up annunciation occurs the current is probably too low or the phase relationship of the test circuit is not correct. If there is no indication whatsoever, it is possible that the threshold value of the displacement voltage (Address 3104 Ue>) has not been reached.

Finally, **properly reconnect all the transformer connections! Switch distance protection on** (address 1201 DIST.PROT = *ON*)**!**

6.7.5 Checking the carrier transmission system

All the equipment associated with transmission of signals should be commissioned in accordance with the appropriate documents.

6.7.5.1 Checking overreach zone comparison via pilot wires

This overreaching zone comparison operating mode differs fundamentally from the other teleprotection systems in its transmission method (d.c. current, fail-safe loop). The test procedure is described in the following. If a different teleprotection method is used, this sub-section can be passed over.

In the scope of functions under address 7821 must be set TELEPROTEC. = *OVERREACH* (refer to Section 5.4.2) and POTT MODE (address 2202) must be parameterized as *PILOT WIRE COMP.* (refer to Section 6.3.6.2). The protection devices at both line ends must be in operation. At first the auxiliary voltage for the fail-safe current loop around the pilot wires should not be switched on, the additional relays are not energized.

Simulate a short circuit beyond Z1 but within the overreach zone Z1B. Because of the presence of the block signal the relay first trips in one of the upper zones (normally T2). Make this test from both line ends.

Now switch on the d.c. voltage for the fail-safe loop. The additional relays for teleprotection must be in operation. The loop now carries monitoring current, the additional relays at both line ends are energized.

Simulate a short circuit at one line end beyond the first zone but within the overreach zone Z1B. Tripping occurs after T1B (when a delay is set). Make this test also at both line ends.

Since the d.c. monitor is an essential part of the pilot wire system, this test has simultaneously proved that the pilot wires are functioning correctly. All other tests described in this Section 6.7.5 become superfluous.

6.7.5.2 Checking reverse interlocking

The test procedure is described in the following. If a different teleprotection method is used, this subsection can be passed over.

In the scope of functions under address 7821 must be set TELEPROTEC. = *OVERREACH* (refer to Section 5.4.2) and POTT MODE (address 2202) must be parameterized as *REVERS INTERLOCK* (refer to Section 6.3.6.2). The protection relay on the incoming feeder and those on all outgoing circuits must be in operation. At first the auxiliary voltage for reverse interlocking should not be switched on.

Simulate a short circuit within zone Z1 and within the overreach zone Z1B. Because of the absence of the receive signal the relay trips in the (delayed) time T1B.

Now switch on the d.c. voltage for the reverse interlocking. The test as described above is repeated, with the same result.

Simulate a trip on each protective device on all outgoing feeders. Simultaneously, a short circuit is simulated on the incoming feeder (as described before). Tripping now occurs after delay T1.

These tests have simultaneously proved that the pilot wires are functioning correctly. All other tests described in this Section 6.7.5 become superfluous.

6.7.5.3 Checking carrier transmission with release signal

With permissive overreach transfer trip (POTT) using release signal transmission: POTT MODE = *Z1B RELEASE* or *FD DIREC RELEASE* or *Z1B UNBLOCK* or *FD UNBLOCK* (address 2202), it is simple to check the carrier system from one end of the line with the echo function. Simulate a short circuit in Z1B beyond Z1. Since the relay at the other line end has not picked up on fault, the echo function will be effective at that end and a trip signal results. The precondition is that the echo function is switched on (address 2220) at both line ends. This test is to be performed from both line ends.

The effect of the echo delay time and the input of the circuit breaker position can be checked at this stage. With the following tests the echo function of the relay at the <u>opposite</u> line end is checked:

The circuit breakers at both line ends must be open. A short circuit is simulated as above. Because of the echo function of the relay at the opposite line end, signal is received and a trip signal occurs at once.

Close the circuit breaker at the opposite line end. Repeat above test once more. Received signal and trip command occur again but now with an additional delay caused by the echo delay time at the opposite line end (0.04 s as delivered, see address 2221).

If delayed and undelayed echo are interchanged the function mode (NO/NC operation) of the binary input for CB position should be wrong. Check and correct it at the opposite line end (refer to Section 5.5.2): When the input for the CB auxiliary contact is assigned to the function ">CB Aux.3p cl" (refer to Section 5.5.2), change the function mode from NO to NC: "CB Aux.3p cl NC".

Open circuit breaker. Repeat these tests for the other line end.

6.7.5.4 Checking carrier transmission with blocking signal

With overreaching transfer mode using blocking signal: POTT MODE = *Z1B BLOCKING* (address 2202), and understanding between both line ends is necessary.

At the line end to be tested as sender, simulate a fault in reverse direction; at the other end, simulate a forward fault within zone Z1B but beyond the limit of Z1. Since the transmitter sends a blocking signal, the receiving protection must not trip, unless in a delayed zone, as long as blocking signal is transmitted. After switching off the reverse fault on the sending side the receiving side remains blocked for the send prolongation T−SEND−PRL (address 2206) plus the transient blocking time T−TRANSBLO (address 2203) of the receiving side.

Repeat test for the other transmission direction.

6.7.5.5 Checking carrier transmission with underreach transfer signal

With permissive underreach transfer trip (PUTT), the scope of devices is set TELEPROTEC. = *UNDERREACH* in address 7821. An understanding between both line ends is necessary.

At the line end to be tested as sender, simulate a fault within zone Z1.

At the receiving end, simulate a fault within zone Z1B but beyond Z1, when set PUTT MODE = *Z1B ACCELERATION* (address 2102). The protection trips at once (or T1B), without reception a delayed stage can only be effective.

At the receiving end, simulate any pick-up, when set PUTT MODE = *FD ACCELERATION* (address 2102). The protection trips instantaneous, without reception in a delayed stage.

Repeat tests for the other transmission direction.

6.7.5.6 Checking carrier transmission for directional comparison earth fault protection

If 7SA510 is equipped with directional comparison earth fault protection and this function is set as EARTH FAULT = *DIREC.COMPARISON* in address 7831, carrier transmission must be checked. Switch off distance protection (address 1201 DIST. PROT = *OFF*).

It is simple to check the carrier system from one end of the line with the echo function. Simulate an earth fault in line direction. Since the relay at the other line end has not picked up on fault, the echo function will be effective at that end and a trip signal results. The precondition is that the echo function is switched on (address 3210) at both line ends. This test is to be performed from both line ends.

The effect of the echo delay time and the input of the circuit breaker position can be checked unless it has already been done under 6.7.5.3. The opposite line end is checked:

The circuit breakers at both line ends must be open. An earth fault is simulated as above. Because of the echo function of the relay at the opposite line end, signal is received and a trip signal occurs at once.

Close the circuit breaker at the opposite line end. Repeat above test once more. received signal and trip command occur again but now with an additional delay caused by the echo delay time of the relay at the opposite line end (0.04 s as delivered, see Address 3211).

Open circuit breaker. Repeat these tests for the other line end.

Switch distance protection on (address 1201 DIST.PROT. = *ON*)**!**

6.7.6 Tripping test including circuit breaker

Distance protection 7SA510 allows simple checking of the tripping circuit and the circuit breaker. If the device incorporates an internal auto-reclose system, a trip – close test cycle is also possible. The test can be initiated either via a binary input.

6.7.6.1 TRIP – CLOSE test cycle – address block 43

Prerequisite for the start of a TRIP – CLOSE test cycle is that the relay has an integrated auto-reclose function which is programmed as *EXIST* (address 7834) and it is switched on (Address 3401).

A TRIP – CLOSE test cycle is also possible with an external auto-reclose system. Since in this case, however, 7SA510 only gives the tripping command, the procedure shall be followed as described in Section 6.7.6.2.

If the circuit breaker auxiliary contacts advise the relay, through a binary input, of the circuit breaker position, the test cycle can only be started when the circuit breaker is closed. This additional security feature should not be omitted.

During marshalling of the binary inputs (refer to Section 5.5.2) the relay has been informed which binary input indicates the circuit breaker position. If the auxiliary contact is assigned to a binary input it must be connected, too. If it is not assigned to any binary input then the device will perform tripping test without interrogation of the circuit breaker position!

DANGER!

A successfully started test cycle will lead to closing of the circuit breaker!

Initiation of the test cycle can be given from the operator keyboard or via the operating interface. A codeword input is necessary. The procedure is started with address 4300 which can be reached by direct addressing **DA 4 3 0 0 E** or by paging with ⇓ or ⇑ .

Further prerequisites for the start of test are that no protective function fault detector has picked up and that the conditions for reclose (circuit breaker ready, AR not blocked) are fulfilled.

```
⇑  4 3 0 0 █ C B - T E S T
⇓  T R I P - C L O S E   C Y C L E
```

Beginning of the block "Circuit breaker test, TRIP – CLOSE cycle"

```
↑  4 3 0 4 █ C B   T E S T
   L 1 2 3   W I T H   A R   ?

   C B   C L O S E D   ?
```

Carry out three – pole test cycle of circuit breaker? Confirm with "**J/Y**" – key or abort with page – on key ↑

Confirm with "**J/Y**" – key that circuit breaker is closed or abort with page – on key ↑

After confirmation by the operator that the circuit breaker is closed, the test cycle proceeds. If the test is terminated successfully, this is annunciated in the display or on the PC screen. If, however, the circuit breaker auxiliary contact is assigned to a binary input and connected, the relay rejects the test cycle as long as the auxiliary contact indicates that the circuit breaker is not closed, even if the operator has confirmed that it is. Only when no circuit breaker auxiliary contact is assigned to any binary input, will the relay consider the operator's confirmation valid.

6.7.6.2 Live tripping of the circuit breaker – address block 44

To check the tripping circuits, the circuit breaker can be tripped by 7SA510 independently of whether an auto-reclose will occur or not. However, this test can also be made with an external auto-reclose relay.

If the circuit breaker auxiliary contact advises the relay, through a binary input, of the circuit breaker position, the test can only be started when the circuit breaker is closed. This additional security feature should not be omitted when an external auto-reclose relay is present.

During marshalling of the binary inputs (refer to Section 5.5.2) the relay has been informed which binary input indicates the circuit breaker position. If the auxiliary contact is assigned to a binary input it must be connected, too. If it is not assigned to any binary input then the device will perform tripping test without interrogation of the circuit breaker position!

DANGER!

A successfully started test cycle can lead to closing of the circuit breaker, when an external auto-reclosure device is connected!

Initiation of the test can be given from the operator keyboard or via the operating interface. A codeword input is necessary. The procedure is started with address 4400 which can be reached by direct dialling **DA 4 4 0 0 E** or by paging with ⇑ or ⇓.

Prerequisite for starting the test is that no protection function of the relay be picked up.

```
⇑ 4400 CB TEST
⇓ LIVE TRIP
```

Beginning of the block "trip circuit breaker"

```
↑ 4404 CB TRIP
  CB THREE-POLE ?
```

Trip circuit breaker three-pole? Confirm with "**J/Y**"–key or abort with page-on key ↑

```
CB CLOSED ?
```

Confirm with "**J/Y**"–key that circuit breaker is closed or abort with page-on Key ↑

After confirmation by the operator that the circuit breaker is closed, the test cycle proceeds. If the test is terminated successfully, this is annunciated in the display or on the PC screen. If, however, the circuit breaker auxiliary contact assigned to a binary input and connected, the relay rejects the test cycle as long as the auxiliary contact indicates that the circuit breaker is not closed, even if the operator has confirmed that it is. Only when no circuit breaker auxiliary contact is assigned to any binary input, will the relay consider the operator's confirmation valid.

6.7.7 Starting a test fault record – address block 49

A fault record storage can be started using the operating panel or via the operating interface. Starting a test fault record is also possible via a binary input provided this is accordingly allocated (FNo 4 ">Start FltRec").

The configuration parameters as set in address block 74 are decisive for this fault recording (refer to Section 5.3.4): address 7431 concerns triggering via binary input, address 7432 triggering via the operating keyboard or via the operating interface. The pretrigger time was set under address 7411.

Scanning a test fault record is especially interesting for use on cables and long overhead lines where considerable inrush currents can be produced by charging of the line capacitances. The fault record is triggered via a binary input at the instant of the breaker closing command.

Manual starting of a fault record can be carried out in address block 49, which can be reached by paging with ⇑ or ⇓, or by direct dialling with **DA 4 9 0 0 E**. The start address is reached with ↑:

⇑⇓
```
4900█TEST
FAULT RECORDING
```

Beginning of block "Test fault recording"
page on with ↑ to address 4901

↑
```
4901█FAULT REC.
START ?
```

Start fault recording? Confirm with "**J/Y**"–key or abort with page-on key ↑

```
SUCCESSFUL
```

The relay acknowledges successful completion of the test recording

---

6.8 Putting the relay into operation

All setting values should be checked again, in case they were altered during the tests. Particularly check that all desired protection functions have been programmed in the configuration parameters (address blocks 78 and 79, refer to Section 5.4) and all desired protection functions have been switched *ON*.

The counters for circuit breaker operation statistics should be erased (address block 82, refer to Section 6.5.2).

Push the key **M**/**S** on the front. The display shows the beginning of the annunciation blocks. Thus, it is possible that the measured values for the quiescent state of the relay can be displayed (see below). These values has been chosen during configuration (refer to Section 5.3.2) under the addresses 7105 and 7106.

Stored indications on the front plate should be reset by pressing the push-button ”RESET LED” on the front so that from then on only real faults are indicated. From that moment the measured values of the quiescent state are displayed. During pushing the RESET button, the LEDs on the front will light up (except the ”Blocked” – LED); thus, a LED test is performed at the same time.

Check that the module is properly inserted. The green LED must be on on the front; the red LED must not be on.

Close housing cover.

All terminal screws – even those not in use – must be tightened.

If a test switch is available, then this must be in the operating position.

The distance protection relay is now ready for operation.

7 Maintenance and fault tracing

Siemens digital protection relays are designed to require no special maintenance. All measurement and signal processing circuits are fully solid state and therefore completely maintenance free. Input modules are even static, relays are hermetically sealed or provided with protective covers.

If the device is equipped with a back–up battery for saving of stored annunciations and the internal time clock, the battery should be replaced after at most 10 years of operation (refer to Section 7.2). This recommendation is valid independent on whether the battery has been discharged by occasional supply voltage failures or not.

As the protection is almost completely self–monitored, from the measuring inputs to the command output relays, hardware and software faults are automatically annunciated. This ensures the high availability of the relay and allows a more corrective rather than preventive maintenance strategy. Tests at short intervals become, therefore, superfluous.

With detected hardware faults the relay blocks itself; drop–off of the availability relay signals ”equipment fault”. If there is a fault detected in the external measuring circuits, generally an alarm is given only.

Recognized software faults cause the processor to reset and restart. If such a fault is not eliminated by restarting, further restarts are initiated. If the fault is still present after three restart attempts the protective system will switch itself out of service and indicate this condition by the red LED ”Blocked” on the front plate. Drop–off of the availability relay signals ”equipment fault”.

The reaction to defects and indications given by the relay can be individually and in chronological sequence read off as operational annunciations under the address 5100, for defect diagnosis (refer to Section 6.4.2).

If the relay is connected to a local substation automation system (LSA), defect indications will also be transferred via the serial interface to the central control system.

⚠ Warning

Ensure that the connection modules are not damaged when removing or inserting the device modules! Hazardous voltages may occur when the heavy current plugs are damaged!

7.1 Routine checks

Routine checks of characteristics or pick–up values are not necessary as they form part of the continuously supervised firmware programs. The planned maintenance intervals for checking and maintenance of the plant can be used to perform operational testing of the protection equipment. This maintenance serves mainly for checking the interfaces of the unit, i.e. the coupling with the plant. The following procedure is recommended:

– Read–out of operational values (address block 57) and comparison with the actual values for checking the analog interfaces.

– Simulation of an internal short–circuit with 4 x I_N for checking the analog input at high currents.

⚠ Warning

Hazardous voltages can be present on all circuits and components connected with the supply voltage or with the measuring and test quantities!

⚠ Caution!

Test currents larger than 4 times I_N may overload and damage the relay if applied continuously (refer to Section 3.1.1 for overload capability). Observe a cooling down period!

– Circuit–breaker trip circuits are tested by actual live tripping. Respective notes are given in Section 6.7.6.

7.2 Replacing the back–up battery

The device annunciations are stored in NV–RAMs. A back–up battery is inserted so that they are retained even with a longer failure of the d.c. supply voltage. The back–up battery is also required for the internal system clock with calender to continue in the event of a power supply failure.

The back–up battery should be replaced at the latest after 10 years of operation.

Recommended battery:

Lithium battery 3 V/1 Ah, type CR 1/2 AA, e.g.
– VARTA Order No. 6127 101 501.

The battery is located at the rear edge of the processor board of the basic module. The basic module must be removed from the housing in order to replace the battery.

– Prepare area of work: provide conductive surface for the basic module.

– Open housing cover.

– Read out device annunciations, i.e. all addresses which commence with 5 (5000 onwards). This is carried out most convenient using the front operating interface and a personal computer with the DIGSI® protection data processing program; the information is thus stored in the PC.

  Note: All configuration data and settings of the device are stored in EEPROMs protected against switching off of the power supply. They are stored independent of the back–up battery. They are, therefore, neither lost when the battery is replaced nor when the device is operated without a battery.

– Loosen the basic module using the pulling aids provided at the top and bottom. (Figure 7.3).

⚠ Warning

Hazardous voltages may be present in the device even after disconnection of the supply voltage or after removal of the modules from the housing (storage capacitors)!

⚠ Caution!

Electrostatic discharges via the component connections, the PCB tracks or the connecting pins of the modules must be avoided under all circumstances by previously touching an earthed metal surface.

– Pull out basic module and place onto the conductive surface.

– Remove used battery from the holder; **do not place on the conductive surface!** Refer to Figure 7.1.

– Insert the prepared battery into the holder as in Figure 7.1.

– Insert basic module into the housing; ensure that the releasing lever is pushed fully to the left before the module is pressed in.

– Firmly push in the module using the releasing lever. (Figure 7.3).

⚠ Warning

The discharged battery contains Lithium. It must only be disposed off in line with the applicable regulations!
Do not reverse polarities! Do not recharge! Do not throw into fire! Danger of explosion!

– Provided the internal system clock is not automatically synchronized via the LSA interface, it can now be set or synchronized as described in Section 6.5.1

– Close housing cover.

The replacement of the back–up battery has thus been completed.

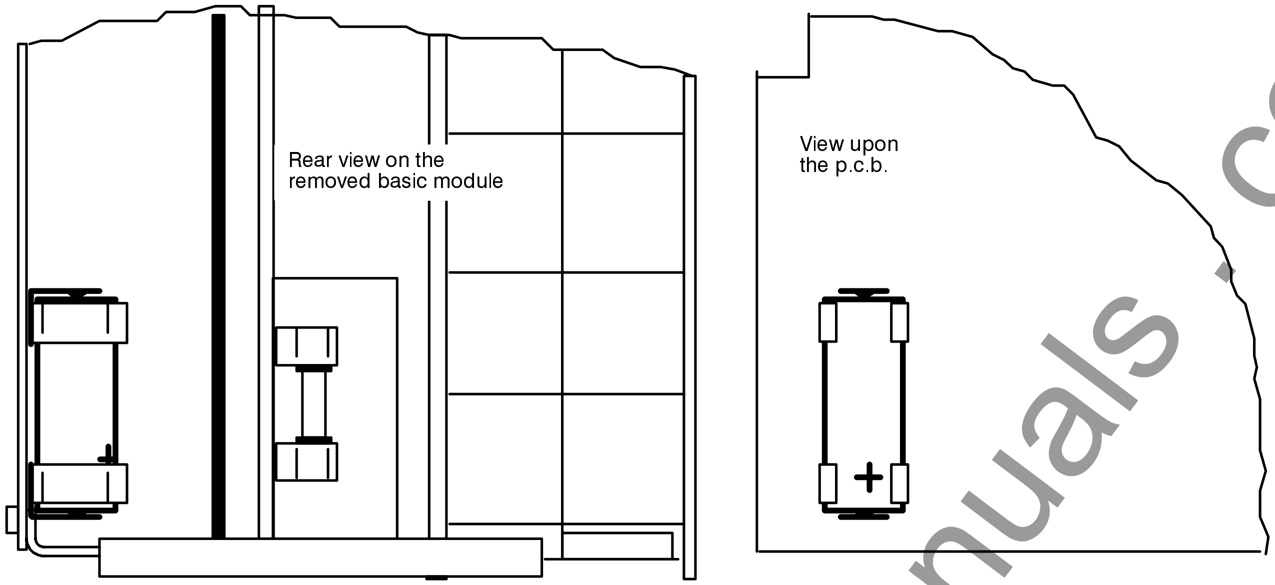


Figure 7.1 Installation of the back–up battery

7.3 Fault tracing

If the protective device indicates a defect, the following procedure is suggested:

If none of the LEDs on the front plate of the module is on, then check:

– Have the modules been properly pushed–in and locked?

– Is the ON/OFF switch on the front plate in the ON position ⊙?

– Is the auxiliary voltage available with the correct polarity and of adequate magnitude, connected to the correct terminals (General diagrams in Appendix A)?

– Has the mini–fuse in the power supply section blown (see Figure 7.2)? If appropriate, replace the fuse according to Section 7.3.1.

If the red fault indicator "Blocked" on the front is on and the green ready LED remains dark, the device has recognized an internal fault. Re–initialization of the protection system could be tried by switching the d.c. auxiliary voltage off and on again. This, however, results in loss of fault data and messages if the relay is not equipped with a buffer battery, and, if a parameterizing process has not yet been completed, the last parameters are not stored.

7.3.1 Replacing the mini–fuse

– Select a replacement fuse 5 × 20 mm. Ensure that the rated value, time lag (medium slow) and code letters are correct. (Figure 7.2).

– Prepare area of work: provide conductive surface for the basic module.

– Open housing cover.

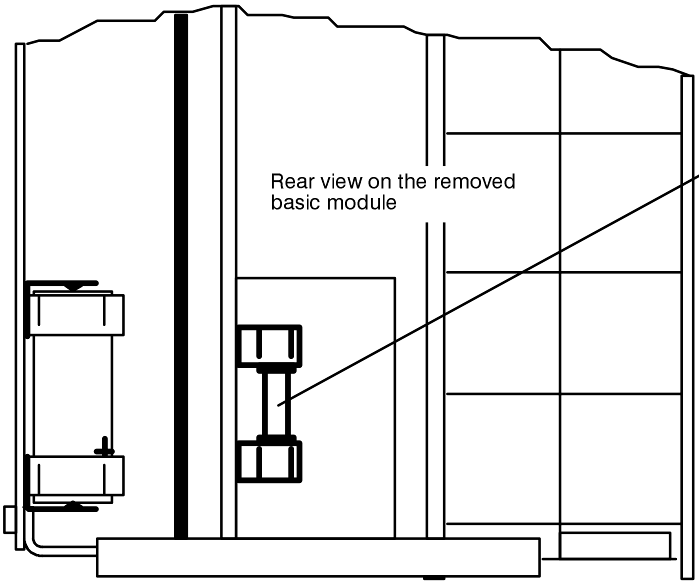
⚠ Warning

Hazardous voltages can be present in the device even after disconnection of the supply voltage or after removal of the modules from the housing (storage capacitors)!

– Loosen the basic module using the pulling aids provided at the top and bottom. (Figure 7.3).

⚠ Caution!

Electrostatic discharges via the component connections, the PCB tracks or the connecting pins of the modules must be avoided under all circumstances by previously touching an earthed metal surface.



Mini−fuse of the power supply;
medium slow (M)

at U_{HN}/V−	rated value
24/48	2 A/E
60/110/125	1,6 A/E
220/250	1 A/G

Figure 7.2 Mini−fuse of the power supply

– Pull out basic module and place onto the conductive surface.

– Remove blown fuse from the holder (Figure 7.2).

– Fit new fuse into the holder (Figure 7.2).

– Insert basic module into the housing; ensure that the releasing lever is pushed fully to the left before the module is pressed in (Figure 7.3).

– Firmly push in the module using the releasing lever. (Figure 7.3).

– Close housing cover.

Switch on the device again. If a power supply failure is still signalled, a fault or short−circuit is present in the internal power supply. The device should be returned to the factory (see Chapter 8).

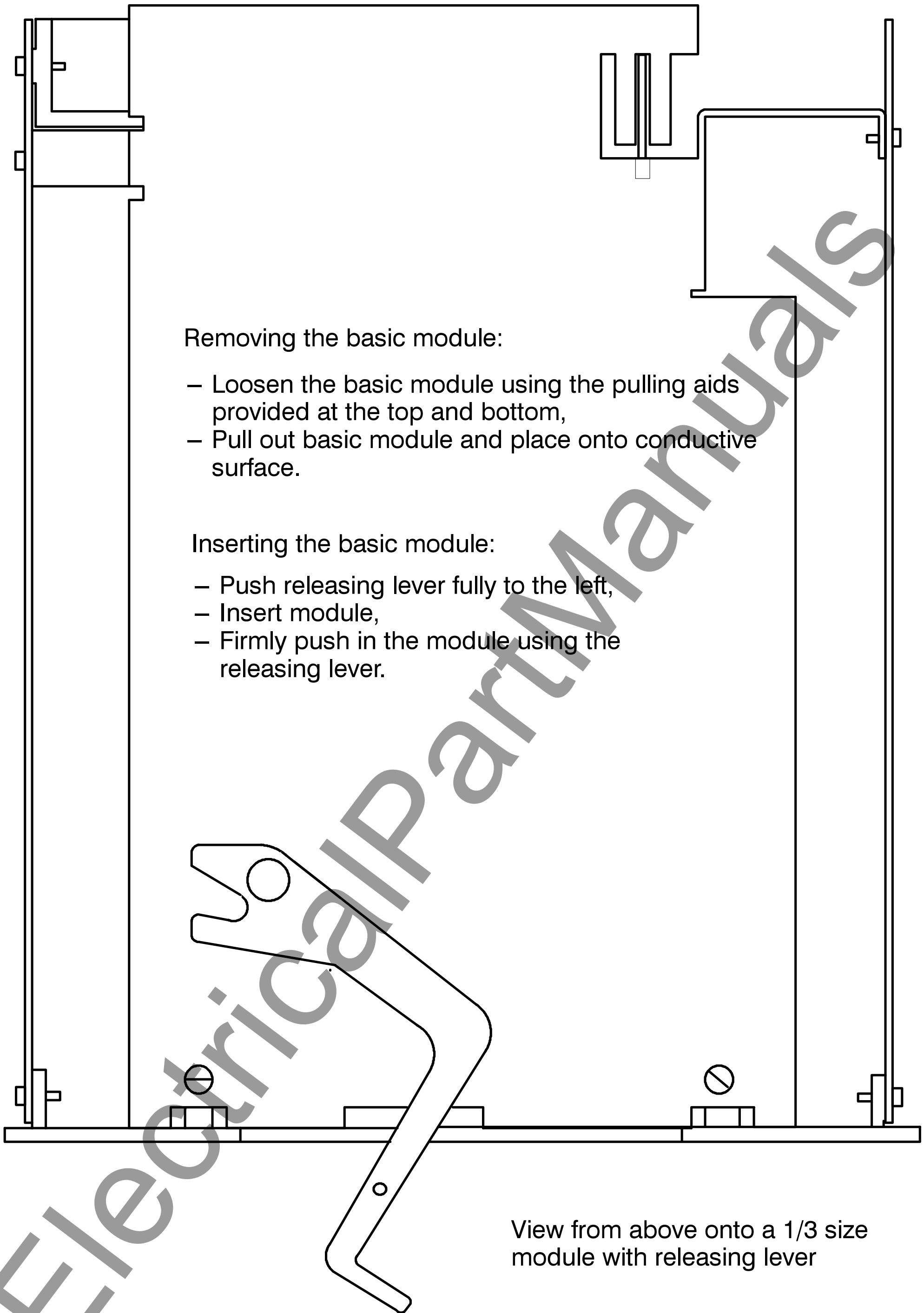


Figure 7.3 Aid for removing and inserting basic module

8 Repairs

Repair of defective modules is not recommended at all because specially selected electronic components are used which must be handled in accordance with the procedures required for **E**lectrostatically **E**ndangered **C**omponents (EEC). Furthermore, special manufacturing techniques are necessary for any work on the printed circuit boards in order to do not damage the bath–soldered multilayer boards, the sensitive components and the protective finish.

Therefore, if a defect cannot be corrected by operator procedures such as described in Chapter 7, it is recommended that the complete relay should be returned to the manufacturer. Use the original transport packaging for return. If alternative packing is used, this must provide the degree of protection against mechanical shock, as laid down in IEC 255–21–1 class 2 and IEC 255–21–2 class 1.

If it is unavoidable to replace individual modules, it is imperative that the standards related to the handling of **E**lectrostatically **E**ndangered **C**omponents are observed.

⚠ Warning

Hazardous voltages can be present in the device even after disconnection of the supply voltage or after removal of the module from the housing (storage capacitors)!

⚠ Caution!

Electrostatic discharges via the component connections, the PCB tracks or the connecting pins of the modules must be avoided under all circumstances by previously touching an earthed metal surface. This applies equally for the replacement of removable components, such as EPROM or EEPROM chips. For transport and returning of individual modules electrostatic protective packing material must be used.

Components and modules are not endangered as long as they are installed within the relay.

Should it become necessary to exchange any device or module, the complete parameter assignment should be repeated. Respective notes are contained in Chapter 5 and 6.

9 Storage

Solid state protective relays shall be stored in dry and clean rooms. The limit temperature range for storage of the relays or associated spare parts is –25 °C to +55 °C (refer Section 3.1.4 under the Technical data), corresponding to –12 °F to 130 °F.

The relative humidity must be within limits such that neither condensation nor ice forms.

It is recommended to reduce the storage temperature to the range +10 °C to +35 °C (50 °F to 95 °F); this prevents from early ageing of the electrolytic capacitors which are contained in the power supply.

For very long storage periods, it is recommended that the relay should be connected to the auxiliary voltage source for one or two days every other year, in order to regenerate the electrolytic capacitors. The same is valid before the relay is finally installed. In extreme climatic conditions (tropics) pre–warming would thus be achieved and condensation avoided.

Before initial energization with supply voltage, the relay shall be situated in the operating area for at least two hours in order to ensure temperature equalization and to avoid humidity influences and condensation.

Appendix

A General diagrams

B Connection diagrams

C Tables

A General diagrams

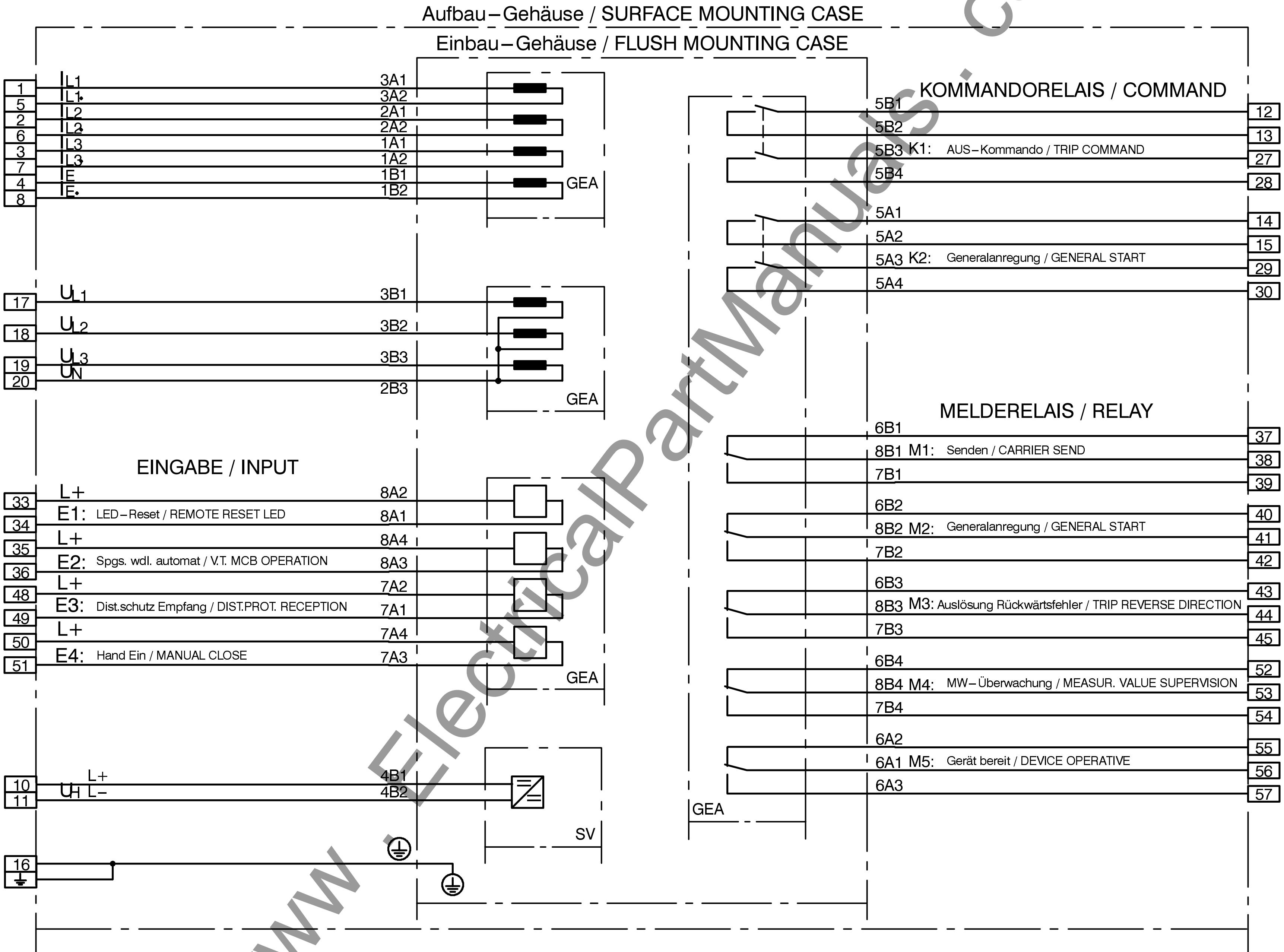
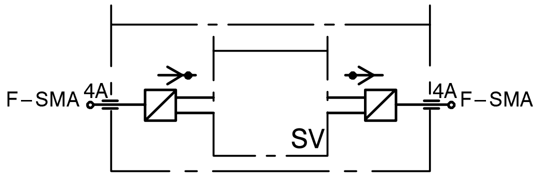
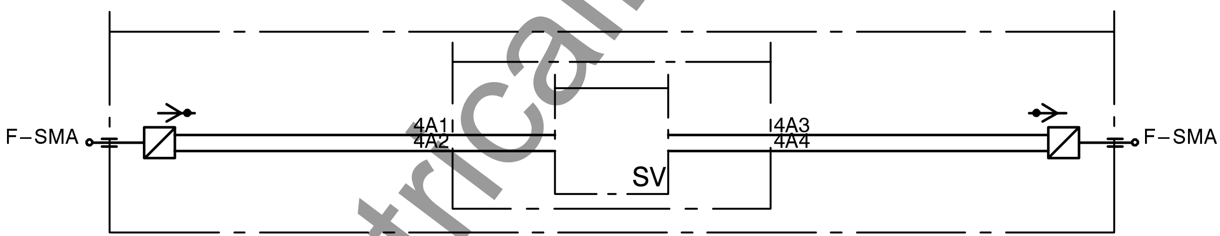


Figure A.1 General diagram 7SA510 (sheet 1 of 2)



Einbau– Gehäuse mit LWL – Modul
FLUSH MOUNTING CASE WITH FIBRE OPTIC INTERFACE
7SA510*–*1)A**–*C**/
1) C,E



Aufbau– Gehäuse mit LWL – Modul
SURFACE MOUNTING CASE WITH FIBRE OPTIC INTERFACE
7SA510*–*BA**–*C**/

Figure A.2 General diagram 7SA510 (sheet 2 of 2)

B Connection diagrams

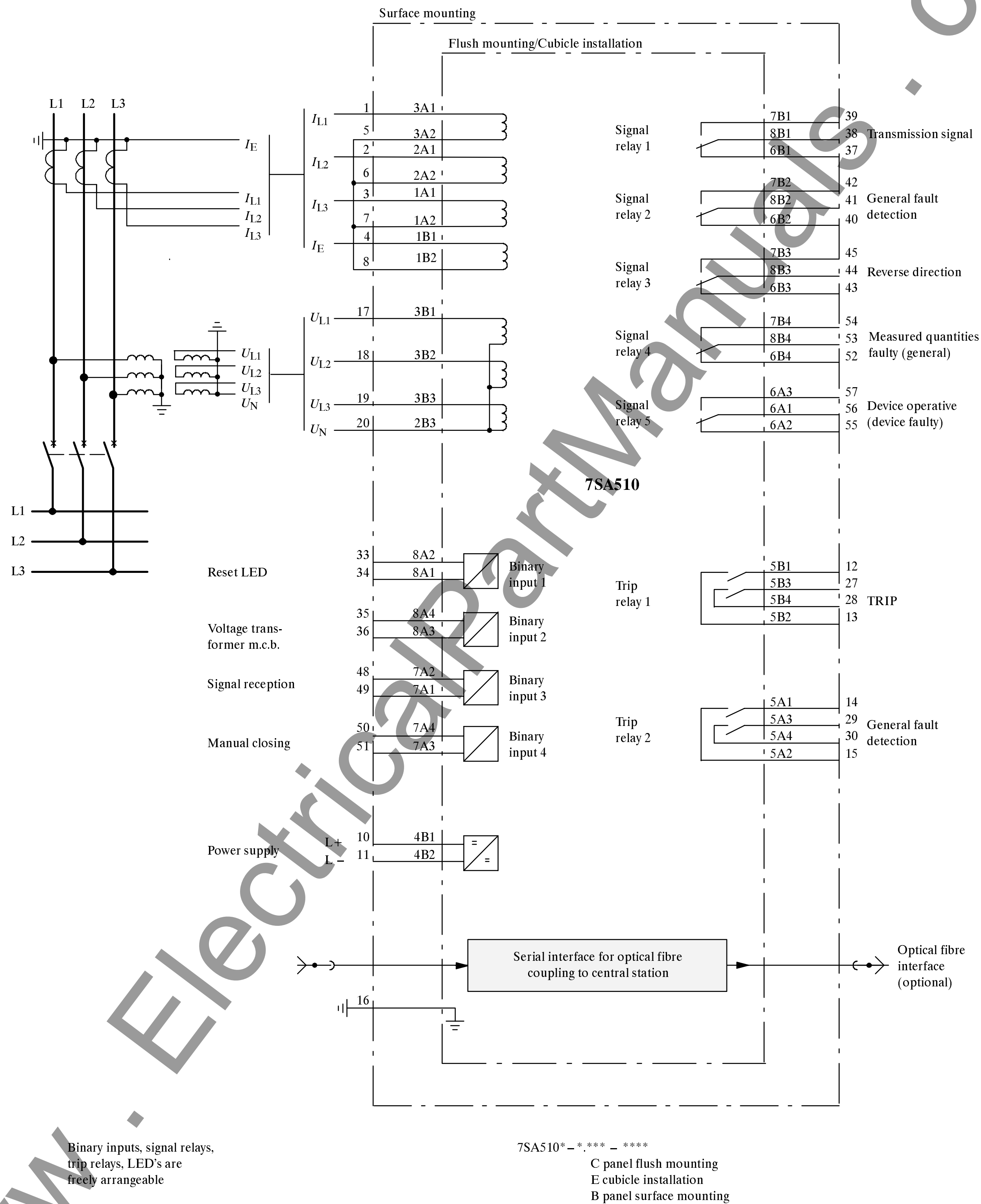


Figure B.1 Connection example 7SA510

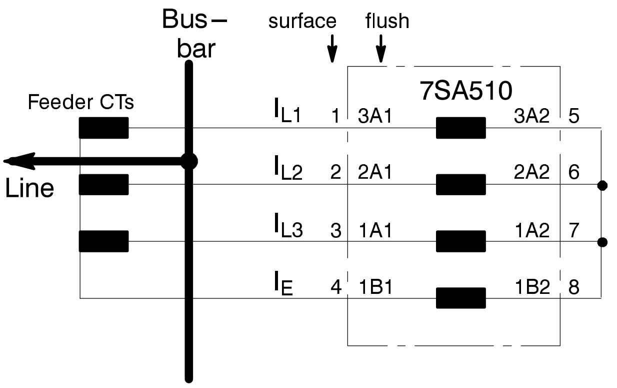
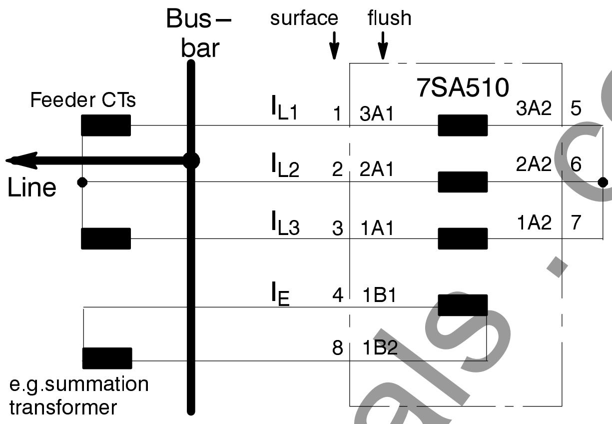
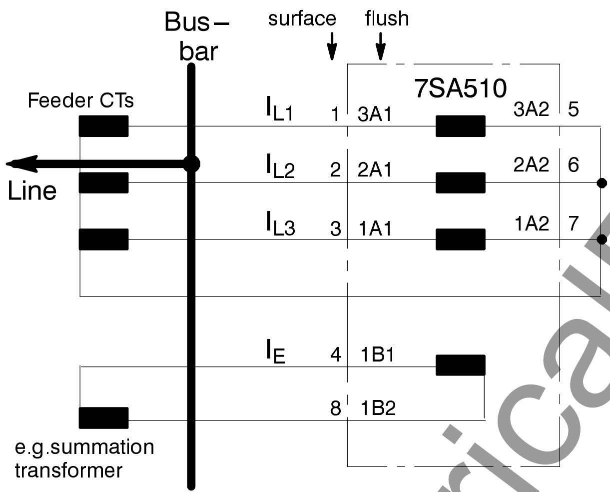


Figure B.2 CT circuits with 3 CTs



Note: If the current polarity is changed under address 1101), this changes also the polarity of the current input I_E!

Figure B.4 CT circuits with 2 CTs and additional I_E summation CT (not for earthed systems)



Note: If the current polarity is changed under address 1101), this changes also the polarity of the current input I_E!

Figure B.3 CT circuits with 3 CTs and additional I_E summation CT

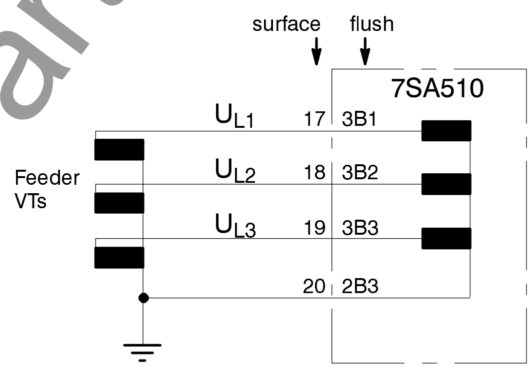


Figure B.5 VT circuits with 3 VTs

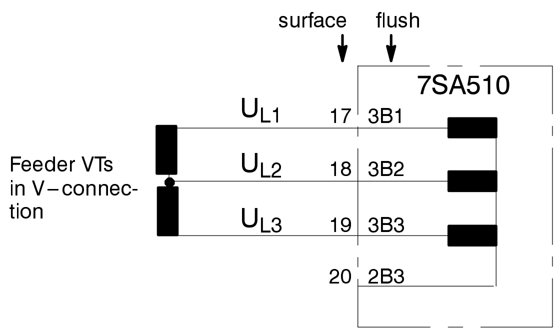


Figure B.6 VT circuits with 2 VTs in V–connection (not for earthed systems)

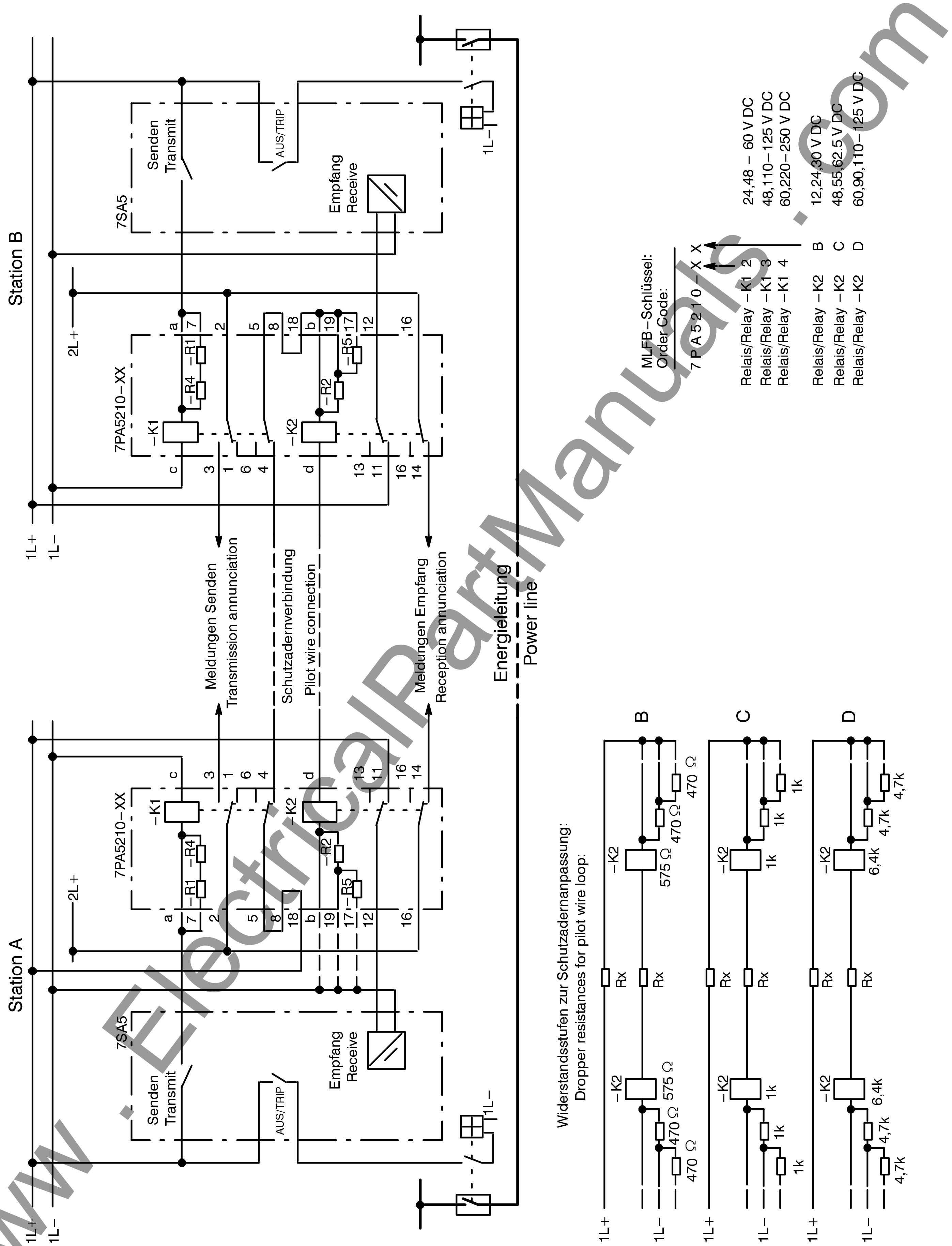


Figure B.7 Pilot wire connection scheme for overreach transfer via pilot wires, with 7SA5 at both line ends

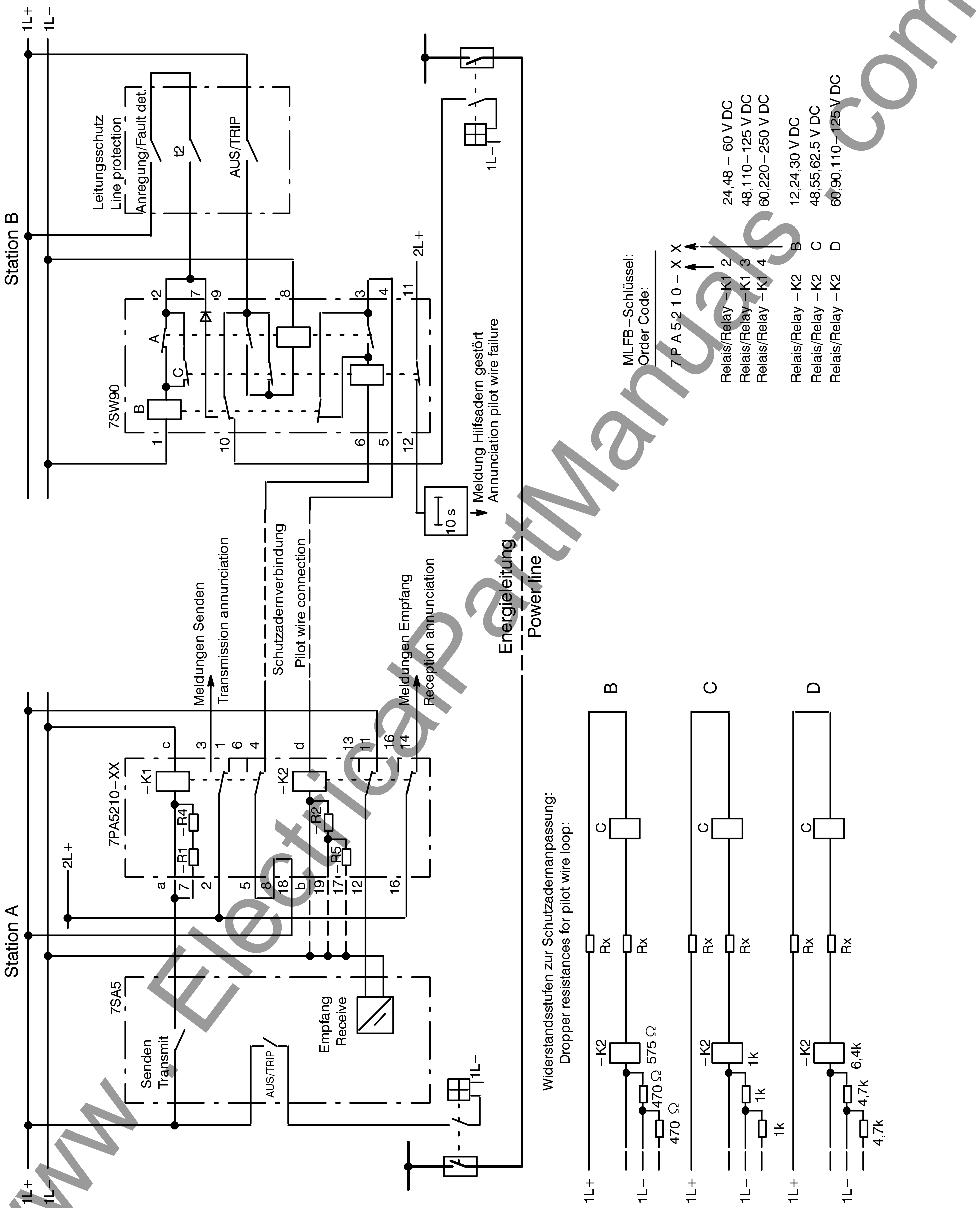


Figure B.8 Pilot wire connection scheme for overreach transfer via pilot wires, with 7SA5 at one line end and 7SW90 at the other line end

C Tables

NOTE: The following tables list all data which are available in the maximum complement of the device. Dependent on the ordered model, only those data may be present which are valid for the individual version.

NOTE: The actual tables are attached to the purchased relay.

Annunciations 7SA510 for LSA (according IEC 60 870-5-103)

FNo. - Function number of annunciation
Op/Ft - Operation/Fault annunciation
C/CG: Coming/Coming and Going annunciation
V : Annunciation with Value
M : Measurand

according to IEC 60 870-5-103:
CA - Compatible Annunciation
GI - Annunciation for General Interrogation
BT - Binary Trace for fault recordings
Typ - Function type (p: according to the configured "Function type")
Inf - Information number

		Ann.		LSA	IEC 60 870-5-103				
FNo.	Meaning	Op	Ft	No.	CA	GI	BT	Typ	Inf
11	>User defined annunciation 1	CG			CA	GI	BT	p	27
12	>User defined annunciation 2	CG			CA	GI	BT	p	28
13	>User defined annunciation 3	CG			CA	GI	BT	p	29
14	>User defined annunciation 4	CG			CA	GI	BT	p	30
15	>Testing via system-interface							135	53
16	>Block. of monitoring dir. via sys.-int							135	54
51	Device operative / healthy	CG				GI		135	81
52	Any protection operative	CG			CA	GI		p	18
55	Re-start of processor system	C			CA			p	4
56	Initial start of processor system	C			CA			p	5
59	Real time response to LSA	C							
60	LED Reset	C			CA			p	19
61	Logging and measuring functions blocked	CG			CA	GI		p	20
62	Test mode	CG			CA	GI		p	21
63	PC operation via system interface	CG				GI		135	83
95	Parameters are being set	CG			CA	GI		p	22
96	Parameter set A is active	CG			CA	GI		p	23
97	Parameter set B is active	CG			CA	GI		p	24
98	Parameter set C is active	CG			CA	GI		p	25
99	Parameter set D is active	CG			CA	GI		p	26
110	Annunciations lost (buffer overflow)	C						135	130
112	Annunciations for LSA lost	C						135	131
113	Fault tag lost						BT	135	136
140	General internal failure of device	CG			CA	GI		p	47
141	Failure of internal 24 VDC power supply	CG				GI		135	161
143	Failure of internal 15 VDC power supply	CG				GI		135	163
144	Failure of internal 5 VDC power supply	CG				GI		135	164
145	Failure of internal 0 VDC power supply	CG				GI		135	165
151	Failure in I/O module 1	CG				GI		135	166
154	Supervision trip circuit	CG			CA	GI		p	36
160	Common alarm	CG			CA	GI		p	46
161	Measured value supervision of currents	CG			CA	GI		p	32
162	Failure: Current summation supervision	CG				GI		135	182
163	Failure: Current symmetry supervision	CG				GI		135	183
164	Measured value supervision of voltages	CG			CA	GI		p	33
167	Failure: Voltage symmetry supervision	CG				GI		135	186
168	Failure: Measuring voltages absent	CG				GI		135	187
169	Fuse failure monitor operated (>10s)	CG				GI		135	188
171	Failure: Phase sequence supervision	CG			CA	GI		p	35
204	Fault recording initiated via bin.input						BT	135	204
205	Fault recording initiated via keyboard						BT	135	205

FNo.	Meaning	Ann.		LSA	IEC 60 870-5-103				
		Op	Ft	No.	CA	GI	BT	Typ	Inf
206	Fault recording initiated via PC interf						BT	135	206
301	Fault in the power system		CG					135	231
302	Flt. event w. consecutive no.		C					135	232
303	E/Flt.det. in isol/comp.netw.	CG				GI		135	233
361	>U Line side VT MCB tripped	CG			CA	GI		p	38
501	General fault detection of device		CG		CA	GI	BT	p	84
502	General drop-off of device		C					150	152
503	General device fault detection: Ph. L1		CG		CA	GI	BT	p	64
504	General device fault detection: Ph. L2		CG		CA	GI	BT	p	65
505	General device fault detection: Ph. L3		CG		CA	GI	BT	p	66
506	General device fault detection: Ph. N		CG		CA	GI	BT	p	67
511	General trip of device		C		CA		BT	p	68
516	General trip for fault in forward dir.		C					150	166
517	General trip for fault in reverse dir.		C					150	167
521	Interrupted current: Phase L1(I/In)		V					150	171
522	Interrupted current: Phase L2(I/In)		V					150	172
523	Interrupted current: Phase L3(I/In)		V					150	173
561	Circuit breaker manually closed (pulse)	C						150	211
562	CB close command for manual closing	C						150	212
601	Current in phase IL1 [%] =	M			CA			134	128
602	Current in phase IL2 [%] =	M			CA			134	128
603	Current in phase IL3 [%] =	M			CA			134	128
621	UL1E [%]=	M			CA			134	128
622	UL2E [%]=	M			CA			134	128
623	UL3E [%]=	M			CA			134	128
624	UL12 [%] =	M						134	128
625	UL23 [%] =	M						134	128
626	UL31 [%] =	M						134	128
641	Active power Pa [%] =	M			CA			134	128
642	Reactive power Pr [%] =	M			CA			134	128
644	Frequency f [%] =	M			CA			134	128
701	Iea [mA] =	M						134	128
702	Ier [mA] =	M						134	128
1114	Fault resistance, Ohm prim.		V					151	14
1115	Fault reactance, Ohm prim.		V		CA			p	73
1117	Fault resistance, Ohm sec.		V					151	17
1118	Fault reactance, Ohm sec.		V					151	18
1119	Distance to fault in km		V					151	19
1120	Distance to fault in %		V					151	20
1174	Circuit breaker test in progress	CG				GI		151	74
1181	Circuit breaker test: General trip	C						151	81
1261	E/F det. (isol./comp. net) switched off	CG				GI		151	161
1262	E/F detection (isol./comp. net) blocked	CG				GI		151	162
1263	E/F detection (isol./comp. net) active	CG				GI		151	163
1272	Earth fault (isol./comp.) L1 detected	CG			CA	GI		p	48
1273	Earth fault (isol./comp.) L2 detected	CG			CA	GI		p	49
1274	Earth fault (isol./comp.) L3 detected	CG			CA	GI		p	50
1276	Earth fault (isol./comp.) forward dir.	CG			CA	GI		p	51
1277	Earth fault (isol./comp.) reverse dir.	CG			CA	GI		p	52
1278	Earth fault (isol./comp.) undef. dir.	CG				GI		151	178
1281	Trip by earth fault det. (isol./comp.)		C					151	181
1316	>Carrier reception for direct. E/F comp	CG				GI		166	16
1317	>Carrier reception for dir. E/F faulty	CG				GI		166	17
1331	Earth fault protection is switched off	CG				GI		166	31
1332	Earth fault protection is blocked	CG				GI		166	32
1333	Earth fault protection is active	CG				GI		166	33
1334	Earth fault prot. direct.stage blocked	CG				GI		166	34

FNo.	Meaning	Ann. Op	Ann. Ft	LSA No.	IEC 60 870-5-103 CA	GI	BT	Typ	Inf
1341	Earth fault detection 75% Ie picked up		CG				BT	166	41
1342	Earth fault detection non-direct. Ie		CG					166	42
1343	Earth fault detection directional Ie		CG					166	43
1352	Earth fault prot. dir. time expired		C					166	52
1353	Earth fault prot. non-dir. time expired		C					166	53
1381	Earth fault dir. comp. is switched off	CG				GI		166	81
1384	Carrier transmission for dir. comp. E/F		C					166	84
1385	Echo signal for directional comp. E/F	C						166	85
1386	Transient block. of E/F protection		C					166	86
1511	Thermal overload prot. is switched off	CG				GI		167	11
1512	Thermal overload protection is blocked	CG				GI		167	12
1513	Thermal overload protection is active	CG				GI		167	13
1515	Thermal overload prot.: Current warning	CG				GI		167	15
1516	Thermal overload prot.: Thermal warning	CG				GI		167	16
1517	Thermal overload prot.: Pick-up thermal	CG				GI		167	17
1521	Thermal overload protection trip		C				BT	167	21
2051	Emergency O/C protect. is switched off	CG				GI		61	51
2052	Emergency O/C protection is blocked	CG				GI		61	52
2053	Emergency O/C protection is active	CG				GI		61	53
2054	Emergency O/C protection is running	CG			CA	GI		p	37
2061	Emerg. O/C prot.: General fault detect.		CG				BT	61	61
2062	Emerg. O/C prot.: Fault detection L1		CG					61	62
2063	Emerg. O/C prot.: Fault detection L2		CG					61	63
2064	Emerg. O/C prot.: Fault detection L3		CG					61	64
2065	Emerg. O/C prot.: Earth fault detection		CG					61	65
2071	Emerg. O/C earth fault detection only		C					61	71
2072	Emerg. O/C fault detection L1 only		C					61	72
2073	Emerg. O/C fault detection L1E		C					61	73
2074	Emerg. O/C fault detection L2 only		C					61	74
2075	Emerg. O/C fault detection L2E		C					61	75
2076	Emerg. O/C fault detection L12		C					61	76
2077	Emerg. O/C fault detection L12E		C					61	77
2078	Emerg. O/C fault detection L3 only		C					61	78
2079	Emerg. O/C fault detection L3E		C					61	79
2080	Emerg. O/C fault detection L13		C					61	80
2081	Emerg. O/C fault detection L13E		C					61	81
2082	Emerg. O/C fault detection L23		C					61	82
2083	Emerg. O/C fault detection L23E		C					61	83
2084	Emerg. O/C fault detection L123		C					61	84
2085	Emerg. O/C fault detection L123E		C					61	85
2091	Emerg. O/C phase fault detection I>>		CG					61	91
2093	Emerg. O/C phase fault detection I>		CG					61	93
2097	Emerg. O/C earth fault detection IE>		CG					61	97
2121	Emerg. O/C prot.: Time TI>> expired		C					61	121
2123	Emerg. O/C prot.: Time TI> expired		C					61	123
2127	Emerg. O/C prot.: Time TIE> expired		C					61	127
2141	Emerg. O/C protection: General Trip		C		CA			p	72
2145	Emerg. O/C protection: Trip 3pole		C					61	145
2704	>AR: Reset auto-reclose function	CG				GI		40	4
2709	>AR: Block delayed auto-reclose	CG				GI		40	9
2711	>AR: External start for internal AR	CG				GI		40	11
2781	AR: Auto-reclose is switched off	CG				GI		40	81
2782	AR: Auto-reclose is switched on	CG			CA	GI		p	16
2783	AR: Auto-reclose is blocked	CG				GI		40	83
2784	AR: Auto-reclose is not ready	CG			CA	GI	BT	p	130
2785	AR: Auto-reclose is dynamically blocked	CG				GI		40	85
2787	AR: Circuit breaker not ready	CG				GI		40	87

FNo.	Meaning	Ann.		LSA	IEC 60 870-5-103				
		Op	Ft	No.	CA	GI	BT	Typ	Inf
2801	AR: Auto-reclose in progress	CG	CG			GI		40	101
2814	AR: 3pole dead time for RAR is running	CG	CG			GI		40	114
2833	AR: 3pole dead time 1 for DAR running	CG	CG			GI		40	133
2834	AR: 3pole dead time 2 for DAR running	CG	CG			GI		40	134
2835	AR: 3pole dead time 3 for DAR running	CG	CG			GI		40	135
2851	AR: Close command from auto-reclose	C			CA		BT	p	128
2854	AR: Close command after 3pole DAR cycle	C			CA			p	129
2863	AR: Definitive trip		C					40	163
3651	Distance protection is switched off	CG				GI		28	51
3652	Distance protection is blocked	CG				GI		28	52
3653	Distance protection is active	CG				GI		28	53
3671	Dist.: General fault detection		CG					28	71
3672	Dist.: Fault detection , phase L1		CG			GI	BT	28	72
3673	Dist.: Fault detection , phase L2		CG			GI	BT	28	73
3674	Dist.: Fault detection , phase L3		CG			GI	BT	28	74
3675	Dist.: Fault detection , earth fault		CG			GI	BT	28	75
3681	Dist.: Fault detection only phase L1		C					28	81
3682	Dist.: Fault detection phase L1,E		C					28	82
3683	Dist.: Fault detection only phase L2		C					28	83
3684	Dist.: Fault detection phase L2,E		C					28	84
3685	Dist.: Fault detection phase L1,2		C					28	85
3686	Dist.: Fault detection phase L1,2,E		C					28	86
3687	Dist.: Fault detection only phase L3		C					28	87
3688	Dist.: Fault detection phase L3,E		C					28	88
3689	Dist.: Fault detection phase L1,3		C					28	89
3690	Dist.: Fault detection phase L1,3,E		C					28	90
3691	Dist.: Fault detection phase L2,3		C					28	91
3692	Dist.: Fault detection phase L2,3,E		C					28	92
3693	Dist.: Fault detection phase L1,2,3		C					28	93
3694	Dist.: Fault detection phase L1,2,3,E		C					28	94
3719	Dist.: Fault det. in forward direction		C		CA		BT	p	74
3720	Dist.: Fault det. in reverse direction		C		CA		BT	p	75
3771	Dist.: Time T1 (Zone Z1) expired		C		CA			p	78
3774	Dist.: Time T2 (Zone Z2) expired		C		CA			p	79
3777	Dist.: Time T3 (Zone Z3) expired		C		CA			p	80
3778	Dist.: Time T4 (direct. zone) expired		C		CA			p	81
3779	Dist.: Time T5 (non-dir. zone) expired		C		CA			p	82
3780	Dist.: Time T1B (Zone Z1B) expired		C					28	180
3783	Dist.: Time T1L (Zone Z1L) expired		C					28	183
3801	Distance protection: General trip		C					28	201
3805	Dist.: Trip 3pole		C					28	205
4051	Dist. teleprotection is switched on	CG			CA	GI		p	17
4052	Dist. teleprotection is switched off	CG				GI		29	52
4054	Dist. teleprotection: Carrier reception		C		CA			p	77
4055	Dist. teleprotection: Carrier faulty	CG			CA	GI		p	39
4056	Dist. teleprotection: Carrier send		C		CA			p	76
4067	POTT teleprotection: Carrier echo send	C						29	67
4068	POTT teleprotection: Transient block		C					29	68
4164	Power swing detection	CG				GI		29	164
4166	Out-of-step trip 3pole	C						29	166
4431	Ext. trip via binary input: Trip		C					51	31
4435	Ext. trip via binary input: 3pole		C					51	35
4436	Ext. trip via binary input: Without AR		C					51	36
6254	Output signal of user defined timer T1	CG				GI		214	54
6255	Output signal of user defined timer T2	CG				GI		214	55

Annunciations 7SA510 for PC, LC-display and binary inputs/outputs

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FNo.   - Function number of annunciation
Op/Ft  - Operation/Fault annunciation
         C/CG: Coming/Coming and Going annunciation
         M   : Measurand
E      - Earth fault annunciation
IOT    - I: can be marshalled to binary input
         O: can be marshalled to binary output (LED, signal relay)
         T: can be marshalled to trip relay
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FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
3	>Time Synchro	>Time synchronization				IO
4	>Start FltRec	>Start fault recording	C			IO
5	>LED reset	>Reset LED indicators				IO
7	>ParamSelec.1	>Parameter set selection 1 (with No.8)				IO
8	>ParamSelec.2	>Parameter set selection 2 (with No.7)				IO
11	>Annunc. 1	>User defined annunciation 1	CG			IOT
12	>Annunc. 2	>User defined annunciation 2	CG			IOT
13	>Annunc. 3	>User defined annunciation 3	CG			IOT
14	>Annunc. 4	>User defined annunciation 4	CG			IOT
15	>Sys-Test	>Testing via system-interface				IO
16	>Sys-MM-block	>Block. of monitoring dir. via sys.-int				IO
51	Dev.operative	Device operative / healthy	CG			O
52	Prot. operat.	Any protection operative	CG			O
56	Initial start	Initial start of processor system	C			
60	LED reset	LED Reset	C			O
61	LogMeasBlock	Logging and measuring functions blocked	CG			
62	Test mode	Test mode	CG			
95	Param.running	Parameters are being set	CG			O
96	Param. Set A	Parameter set A is active	CG			O
97	Param. Set B	Parameter set B is active	CG			O
98	Param. Set C	Parameter set C is active	CG			O
99	Param. Set D	Parameter set D is active	CG			O
100	Wrong SW-vers	Wrong software-version	C			
101	Wrong dev. ID	Wrong device identification	C			
110	Annunc. lost	Annunciations lost (buffer overflow)	C			
111	Annu. PC lost	Annunciations for PC lost	C			
115	Flt.Buff.Over	Fault annunciation buffer overflow		C		
116	E/F Buff.Over	E/F buffer overflow			E	
120	Oper.Ann.Inva	Operational annunciations invalid	CG			
121	Flt.Ann.Inval	Fault annunciations invalid	CG			
122	E/F.Prot Inva	Earth fault annunciations invalid	CG			
123	Stat.Buff.Inv	Statistic annunciation buffer invalid	CG			
124	LED Buff.Inva	LED annunciation buffer invalid	CG			
129	VDEW-StateInv	VDEW state invalid	CG			
135	Chs Error	Error in check sum	CG			
136	Chs.A Error	Error in check sum for parameter set A	CG			
137	Chs.B Error	Error in check sum for parameter set B	CG			
138	Chs.C Error	Error in check sum for parameter set C	CG			
139	Chs.D Error	Error in check sum for parameter set D	CG			
141	Failure 24V	Failure of internal 24 VDC power supply	CG			OT
143	Failure 15V	Failure of internal 15 VDC power supply	CG			OT
144	Failure 5V	Failure of internal 5 VDC power supply	CG			OT
145	Failure 0V	Failure of internal 0 VDC power supply	CG			OT
151	Failure I/O 1	Failure in I/O module 1	CG			OT
154	Fail. TripRel	Supervision trip circuit	CG			
159	LSA disrupted	LSA (system interface) disrupted	CG			

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
161	I supervision	Measured value supervision of currents				O
162	Failure ∑I	Failure: Current summation supervision	CG			OT
163	Failure Isymm	Failure: Current symmetry supervision	CG			OT
164	U supervision	Measured value supervision of voltages				O
167	Failure Usymm	Failure: Voltage symmetry supervision	CG			OT
168	Failure Umeas	Failure: Measuring voltages absent	CG			OT
169	Fuse-Failure	Fuse failure monitor operated (>10s)	CG			OT
170	FFM pick-up	Fuse failure monitor pick-up	CG			
171	Fail.PhaseSeq	Failure: Phase sequence supervision	CG			OT
203	Flt.RecDatDel	Fault recording data deleted	C			
204	Flt.Rec.viaBI	Fault recording initiated via bin.input	C			
205	Flt.Rec.viaKB	Fault recording initiated via keyboard	C			
206	Flt.Rec.viaPC	Fault recording initiated via PC interf	C			
244	D Time=	Diff. time of clock synchronism	M			
301	Syst.Flt	Fault in the power system	CG	C		
302	Fault	Flt. event w. consecutive no.		C		
303	E/F Det.	E/Flt.det. in isol/comp.netw.	CG		E	
354	>CB Aux.3p cl	>CB aux. contact:3poles closed (series)				IOT
356	>Manual Close	>Manual close				IOT
357	>CloseCmd.Blo	>Block all close commands from external	CG			IOT
361	>VT mcb Trip	>U Line side VT MCB tripped	CG			IOT
383	>RAR Release	>Release overreach zones RAR	CG	CG		IOT
384	>DAR Release	>Release overreach zones DAR	CG	CG		IOT
501	Device FltDet	General fault detection of device				OT
502	Dev. Drop-off	General drop-off of device		C		
503	Dev.FltDet L1	General device fault detection: Ph. L1				OT
504	Dev.FltDet L2	General device fault detection: Ph. L2				OT
505	Dev.FltDet L3	General device fault detection: Ph. L3				OT
506	Dev.FltDet N	General device fault detection: Ph. N				OT
511	Device Trip	General trip of device		G		OT
515	Dev.Trip 3p	General 3pole trip of device				OT
516	Dev.Trip forw	General trip for fault in forward dir.				OT
517	Dev.Trip rev.	General trip for fault in reverse dir.		C		OT
521	IL1/In=	Interrupted current: Phase L1(I/In)		C		
522	IL2/In=	Interrupted current: Phase L2(I/In)		C		
523	IL3/In=	Interrupted current: Phase L3(I/In)		C		
545	T-Drop	Time from fault detection to drop-off				
546	T-Trip	Time from fault detection to trip				
561	Manual Close	Circuit breaker manually closed (pulse)	C			OT
562	Man.Close Cmd	CB close command for manual closing				OT
563	CB Alarm Supp	CB alarm suppressed				OT
601	IL1[%] =	Current in phase IL1 [%] =	M			
602	IL2[%] =	Current in phase IL2 [%] =	M			
603	IL3[%] =	Current in phase IL3 [%] =	M			
621	UL1E[%]=	UL1E [%]=	M			
622	UL2E[%]=	UL2E [%]=	M			
623	UL3E[%]=	UL3E [%]=	M			
624	UL12[%]=	UL12 [%] =	M			
625	UL23[%]=	UL23 [%] =	M			
626	UL31[%]=	UL31 [%] =	M			
641	Pa[%]=	Active power Pa [%] =	M			
642	Pr[%]=	Reactive power Pr [%] =	M			
644	f [%]=	Frequency f [%] =	M			
651	IL1 =	Current in phase IL1 =	M			
652	IL2 =	Current in phase IL2 =	M			
653	IL3 =	Current in phase IL3 =	M			
671	UL1E=	Voltage UL1E =	M			
672	UL2E=	Voltage UL2E =	M			

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
673	UL3E=	Voltage UL3E =	M			
674	UL12=	Voltage UL12 =	M			
675	UL23=	Voltage UL23 =	M			
676	UL31=	Voltage UL31 =	M			
691	Pa=	Active power Pa =	M			
692	Pr=	Reactive power Pr =	M			
701	Iea[mA]=	Iea [mA] =	M			
702	Ier[mA]=	Ier [mA] =	M			
711	Iea =	Iea =	M			
712	Ier =	Ier =	M			
801	Θ/Θtrip =	Temperat. rise for warning and trip	M			
802	Θ/ΘtripL1=	Temperature rise for phase L1	M			
803	Θ/ΘtripL2=	Temperature rise for phase L2	M			
804	Θ/ΘtripL3=	Temperature rise for phase L3	M			
999	Trip No =	Number of trip commands issued	M			
1004	∑IL1/In=	Summated current tripped IL1/In	M			
1005	∑IL2/In=	Summated current tripped IL2/In	M			
1006	∑IL3/In=	Summated current tripped IL3/In	M			
1012	AR 3pole=	No. of auto-reclose commands:3p RAR	M			
1013	DAR 3pol=	No. of auto-reclose commands:3p DAR	M			
1106	>Start FltLoc	>Start fault locator	CG			IOT
1114	Rpri=	Fault resistance, Ohm prim.		C		
1115	Xpri=	Fault reactance, Ohm prim.		C		
1117	Rsec=	Fault resistance, Ohm sec.		C		
1118	Xsec=	Fault reactance, Ohm sec.		C		
1119	d km=	Distance to fault in km		C		
1120	d % =	Distance to fault in %		C		
1156	>CB Test	>CB test start				IOT
1174	CB in Test	Circuit breaker test in progress	CG			OT
1181	CB Test Trip	Circuit breaker test: General trip				OT
1185	CB Test 3p	Circuit breaker test: Trip 3pole	C			OT
1251	>E/F Det. on	>Switch on E/F det. for isol./comp. net				IOT
1252	>E/F Det. off	>Switch off E/F det. for isol./comp.net				IOT
1253	>E/F Det.bloc	>Block E/F det. for isol./comp. net				IOT
1261	E/F Det. off	E/F det. (isol./comp. net) switched off	CG			OT
1262	E/F Det.block	E/F detection (isol./comp. net) blocked	CG			OT
1263	E/F Det.activ	E/F detection (isol./comp. net) active				OT
1271	E/F Detection	Earth fault in isol./comp. net detected		C	E	OT
1272	E/F Detec. L1	Earth fault (isol./comp.) L1 detected			E	OT
1273	E/F Detec. L2	Earth fault (isol./comp.) L2 detected			E	OT
1274	E/F Detec. L3	Earth fault (isol./comp.) L3 detected			E	OT
1276	E/F forwards	Earth fault (isol./comp.) forward dir.			E	OT
1277	E/F reverse	Earth fault (isol./comp.) reverse dir.			E	OT
1278	E/F undefined	Earth fault (isol./comp.) undef. dir.			E	OT
1281	E/F Det. Trip	Trip by earth fault det. (isol./comp.)		C	E	OT
1289	Iea	Active component Iea			E	
1290	Ier	Reactive component Ier			E	
1303	>E/F block	>Block E/F protection				IOT
1311	>E/F comp. on	>Switch on directional E/F comparison				IOT
1312	>E/F comp.off	>Switch off directional E/F comparison				IOT
1316	>E/F Recept	>Carrier reception for direct. E/F comp	C	C		IOT
1317	>E/F Rec.Fail	>Carrier reception for dir. E/F faulty	CG			IOT
1331	E/F Prot. off	Earth fault protection is switched off	CG			OT
1332	E/F blocked	Earth fault protection is blocked	CG	CG		OT
1333	E/F active	Earth fault protection is active				OT
1334	E/F Dir.block	Earth fault prot. direct.stage blocked				OT
1341	E/F Flt75%Ie>	Earth fault detection 75% Ie picked up		CG		OT
1342	E/F Flt Ie<->	Earth fault detection non-direct. Ie		C		OT

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
1343	E/F Flt Ie ->	Earth fault detection directional Ie		C		OT
1344	E/F Ue>	Earth fault displacement voltage Ue>				OT
1351	E/F T-Delay	Earth fault protection time expired				OT
1352	E/F T->	Earth fault prot. dir. time expired				OT
1353	E/F T<->	Earth fault prot. non-dir. time expired				OT
1361	E/F Trip	Trip by earth fault protection		C		OT
1381	E/F Dir off	Earth fault dir. comp. is switched off	CG			OT
1384	E/F Send	Carrier transmission for dir. comp. E/F		C		OT
1385	E/F Echo	Echo signal for directional comp. E/F	C			OT
1386	E/F TransBloc	Transient block. of E/F protection		C		OT
1501	>O/L on	>Switch on thermal overload protection				IOT
1502	>O/L off	>Switch off thermal overload protection				IOT
1503	>O/L block	>Block thermal overload protection				IOT
1511	O/L Prot. off	Thermal overload prot. is switched off	CG			OT
1512	O/L blocked	Thermal overload protection is blocked	CG			OT
1513	O/L active	Thermal overload protection is active				OT
1515	O/L Warn I	Thermal overload prot.: Current warning	CG			OT
1516	O/L Warn Θ	Thermal overload prot.: Thermal warning	CG			OT
1517	O/L pickup Θ	Thermal overload prot.: Pick-up thermal	CG			OT
1521	O/L Trip	Thermal overload protection trip		C		OT
2003	>Emer. block	>Block emergency overcurrent protection				IOT
2010	>I>> block	>Block I>> stage of emerg. O/C protec.	CG			IOT
2051	Emer. off	Emergency O/C protect. is switched off	CG			OT
2052	Emer. block	Emergency O/C protection is blocked	CG			OT
2053	Emer. active	Emergency O/C protection is active				OT
2054	Emer. mode	Emergency O/C protection is running	CG			OT
2061	Emer.Gen.Flt	Emerg. O/C prot.: General fault detect.				OT
2062	Emer. Flt L1	Emerg. O/C prot.: Fault detection L1				OT
2063	Emer. Flt L2	Emerg. O/C prot.: Fault detection L2				OT
2064	Emer. Flt L3	Emerg. O/C prot.: Fault detection L3				OT
2065	Emer. Flt E	Emerg. O/C prot.: Earth fault detection				OT
2071	Emer. Flt E	Emerg. O/C earth fault detection only		C		
2072	Emer. Flt L1	Emerg. O/C fault detection L1 only		C		
2073	Emer. Flt L1E	Emerg. O/C fault detection L1E		C		
2074	Emer. Flt L2	Emerg. O/C fault detection L2 only		C		
2075	Emer. Flt L2E	Emerg. O/C fault detection L2E		C		
2076	Emer. Flt L12	Emerg. O/C fault detection L12		C		
2077	Emer.Flt L12E	Emerg. O/C fault detection L12E		C		
2078	Emer. Flt L3	Emerg. O/C fault detection L3 only		C		
2079	Emer. Flt L3E	Emerg. O/C fault detection L3E		C		
2080	Emer. Flt L13	Emerg. O/C fault detection L13		C		
2081	Emer.Flt L13E	Emerg. O/C fault detection L13E		C		
2082	Emer. Flt L23	Emerg. O/C fault detection L23		C		
2083	Emer.Flt L23E	Emerg. O/C fault detection L23E		C		
2084	Emer.Flt L123	Emerg. O/C fault detection L123		C		
2085	Emer.Flt 123E	Emerg. O/C fault detection L123E		C		
2091	Emer. I>>	Emerg. O/C phase fault detection I>>		C		OT
2093	Emer. I>	Emerg. O/C phase fault detection I>		C		OT
2097	Emer. IE>	Emerg. O/C earth fault detection IE>		C		OT
2121	Emer. TI>>	Emerg. O/C prot.: Time TI>> expired				OT
2123	Emer. TI>	Emerg. O/C prot.: Time TI> expired				OT
2127	Emer. TIE>	Emerg. O/C prot.: Time TIE> expired				OT
2141	Emer.Gen.Trip	Emerg. O/C protection: General Trip				OT
2145	Emer.Trip 3p	Emerg. O/C protection: Trip 3pole		C		OT
2701	>AR on	>AR: Switch on auto-reclose function				IOT
2702	>AR off	>AR: Switch off auto-reclose function				IOT
2703	>AR block	>AR: Block auto-reclose function	CG			IOT
2704	>AR reset	>AR: Reset auto-reclose function	C			IOT

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
2708	>RAR block	>AR: Block rapid auto-reclose	CG			IOT
2709	>DAR block	>AR: Block delayed auto-reclose	CG			IOT
2711	>Start AR	>AR: External start for internal AR	C			IOT
2716	>Trip 3p AR	>AR: Ext. 3pole trip for internal AR	C			IOT
2721	>DAR aft. RAR	>AR: Delayed AR only after rapid AR	CG			IOT
2730	>CB ready	>AR: Circuit breaker ready for reclose				IOT
2731	>Sync.release	>AR: Synchronism from ext. sync.-check				IOT
2781	AR off	AR: Auto-reclose is switched off	CG			OT
2782	AR on	AR: Auto-reclose is switched on				OT
2783	AR inoperativ	AR: Auto-reclose is blocked	CG			OT
2784	AR not ready	AR: Auto-reclose is not ready				OT
2785	AR block.dyn.	AR: Auto-reclose is dynamically blocked		C		OT
2787	CB not ready	AR: Circuit breaker not ready				OT
2788	AR T-CB Exp.	AR: CB supervision time expired				OT
2801	AR in prog.	AR: Auto-reclose in progress		C		OT
2811	RAR only	AR: Only rapid auto-reclosing allowed				OT
2812	RAR T-act.run	AR: Action time for RAR is running				OT
2814	RAR T-3p run.	AR: 3pole dead time for RAR is running		C		OT
2817	RAR Zone Rel.	AR: Zone extension for rapid reclosing				OT
2831	DAR Only	AR: Only delayed auto-reclosing allowed				OT
2832	DAR T-act.run	AR: Action time for DAR is running				OT
2833	DAR T-3p1 run	AR: 3pole dead time 1 for DAR running		C		OT
2834	DAR T-3p2 run	AR: 3pole dead time 2 for DAR running		C		OT
2835	DAR T-3p3 run	AR: 3pole dead time 3 for DAR running		C		OT
2837	DAR Zone Rel.	AR: Zone extension for delayed reclose				OT
2851	AR Close Cmd.	AR: Close command from auto-reclose	C	C		OT
2853	RAR 3p Close	AR: Close command after 3pole RAR cycle				OT
2854	DAR 3p Close	AR: Close command after 3pole DAR cycle				OT
2861	AR T-Recl.run	AR: Reclaim time is running				OT
2862	AR successful	AR: Auto-reclose cycle successful				OT
2863	Definit.Trip	AR: Definitive trip				OT
2865	Sync.Meas.Req	AR: Sync-check request				OT
3603	>Dist. block	>Block distance protection				IOT
3611	>Extens. Z1B	>Dist.: Zone 1B extension from external	CG			IOT
3612	>Extens. Z1L	>Dist.: Zone 1L extension from external	CG			IOT
3651	Dist. off	Distance protection is switched off	CG			OT
3652	Dist. blocked	Distance protection is blocked	CG			OT
3653	Dist. active	Distance protection is active				OT
3661	DisZ1B AR blk	Dist.: Block AR by fault detec. Z1B		C		OT
3662	DisZ1L AR blk	Dist.: Block AR by fault detec. Z1L		C		OT
3671	Dist.Gen.Flt.	Dist.: General fault detection				OT
3672	Dist.Fault L1	Dist.: Fault detection , phase L1				OT
3673	Dist.Fault L2	Dist.: Fault detection , phase L2				OT
3674	Dist.Fault L3	Dist.: Fault detection , phase L3				OT
3675	Dist.Fault E	Dist.: Fault detection , earth fault				OT
3681	Dist.Flt.L1	Dist.: Fault detection only phase L1		C		
3682	Dist.Flt.L1E	Dist.: Fault detection phase L1,E		C		
3683	Dist.Flt.L2	Dist.: Fault detection only phase L2		C		
3684	Dist.Flt.L2E	Dist.: Fault detection phase L2,E		C		
3685	Dist.Flt.L12	Dist.: Fault detection phase L1,2		C		
3686	Dist.Flt.L12E	Dist.: Fault detection phase L1,2,E		C		
3687	Dist.Flt.L3	Dist.: Fault detection only phase L3		C		
3688	Dist.Flt.L3E	Dist.: Fault detection phase L3,E		C		
3689	Dist.Flt.L13	Dist.: Fault detection phase L1,3		C		
3690	Dist.Flt.L13E	Dist.: Fault detection phase L1,3,E		C		
3691	Dist.Flt.L23	Dist.: Fault detection phase L2,3		C		
3692	Dist.Flt.L23E	Dist.: Fault detection phase L2,3,E		C		
3693	Dist.Flt.L123	Dist.: Fault detection phase L1,2,3		C		

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
3694	Dist.Flt.123E	Dist.: Fault detection phase L1,2,3,E		C		
3701	Loop L1-E f	Dist.: Loop L1E selected forward		CG		OT
3702	Loop L2-E f	Dist.: Loop L2E selected forward		CG		OT
3703	Loop L3-E f	Dist.: Loop L3E selected forward		CG		OT
3704	Loop L1-2 f	Dist.: Loop L12 selected forward		CG		OT
3705	Loop L2-3 f	Dist.: Loop L23 selected forward		CG		OT
3706	Loop L3-1 f	Dist.: Loop L31 selected forward		CG		OT
3707	Loop L1-E r	Dist.: Loop L1E selected reverse		CG		OT
3708	Loop L2-E r	Dist.: Loop L2E selected reverse		CG		OT
3709	Loop L3-E r	Dist.: Loop L3E selected reverse		CG		OT
3710	Loop L1-2 r	Dist.: Loop L12 selected reverse		CG		OT
3711	Loop L2-3 r	Dist.: Loop L23 selected reverse		CG		OT
3712	Loop L3-1 r	Dist.: Loop L31 selected reverse		CG		OT
3719	Dist. For.Dir	Dist.: Fault det. in forward direction				OT
3720	Dist. Rev.Dir	Dist.: Fault det. in reverse direction				OT
3771	Dist. T1	Dist.: Time T1 (Zone Z1) expired				OT
3774	Dist. T2	Dist.: Time T2 (Zone Z2) expired				OT
3777	Dist. T3	Dist.: Time T3 (Zone Z3) expired				OT
3778	Dist. T4	Dist.: Time T4 (direct. zone) expired				OT
3779	Dist. T5	Dist.: Time T5 (non-dir. zone) expired				OT
3780	Dist. T1B	Dist.: Time T1B (Zone Z1B) expired				OT
3783	Dist. T1L	Dist.: Time T1L (Zone Z1L) expired				OT
3801	Dis.Gen. Trip	Distance protection: General trip				OT
3805	Dis.Trip 3p	Dist.: Trip 3pole		C		OT
3808	Dis.Trip back	Dist.: Trip in back-up stage				OT
3812	Dis.TripZ1/3p	Dist.: Trip 3pole in zone Z1/T1				OT
3814	Dis.TripZ1B3p	Dist.: Trip 3pole in zone Z1B/T1B				OT
3815	Dis.Trip Z1L	Dist.: Trip for fault in zone Z1L/T1L				OT
3817	Dis.TripZ2/3p	Dist.: Trip 3pole in zone Z2/T2				OT
3818	Dis.TripZ3/T3	Dist.: Trip for fault in zone Z3/T3				OT
3819	Dis.Trip FD->	Dist.: Trip by fault detection, direct				OT
3820	Dis.Trip <->	Dist.: Trip by fault detec., non-direct				OT
4004	>Dis. Recept	>Dist. teleprotection: Carrier receive	C	C		IOT
4005	>Dis.RecFail	>Dist. teleprotection: Carrier faulty	CG			IOT
4011	>Dis.POTT on	>Dist.:Switch on teleprotection POTT				IOT
4012	>Dis.POTT off	>Dist.:Switch off teleprotection POTT				IOT
4021	>Dis.PUTT on	>Dist.:Switch on teleprotection PUTT				IOT
4022	>Dis.PUTT off	>Dist.:Switch off teleprotection PUTT				IOT
4051	Dis.Tele.on	Dist. teleprotection is switched on				OT
4052	Dis.Tele.off	Dist. teleprotection is switched off	CG			OT
4054	Dis. Recept	Dist. teleprotection: Carrier reception				OT
4055	Dis. RecFail	Dist. teleprotection: Carrier faulty	CG			OT
4056	Dis. Send	Dist. teleprotection: Carrier send		C		OT
4067	Dis.POTT Echo	POTT teleprotection: Carrier echo send	C			OT
4068	Dis.TransBlo	POTT teleprotection: Transient block		C		OT
4164	Power Swing	Power swing detection	CG			OT
4165	P/S T-action	Power swing action time running				OT
4166	O/S Trip	Out-of-step trip 3pole	C	C		OT
4403	>Ext.Trip blk	>Block external trip function	CG			IOT
4415	>Ext.Trp.L123	>External trip L123 via binary input	C			IOT
4416	>Ext.Trp.woAR	>External 3pole trip without AR	CG			IOT
4431	Ext.Gen. Trip	Ext. trip via binary input: Trip				OT
4435	Ext.Trip 3p	Ext. trip via binary input: 3pole		C		OT
4436	Ext.Trip woAR	Ext. trip via binary input: Without AR		C		OT
6206	>User T1Start	>Start of user defined timer T1	CG	CG		IOT
6207	>User T1Reset	>Reset of user defined timer T1	C	C		IOT
6208	>User T2Start	>Start of user defined timer T2	CG	CG		IOT
6209	>User T2Reset	>Reset of user defined timer T2	C	C		IOT

FNo.	Abbreviation	Meaning	Op	Ft	E	IOT
6254	User output 1	Output signal of user defined timer T1	CG	C		OT
6255	User output 2	Output signal of user defined timer T2	CG	C		OT

Reference Table for Functional Parameters 7SA510

1000 PARAMETERS

1100 POWERSYSTEM DATA

```
1101 CT STARPNT                Current transformer polarity
     TOWARDS LINE        [ ] Towards line
     TOWARDS BUSBAR      [ ] Towards busbar

1102 SYSTEMSTAR                System star-point condition
     SOLIDLY EARTHED     [ ] Solidly earthed
     COMPENSATED         [ ] Compensated
     ISOLATED            [ ] Isolated

1103 Un PRIMARY                Primary rated voltage
     min. 1                    kV
     max. 1200          ____

1104 Un SECOND.                Secondary rated voltage
     min. 80                   V
     max. 125           ____

1105 In PRIMARY                Primary rated current
     min. 10                   A
     max. 5000          ____

1112 Ie/Iph                    Matching factor Ie/Iph for earth current
     min. 0.001
     max. 20.000        ____

1117 RE/RL                     Residual compensating factor RE/RL
     min. -7.00
     max. 7.00          ____

1118 XE/XL                     Residual compensating factor XE/XL
     min. -7.00
     max. 7.00          ____

1122 X SEC                     Secondary reactance per unit line length Xsec
     min. 0.010                Ω/km
     max. 5.000         ____

1124 LINELENGTH                Line length
     min. 1.0                  km
     max. 550.0         ____

1130 T-TRIP I>                 Trip command min.duration for I > I-RES
     min. 0.00                 s
     max. 32.00         ____

1131 T-TRIP I<                 Trip command min.duration for I < I-RES
     min. 0.01                 s
     max. 32.00         ____

1135 T-CLOSE                   Maximum close command duration
     min. 0.01                 s
     max. 32.00         ____
```

1145 T-M/C-PROL Prolongation time after manual closing
min. 0.01 s
max. 32.00 _____

1149 T-EXT.STAB Stabilization time for external trip
min. 0.00 s
max. 32.00 _____

1150 FILTER Filter for measured quantities
NORMAL [ ] Normal
LONG [ ] Long

1200 DIST.PROT. GENERAL SETTINGS

1201 DIST.PROT. Distance protection function
ON [ ] on
OFF [ ] off

1202 DIR. FD&T4 Direction for fault detection directional trip
FORWARDS [ ] Forwards
REVERSE [ ] Reverse
NON-DIRECTIONAL [ ] Non-directional

1203 T4 Delay T4 fault detection directional trip
min. 0.00 s
max. 32.00/∞ _____

1204 T5 Delay T5 fault detection non-directional trip
min. 0.00 s
max. 32.00/∞ _____

1205 MAN. CLOSE Distance zone effective with manual close
Z1B DIRECTIONAL [ ] Z1B directional
Z1B NON DIRECT. [ ] Z1B non-directional
FD EFFECTIVE [ ] Fault detection
Z1 EFFECTIVE [ ] Z1 effective

1216 RAR -> Z1B Distance zone Z1B effective before 1st RAR
YES [ ] yes
NO [ ] no

1217 DAR BLOCK Effective zone if DAR is blocked
Z1; T1 [ ] Z1; T1
Z1; T1B [ ] Z1; T1B

1218 DAR -> Z1L Distance zone Z1L effective before DAR
YES [ ] yes
NO [ ] no

1221 BLK.AR Z1B Autoreclosure is blocked for Z1B faults
NO [ ] no
WITHIN [ ] Within
OUTSIDE [ ] Outside

1222 BLK.AR Z1L Autoreclosure is blocked for Z1L faults
NO [ ] no
WITHIN [ ] Within
OUTSIDE [ ] Outside

```
1300 DIST.PROT. INDEPEND. ZONES

1301 R1                      Zone 1: Resistance (phase-phase) R1
     min. 0.05               Ω
     max. 65.00         ____

1302 X1                      Zone 1: Reactance (reach) X1
     min. 0.05               Ω
     max. 130.00        ____

1303 R1E                     Zone 1: Resistance (phase-earth) R1E
     min. 0.05               Ω
     max. 130.00        ____

1304 DIREC. Z1               Zone 1: Direction
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

1305 T1 1PHASE               Zone 1: Delay for single phase faults T1 1PH
     min. 0.00               s
     max. 32.00/∞       ____

1306 T1 >1PHASE              Zone 1: Delay for multi-phase faults T1
     min. 0.00               s
     max. 32.00/∞       ____

1311 R2                      Zone 2: Resistance (phase-phase) R2
     min. 0.05               Ω
     max. 65.00         ____

1312 X2                      Zone 2: Reactance (reach) X2
     min. 0.05               Ω
     max. 130.00        ____

1313 R2E                     Zone 2: Resistance (phase-earth) R2E
     min. 0.05               Ω
     max. 130.00        ____

1314 DIREC. Z2               Zone 2: Direction
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

1315 T2 1PHASE               Zone 2: Delay for single phase faults T2 1PH
     min. 0.00               s
     max. 32.00/∞       ____

1316 T2 >1PHASE              Zone 2: Delay for multi-phase faults T2
     min. 0.00               s
     max. 32.00/∞       ____

1321 R3                      Zone 3: Resistance (phase-phase) R3
     min. 0.05               Ω
     max. 65.00         ____

1322 X3                      Zone 3: Reactance (reach) X3
     min. 0.05               Ω
     max. 130.00        ____
```

```
1323 R3E                     Zone 3: Resistance (phase-earth) R3E
     min. 0.05               Ω
     max. 130.00       ____

1324 DIREC. Z3               Zone 3: Direction
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

1325 T3                      Zone 3: Delay for all faults T3
     min. 0.00               s
     max. 32.00/∞      ____
```

```
1400 DIST.PROT. CONTROLLED ZONES

1401 R1B                     Zone 1B: Resistance (phase-phase) R1B
     min. 0.05               Ω
     max. 65.00        ____

1402 X1B                     Zone 1B: Reactance (reach) X1B
     min. 0.05               Ω
     max. 130.00       ____

1403 R1BE                    Zone 1B: Resistance (phase-earth) R1BE
     min. 0.05               Ω
     max. 130.00       ____

1404 DIREC. Z1B              Zone 1B: Direction
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

1405 T1B 1PHASE              Zone 1B: Delay for single phase faults T1B 1PH
     min. 0.00               s
     max. 32.00/∞      ____

1406 T1B >1PHAS              Zone 1B: Delay for multi-phase faults T1B
     min. 0.00               s
     max. 32.00/∞      ____

1411 R1L                     Zone 1L: Resistance (phase-phase) R1L
     min. 0.05               Ω
     max. 65.00        ____

1412 X1L                     Zone 1L: Reactance (reach) X1L
     min. 0.05               Ω
     max. 130.00       ____

1413 R1LE                    Zone 1L: Resistance (phase-earth) R1LE
     min. 0.05               Ω
     max. 130.00       ____

1414 DIREC. Z1L              Zone 1L: Direction
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

1415 T1L                     Zone 1L: Delay for all faults T1L
     min. 0.00               s
     max. 32.00/∞      ____
```

```
1500 DIST.PROT. FAULT DETEC.PROG

1501 PROG. U/I                Program for U/I fault detection
     LE:Uphe/LL:Uphph [ ] LE:Uphe/LL:Uphph
     LE:Uphph/LL:Uphp [ ] LE:Uphph/LL:Uphp
     LE:Uphe/LL:Uphe  [ ] LE:Uphe/LL:Uphe
     LE:Uphe/LL:I>>   [ ] LE:Uphe/LL:I>>

1503 PROG. ZA                 Program for impedance fault detection
     LE:Zphe/LL:Zphph [ ] LE:Zphe/LL:Zphph
     LE:Zphe/LL:I>>   [ ] LE:Zphe/LL:I>>
```

```
1600 DIST.PROT. FAULT DETECTION

1601 Iph>>                    Overcurrent detection Iph>>
     min. 0.25                I/In
     max. 4.00         ____

1602 Ie>                      Earth fault detection Ie>
     min. 0.10                I/In
     max. 1.00         ____

1611 Iph>                     Minimum current for fault detection Iph>
     min. 0.10                I/In
     max. 1.00         ____

1612 Uphe(I>>)                Undervoltage pick-up at I>> (phase-earth)
     min. 20                  V
     max. 70           ____

1613 Uphe(I>)                 Undervoltage pick-up at I> (phase-earth)
     min. 20                  V
     max. 70           ____

1614 Uphph(I>>)               Undervoltage pick-up at I>> (phase-phase)
     min. 40                  V
     max. 130          ____

1615 Uphph(I>)                Undervoltage pick-up at I> (phase-phase)
     min. 40                  V
     max. 130          ____

1621 Iph>                     Minimum current for fault detection Iph>
     min. 0.10                I/In
     max. 4.00         ____

1622 X+A                      Fault detection forward reach X+A
     min. 0.10                Ω
     max. 200.00       ____

1623 X-A                      Fault detection reverse reach X-A
     min. 0.10                Ω
     max. 200.00       ____

1624 RA1                      Fault det. resistance (ph-ph, phi<PHI A) RA1
     min. 0.10                Ω
     max. 200.00       ____
```

```
1625 RA2                       Fault det. resistance (ph-ph, phi>PHI A) RA2
     min. 0.10                 Ω
     max. 200.00      _____

1626 RA1E                      Fault det. resistance (ph-e, phi<PHI AE) RA1E
     min. 0.10                 Ω
     max. 200.00      _____

1627 RA2E                      Fault det. resistance (ph-e, phi>PHI AE) RA2E
     min. 0.10                 Ω
     max. 200.00      _____

1628 ANGLE PHIA                Fault det. ph-ph angle betw. RA1/RA2 PHI A
     min. 30                   °
     max. 80          _____

1629 ANG. PHIAE                Fault det. ph-e angle betw. RA1E/RA2E PHI AE
     min. 30                   °
     max. 80          _____
```

```
1700 FAULT IN EARTHED NETWORKS

1701 Ue>                       Displacement voltage for earth fault det. Ue>
     min. 2                    V
     max. 100/∞       _____

1703 PHPHE FLTS                Loop selection with Ph-Ph-E faults
     PHASE-PHASE ONLY [ ] Phase to phase only
     LEADING PH-E     [ ] Leading phase-earth
     LAGGING PH-E     [ ] Lagging phase-earth

1704 3PH FAULTS                Loop selection with 3phase faults
     E/F CONTROL      [ ] Dependent on E/F det
     PHASE-PHASE ONLY [ ] Phase to phase only
     PHASE-EARTH ONLY [ ] Phase to earth only

1705 1PH FAULTS                Loop select. for single ph. w/o earth flt.det.
     PHASE-EARTH      [ ] Phase-earth
     PHASE-PHASE      [ ] Phase-phase
```

```
1800 FAULT NON-EARTHED NET

1801 TIe 1PHASE                Delay time for single phase flt. det. TIe 1PH
     min. 0.00                 s
     max. 0.50/∞      _____

1802 Ue>                       Displacement voltage for earth fault det. Ue>
     min. 10                   V
     max. 100         _____
```

```
1803 PHASE PREF              Phase preference for double earth faults
     L3(L1) ACYCLIC      [ ] L3(L1) acyclic
     L1(L3) ACYCLIC      [ ] L1(L3) acyclic
     L2(L1) ACYCLIC      [ ] L2(L1) acyclic
     L1(L2) ACYCLIC      [ ] L1(L2) acyclic
     L3(L2) ACYCLIC      [ ] L3(L2) acyclic
     L2(L3) ACYCLIC      [ ] L2(L3) acyclic
     L3(L1) CYCLIC       [ ] L3(L1) cyclic
     L1(L3) CYCLIC       [ ] L1(L3) cyclic
```

```
2000 POWER SWING

2002 P/S PROGR.              Program of power swing (P/S) function
     BLOCK ALL           [ ] Block all zones
     BLOCK Z1 ONLY       [ ] Block Z1 only
     BLOCK ALL BUT Z1    [ ] Block all but Z1
     OUT-OF-STEP TRIP    [ ] Out-of-step trip

2003 Delta R                 Distance between P/S and fault detect. polygon
     min. 0.10               Ω
     max. 50.00          ____

2004 dR/dT                   Rate of change of P/S vector dR/dT
     min. 0                  Ω/s
     max. 200            ____

2005 P/S T-ACT.              Power swing action time P/S T-ACT.
     min. 0.01               s
     max. 32.00/∞        ____
```

```
2100 TELEPROTEC PERM. UNDERREACH

2101 PUTT                    Permissive underreach transfer trip
     ON                  [ ] on
     OFF                 [ ] off

2102 PUTT MODE               Permissive underreach transfer trip mode
     Z1B ACCELERATION    [ ] Z1B acceleration
     FD ACCELERATION     [ ] FD acceleration

2103 T-SEND-PRL              Send signal prolongation for PUTT
     min. 0.01               s
     max. 32.00          ____

2104 T-REC-PROL              Receive signal prolongation for PUTT
     min. 0.00               s
     max. 32.00          ____

2106 T-SEND-DEL              Send signal delay for PUTT
     min. 0.00               s
     max. 32.00          ____
```

```
2200 TELEPROTEC PERM. OVERREACH

2201 POTT                    Permissive overreach transfer trip
     ON                  [ ] on
     OFF                 [ ] off

2202 POTT MODE               Permissive overreach transfer trip mode
     Z1B RELEASE         [ ] Z1B release
     FD DIREC RELEASE    [ ] Direct. comparison
     Z1B UNBLOCK         [ ] Unblocking with Z1B
     FD UNBLOCK          [ ] Unblocking with FD
     Z1B BLOCKING        [ ] Blocking with Z1B
     PILOT WIRE COMP.    [ ] Comp. via pilot wire
     REVERS INTERLOCK    [ ] Reverse interlocking

2203 T-TRANSBLO              Transient blocking time after external fault
     min. 0.01               s
     max. 32.00         ____

2204 T-WAIT                  Waiting time for trans.block. (missing recept)
     min. 0.01               s
     max. 32.00/∞       ____

2206 T-SEND-PRL              Send signal prolongation for POTT
     min. 0.01               s
     max. 32.00         ____

2210 POTT DirFD              Effect. direction for directional comparison
     FORWARDS            [ ] Forwards
     REVERSE             [ ] Reverse
     NON-DIRECTIONAL     [ ] Non-directional

2212 T-SEND DEL              Send signal delay for POTT
     min. 0.00               s
     max. 32.00         ____

2220 ECHO                    Echo function for weak infeed
     ON                  [ ] on
     OFF                 [ ] off

2221 T-ECHO-DEL              Echo delay time
     min. 0.01               s
     max. 32.00/∞       ____

2222 T-ECHO-IMP              Duration of echo impulse
     min. 0.02               s
     max. 32.00         ____

2223 T-ECHO-BLO              Echo blocking time
     min. 0.01               s
     max. 32.00         ____
```

```
2300 USER LOGIC FUNCTIONS

2302 T-PICKUP 1              1st user logic function: Pick-up time
     min. 0.00               s
     max. 32.00/∞       ____
```

```
2303 T-DROP 1              1st user logic function: Drop-off time
     min. 0.00             s
     max. 32.00/∞     ____

2305 T-PICKUP 2            2nd user logic function: Pick-up time
     min. 0.00             s
     max. 32.00/∞     ____

2306 T-DROP 2              2nd user logic function: Drop-off time
     min. 0.00             s
     max. 32.00/∞     ____
```

```
2600 EMERGENCY OVERCURRENT PROT

2601 EMERG. O/C            Emergency overcurrent definite time protection
     ON               [ ]  on
     OFF              [ ]  off

2602 I>>                   Highset phase overcurrent threshold (DT) I>>
     min. 0.50             I/In
     max. 9.99        ____

2603 T-I>>                 Delay time for I>> TI>>
     min. 0.00             s
     max. 32.00/∞     ____

2612 I>                    Phase overcurrent threshold (DT) I>
     min. 0.10             I/In
     max. 4.00        ____

2613 T-I>                  Delay time for I> TI>
     min. 0.00             s
     max. 32.00/∞     ____

2621 M/CLOSE PH            Phase overcurrent stage effect.: Manual close
     I>> UNDELAYED    [ ]  I>> undelayed
     I> UNDELAYED     [ ]  I> undelayed
     INEFFECTIVE      [ ]  Ineffective

2623 RAR ZONE P            Phase overcurrent stage effect.: Auto reclose
     I>> WITH AR      [ ]  I>> only with AR
     I>> ALWAYS       [ ]  I>> always

2642 IE>                   Earth overcurrent threshold (DT) IE>
     min. 0.10             I/In
     max. 4.00        ____

2643 T-IE>                 Delay time for IE> TIE>
     min. 0.00             s
     max. 32.00/∞     ____

2651 M/CLOSE E             Earth overcurrent stage effect: Manual close
     IE> UNDELAYED    [ ]  Ie> undelayed
     INEFFECTIVE      [ ]  Ineffective
```

```
2700 THERMAL OVERLOAD PROT.

2701 THERMAL OL              State of thermal overload protection
     ALARM ONLY        [ ] Alarm only
     ON                [ ] on
     OFF               [ ] off

2702 K-FACTOR              K-factor for thermal overload protection
     min. 0.10
     max. 4.00        _____

2703 T-CONSTANT            Time constant for thermal overload protection
     min. 1.0              min
     max. 999.9       _____

2704 Θ WARN                Thermal warning stage
     min. 50               %
     max. 100         _____

2705 I WARN                Current warning stage
     min. 0.10             I/In
     max. 4.00        _____

2706 O/L CALCUL            Calculation method for thermal stages
     Θ MAX             [ ] Theta max
     Θ MEAN            [ ] Theta mean
     Θ FROM IMAX       [ ] Theta from Imax
```

```
2900 MEAS.VALUE SUPERVISION

2901 SYM.Uthres            Symmetry threshold for voltage monitoring
     min. 10               V
     max. 100         _____

2902 SYM.Fact.U            Symmetry factor for voltage monitoring
     min. 0.58
     max. 0.95        _____

2903 SYM.Ithres            Symmetry threshold for current monitoring
     min. 0.10             I/In
     max. 1.00        _____

2904 SYM.Fact.I            Symmetry factor for current monitoring
     min. 0.10
     max. 0.95        _____

2905 SUM.Ithres            Summation threshold for current monitoring
     min. 0.10             I/In
     max. 2.00        _____

2906 SUM.Fact.I            Factor for current summation monitoring
     min. 0.00
     max. 0.95        _____

2907 UMEAS U<              Threshold for voltage failure monitor
     min. 10               V
     max. 125         _____
```

```
2908 UMEAS I>                Minimum current for voltage failure monitor
     min. 0.06               I/In
     max. 1.00         ____

2910 FUSE-FAIL               Fuse failure monitoring (FFM)
     ON                 [ ] on
     OFF                [ ] off

2911 FFM 3*Uo>               Displacement voltage level for FFM
     min. 30                 V
     max. 100          ____

2912 FFM Ie<                 Earth current for fuse failure monitoring
     min. 0.10               I/In
     max. 1.00         ____
```

```
3000 EARTHFAULT NON-EARTHED NET

3001 EARTHFAULT              Sensitive earth fault det. in non-earthed net
     ALARM ONLY         [ ] Alarm only
     ON                 [ ] on
     OFF                [ ] off

3002 Ue>                     Displacement voltage level Ue>
     min. 10                 V
     max. 100          ____

3003 Uph<                    Phase-earth voltage of faulted phase Uph<
     min. 10                 V
     max. 100          ____

3004 Uph>                    Phase-earth voltage of healthy phases Uph>
     min. 10                 V
     max. 100          ____

3005 Ie>                     Current level for directional determination
     min. 0.003              A
     max. 1.000        ____

3006 CT ERR. I1              Second. current I1 for max error angle of C.T.
     min. 0.003              A
     max. 1.600        ____

3007 CT ERR. F1              Error angle of C.T. at I1
     min. 0.0                °
     max. 5.0          ____

3008 CT ERR. I2              Second. current I2 for max error angle of C.T.
     min. 0.003              A
     max. 1.600        ____

3009 CT ERR. F2              Error angle of C.T. at I2
     min. 0.0                °
     max. 5.0          ____

3010 T-E/F                   Duration of displacement voltage for E/F det.
     min. 0.0                s
     max. 320.0        ____
```

```
3100 EARTHFAULT DIREC/NON-DIREC

3101 E/F D.T.               Earth fault definite time protection
     ON                 [ ] on
     OFF                [ ] off

3103 Ie>                    Pick-up value for earth current detection
     min. 0.10              I/In
     max. 4.00         ____

3104 Ue>                    Minimum voltage for directional determination
     min. 1.0               V
     max. 10.0         ____

3106 T-DIRECT.              Delay time for directional trip
     min. 0.00              s
     max. 32.00/∞      ____

3107 DIRECTION              Direction for directional stage
     FORWARDS           [ ] Forwards
     REVERSE            [ ] Reverse
     NON-DIRECTIONAL    [ ] Non-directional

3108 T-NON-DIR.             Delay time for non-directional trip
     min. 0.00              s
     max. 32.00/∞      ____

3109 T-BLOCK                Blocking time after dist.prot. has dropped off
     min. 0.01              s
     max. 320.00       ____
```

```
3200 EARTHFAULT DIREC.COMPARISON

3201 E/F COMPAR             Directional comparison for E/F def. time prot
     ON                 [ ] on
     OFF                [ ] off

3202 T-DELAY                Delay time for transmission and trip on recept
     min. 0.00              s
     max. 32.00/∞      ____

3203 T-TRANSBLO             Transient blocking time after external fault
     min. 0.01              s
     max. 32.00        ____

3204 T-WAIT                 Waiting time for trans.block. (missing recept)
     min. 0.01              s
     max. 32.00/∞      ____

3210 E/F ECHO               Echo function for directional comparison
     ON                 [ ] on
     OFF                [ ] off

3211 T-ECHO-DEL             Echo delay time
     min. 0.01              s
     max. 32.00/∞      ____

3212 T-ECHO-IMP             Duration of echo impulse
     min. 0.02              s
     max. 32.00        ____
```

```
3213 T-ECHO-BLO            Echo blocking time
     min. 0.01             s
     max. 32.00       ____
```

```
3300 EARTHFAULT NON-DIRECTIONAL

3301 E/F I.T.              Non directional inverse time E/F protection
     ON               [ ] on
     OFF              [ ] off

3302 E/F CHARAC            Trip time characteristic
     NORMAL INVERSE   [ ] Normal inverse
     VERY INVERSE     [ ] Very inverse
     EXTREMELY INVERS [ ] Extremely inverse

3303 Ie>                   Pick-up value for earth current detection
     min. 0.10             I/In
     max. 4.00        ____

3304 T-Ie>                 Delay time multiplier
     min. 0.00             s
     max. 32.00/∞     ____

3305 T-BLOCK               Blocking time after dist.prot. has dropped off
     min. 0.01             s
     max. 320.00      ____
```

```
3400 AUTORECLOSE FUNCTION

3401 AR FUNCT              Auto-reclose function
     ON               [ ] on
     OFF              [ ] off

3402 AR BLO REV            Auto-reclose block with reverse faults
     YES              [ ] yes
     NO               [ ] no

3403 MC BLOCK              Auto-reclose block with manual close
     YES              [ ] yes
     NO               [ ] no

3405 T-RECLAIM             Reclaim time after successful AR
     min. 0.50             s
     max. 320.00      ____

3406 T-LOCK                Lock-out time after unsuccessful AR
     min. 0.50             s
     max. 320.00/∞    ____

3407 T-BLOCK MC            Blocking duration with manual close
     min. 0.50             s
     max. 320.00      ____

3412 CB? 1.TRIP            CB ready interrogation at 1st trip command
     YES              [ ] yes
     NO               [ ] no
```

```
3413 CB? CLOSE              CB ready interrogation before reclosing
     CB? NEVER          [ ] CB? never
     CB? WITH EACH AR   [ ] CB? with each AR
     CB? WITH 2nd AR    [ ] CB? with 2nd AR

3415 T-CB-SUPV              Circuit breaker supervision time
     min. 0.01              s
     max. 320.00       ____

3419 SYN-REQUST             AR request for synchro-check
     BEFORE 3POLE AR    [ ] Before 3pole AR
     ONLY BEFORE DAR    [ ] Only before DAR
     BEFORE 2nd DAR     [ ] Before second DAR
     NEVER              [ ] Never

3424 RAR T-ACT.             Rapid auto-reclose action time
     min. 0.01              s
     max. 320.00/∞     ____

3425 RAR T-3POL             RAR 3pole dead time
     min. 0.01              s
     max. 320.00       ____

3442 DAR PROG.              Delayed auto-reclose program
     NO DAR             [ ] No DAR
     DAR WITHOUT RAR    [ ] DAR without RAR
     DAR AFTER RAR      [ ] DAR only after RAR

3444 DAR No.3PH             Number of DAR shots after 3 pole initiation
     min. 0
     max. 9            ____

3445 DAR T-ACT.             Delayed auto-reclose action time
     min. 0.01              s
     max. 320.00/∞     ____

3446 DAR T3POL1             DAR 3pole dead time for 1st shot
     min. 0.01              s
     max. 1800.00      ____

3447 DAR T3POL2             DAR 3pole dead time for 2nd shot
     min. 0.01              s
     max. 1800.00      ____

3448 DAR T3POL3             DAR 3pole dead time for 3rd and further shots
     min. 0.01              s
     max. 1800.00      ____
```

```
3800 FAULT LOCATION

3802 START                  Start condition for fault locator
     DROP-OFF or TRIP   [ ] Drop-off or trip
     TRIP COMMAND       [ ] Trip command
```

Tests and Commissioning Aids 7SA510

4000 TESTS

4200 DIRECTION/ IMPEDANCES	
4201 DIREC. TEST	Direction test L1-E
4202 IMPEDANCES	Impedance test L1-E
4203 DIREC. TEST	Direction test L2-E
4204 IMPEDANCES	Impedance test L2-E
4205 DIREC. TEST	Direction test L3-E
4206 IMPEDANCES	Impedance test L3-E
4207 DIREC. TEST	Direction test L1-L2
4208 IMPEDANCES	Impedance test L1-L2
4209 DIREC. TEST	Direction test L2-L3
4210 IMPEDANCES	Impedance test L2-L3
4211 DIREC. TEST	Direction test L3-L1
4212 IMPEDANCES	Impedance test L3-L1
4300 CB TEST TRIP-CLOSE CYCLE	
4304 CB TEST	Circuit breaker test with AR 3pole
4400 CB TEST LIVE TRIP	
4404 CB TRIP	Circuit breaker trip test 3pole
4900 TEST FAULT RECORDING	
4901 FAULT REC.	Initiation of fault recording

Annunciations, Measured Values etc. 7SA510

5000 ANNUNCIATIONS

5100 OPERATIONAL ANNUNCIATIONS

5200 LAST FAULT

5300 2nd TO LAST FAULT

5400 3rd TO LAST FAULT

5500 ISOLATED EARTH FLT DATA

5600 CB OPERAT. STATISTICS

5602 AR 3pole=	No. of auto-reclose commands:3p RAR
5603 DAR 3pol=	No. of auto-reclose commands:3p DAR
5604 Trip No =	Number of trip commands issued
5607 ∑IL1/In=	Summated current tripped IL1/In
5608 ∑IL2/In=	Summated current tripped IL2/In
5609 ∑IL3/In=	Summated current tripped IL3/In

5700 OPERATIONAL MEASURED VALUES

5701 IL1 =	Current in phase IL1 =
5702 IL2 =	Current in phase IL2 =
5703 IL3 =	Current in phase IL3 =
5704 UL1E=	Voltage UL1E =
5705 UL2E=	Voltage UL2E =
5706 UL3E=	Voltage UL3E =
5707 UL12=	Voltage UL12 =
5708 UL23=	Voltage UL23 =
5709 UL31=	Voltage UL31 =
5710 Pa=	Active power Pa =
5711 Pr=	Reactive power Pr =
5712 f [%]=	Frequency f [%] =
5713 IL1[%] =	Current in phase IL1 [%] =
5714 IL2[%] =	Current in phase IL2 [%] =
5715 IL3[%] =	Current in phase IL3 [%] =
5716 UL1E[%]=	UL1E [%]=
5717 UL2E[%]=	UL2E [%]=
5718 UL3E[%]=	UL3E [%]=
5719 UL12[%]=	UL12 [%] =
5720 UL23[%]=	UL23 [%] =
5721 UL31[%]=	UL31 [%] =
5722 Pa[%]=	Active power Pa [%] =
5723 Pr[%]=	Reactive power Pr [%] =

```
5800 ISOL. E/F MEASURED VALUES

5801 Iea =                 Iea =
5802 Ier =                 Ier =
5803 Iea[mA]=              Iea [mA] =
5804 Ier[mA]=              Ier [mA] =
```

```
5900 OVERLOAD MEASURED VALUES

5901 Θ/ΘtripL1=            Temperature rise for phase L1
5902 Θ/ΘtripL2=            Temperature rise for phase L2
5903 Θ/ΘtripL3=            Temperature rise for phase L3
5904 Θ/Θtrip =             Temperat. rise for warning and trip
```

Reference Table for Configuration Parameters 7SA510

6000 MARSHALLING

6100 MARSHALLING BINARY INPUTS

6101 BINARY INPUT 1 Binary input 1

6102 BINARY INPUT 2 Binary input 2

6103 BINARY INPUT 3 Binary input 3

6104 BINARY INPUT 4 Binary input 4

6200 MARSHALLING SIGNAL RELAYS

6201 SIGNAL RELAY 1 Signal relay 1

6202 SIGNAL RELAY 2 Signal relay 2

6203 SIGNAL RELAY 3 Signal relay 3

6204 SIGNAL RELAY 4 Signal relay 4

6205 SIGNAL RELAY 5 Signal relay 5

6300 MARSHALLING LED INDICATORS

6301 LED 1 LED 1

6302 LED 2 LED 2

6303 LED 3 LED 3

6304 LED 4 LED 4

6305 LED 5 LED 5

______ ______ ______

______ ______ ______

______ ______ ______

6306 LED 6 LED 6

______ ______ ______

______ ______ ______

______ ______ ______

6400 MARSHALLING TRIP RELAYS

6401 TRIP RELAY 1 Trip relay 1

______ ______ ______

______ ______ ______

______ ______ ______

6402 TRIP RELAY 2 Trip relay 2

______ ______ ______

______ ______ ______

______ ______ ______

7000 OP. SYSTEM CONFIGURATION

7100 INTEGRATED OPERATION

7102 DATE FORMAT Date format
DD.MM.YYYY [ ] dd.mm.yyyy
MM/DD/YYYY [ ] mm/dd/yyyy

7105 OPER. 1st L Operational message for 1st display line

______ ______

7106 OPER. 2nd L Operational message for 2nd display line

______ ______

7107 FAULT 1st L Fault message for 1st display line

______ ______

```
7108 FAULT 2nd L            Fault message for 2nd display line
     _________________      _______________________________________

7110 FAULT INDIC            Fault indication: LED and LCD
     WITH FAULT DETEC [ ] With fault detection
     WITH TRIP COMM.  [ ] With trip command
```

```
7200 PC/SYSTEM INTERFACES

7201 DEVICE ADD.            Device address
     min. 1
     max. 254         ____

7202 FEEDER ADD.            Feeder address
     min. 1
     max. 254         ____

7203 SUBST. ADD.            Substation address
     min. 1
     max. 254         ____

7208 FUNCT. TYPE            Function type in accordance with VDEW/ZVEI
     min. 1
     max. 254         ____

7211 PC INTERF.             Data format for PC-interface
     DIGSI V3         [ ] DIGSI V3
     ASCII            [ ] ASCII

7214 PC GAPS                Transmission gaps for PC-interface
     min. 0.0               s
     max. 5.0         ____

7215 PC BAUDRATE            Transmission baud rate for PC-interface
     9600 BAUD        [ ] 9600 Baud
     19200 BAUD       [ ] 19200 Baud
     1200 BAUD        [ ] 1200 Baud
     2400 BAUD        [ ] 2400 Baud
     4800 BAUD        [ ] 4800 Baud

7216 PC PARITY              Parity and stop-bits for PC-interface
     DIGSI V3         [ ] DIGSI V3
     NO 2 STOP        [ ] No parity,2 stopbits
     NO 1 STOP        [ ] No parity,1 stopbit

7221 SYS INTERF.            Data format for system-interface
     VDEW COMPATIBLE  [ ] VDEW compatible
     VDEW EXTENDED    [ ] VDEW extended
     DIGSI V3         [ ] DIGSI V3

7222 SYS MEASUR.            Measurement format for system-interface
     VDEW COMPATIBLE  [ ] VDEW compatible
     VDEW EXTENDED    [ ] VDEW extended

7224 SYS GAPS               Transmission gaps for system-interface
     min. 0.0               s
     max. 5.0         ____
```

```
7225 SYS BAUDR.              Transmission baud rate for system-interface
     9600 BAUD          [ ] 9600 Baud
     19200 BAUD         [ ] 19200 Baud
     1200 BAUD          [ ] 1200 Baud
     2400 BAUD          [ ] 2400 Baud
     4800 BAUD          [ ] 4800 Baud

7226 SYS PARITY              Parity and stop-bits for system-interface
     VDEW/DIGSIV3/LSA   [ ] VDEW/DIGSI V3/LSA
     NO 2 STOP          [ ] No parity,2 stopbits
     NO 1 STOP          [ ] No parity,1 stopbit

7227 SYS-SWITCH              Online-switch VDEW-DIGSI enabled
     NO                 [ ] no
     YES                [ ] yes

7235 SYS PARAMET             Parameterizing via system-interface
     NO                 [ ] no
     YES                [ ] yes
```

```
7400 FAULT RECORDINGS

7402 INITIATION              Initiation of data storage
     STORAGE BY FD.     [ ] Storage by fault det
     STORAGE BY TRIP    [ ] Storage by trip
     START WITH TRIP    [ ] Start with trip

7403 SCOPE                   Scope of stored data
     FAULT EVENT        [ ] Fault event
     FAULT IN POW.SYS   [ ] Fault in power syst.

7410 T-MAX                   Maximum time period of a fault recording
     min. 0.30               s
     max. 5.00         _____

7411 T-PRE                   Pre-trigger time for fault recording
     min. 0.05               s
     max. 0.50         _____

7412 T-POST                  Post-fault time for fault recording
     min. 0.05               s
     max. 0.50         _____

7431 T-BINARY IN             Storage time by initiation via binary input
     min. 0.10               s
     max. 5.00/∞       _____

7432 T-KEYBOARD              Storage time by initiation via keyboard
     min. 0.10               s
     max. 5.00         _____
```

```
7800 SCOPE OF FUNCTIONS

7812 DIST. PROT.             Distance protection
     EXIST              [ ] Existent
     NON-EXIST          [ ] Non-existent
```

```
7813 DIST.F.DET.              Distance protection: Fault detection program
     OVERCURRENT          [ ] Overcurrent FD.
     IMPEDANCE ZONE       [ ] Impedance zone FD.
     U/I FAULT DET.       [ ] U/I fault detection

7820 POWER SWING              Power swing detection
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7821 TELEPROTEC.              Teleprotection for distance protection
     NON-EXIST            [ ] Non-existent
     UNDERREACH           [ ] Underreach
     OVERREACH            [ ] Overreach

7823 USER LOGIC               User definable logic functions
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7826 EMERG. O/C               Emergency overcurrent time protection
     EXIST                [ ] Existent
     NON-EXIST            [ ] Non-existent

7827 THERMAL OL               Thermal overload protection
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7830 ISOL. E/F                Earth fault detection for isol./comp. networks
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7831 EARTH FAULT              Earth fault protection for earthed networks
     NON-EXIST            [ ] Non-existent
     DIR/NON-DIR          [ ] Directional/non-dir.
     DIREC.COMPARISON     [ ] Direc. comparison
     INVERSE TIME         [ ] Inverse time

7834 INTERNAL AR              Internal auto-reclose function
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7838 FAULT LOCAT              Fault locator
     EXIST                [ ] Existent
     NON-EXIST            [ ] Non-existent

7885 PARAM. C/O               Parameter change-over
     NON-EXIST            [ ] Non-existent
     EXIST                [ ] Existent

7899 FREQUENCY                Rated system frequency
     fN 50 Hz             [ ] fN 50 Hz
     fN 60 Hz             [ ] fN 60 Hz
```

```
7900 DEVICE CONFIGURATION

7910 CB TEST BI               CB test via binary input program
     THREE-POLE TRIP      [ ] Three-pole trip
     TRIP-CLOSE 3POLE     [ ] Trip-close 3pole
```

```
7912 AR w/ DIST.              Auto-reclose with distance protection
     YES                  [ ] yes
     NO                   [ ] no

7921 AR w/o TELE              Auto-reclose when teleprotect. is not operativ
     YES                  [ ] yes
     NO                   [ ] no

7926 AR w/ EMERG              Auto-reclose with emergency overcurrent prot.
     YES                  [ ] yes
     NO                   [ ] no

7930 AR w/ IS.EF              Auto-reclose with E/F det. in isol./comp. net
     YES                  [ ] yes
     NO                   [ ] no

7931 AR w/ E/F                Auto-reclose with E/F protect. in earthed net
     YES                  [ ] yes
     NO                   [ ] no

7941 AR w/ EXT.               Auto-reclose with ext. trip via binary input
     YES                  [ ] yes
     NO                   [ ] no
```

Operational Device Control Facilities 7SA510

```
8000 DEVICE CONTROL
________________________________________________________________________

8100 SETTING REAL TIME CLOCK

8101 DATE / TIME           Actual date and time

8102 DATE                  Setting new date

8103 TIME                  Setting new time

8104 DIFF. TIME            Setting difference time
________________________________________________________________________

8200 RESET

8201 RESET                 Reset of LED memories

8202 RESET                 Reset of operational annunciation buffer

8203 RESET                 Reset of fault annunciation buffer

8204 RESET                 Reset of CB operation counters

8205 RESET                 Reset of the total of interrupted currents

8206 RESET                 Reset of earth fault report buffer
________________________________________________________________________

8300 SYS-VDEW ANNUNC.-MEAS.VAL

8301 SYS TEST              Testing via system-interface
     OFF               [ ] off
     ON                [ ] on

8302 SYS BLOCK             Blocking of monitoring direction via sys.-int.
     OFF               [ ] off
     ON                [ ] on
________________________________________________________________________

8500 PARAMETER CHANGE-OVER

8501 ACTIV PARAM           Actual active parameter set

8503 ACTIVATING            Activation of parameter set
     SET A             [ ] Set a
     SET B             [ ] Set b
     SET C             [ ] Set c
     SET D             [ ] Set d
     SET BY BIN.INPUT  [ ] Set via binary input
     SET BY LSA CONTR  [ ] Set by lsa control

8510 COPY                  Copy original parameter set to set A

8511 COPY                  Copy original parameter set to set B
```

8512 COPY	Copy original parameter set to set C
8513 COPY	Copy original parameter set to set D
8514 COPY	Copy parameter set A to set B
8515 COPY	Copy parameter set A to set C
8516 COPY	Copy parameter set A to set D
8517 COPY	Copy parameter set B to set A
8518 COPY	Copy parameter set B to set C
8519 COPY	Copy parameter set B to set D
8520 COPY	Copy parameter set C to set A
8521 COPY	Copy parameter set C to set B
8522 COPY	Copy parameter set C to set D
8523 COPY	Copy parameter set D to set A
8524 COPY	Copy parameter set D to set B
8525 COPY	Copy parameter set D to set C

To

SIEMENS AKTIENGESELLSCHAFT

Dept. EV S SUP 2

D – 13623 BERLIN

Germany

Dear reader,

printing errors can never be entirely eliminated: therefore, should you come across any when reading this manual, kindly enter them in this form together with any comments or suggestions for improvement that you may have.

From

Name

Company/Dept.

Address

Telephone no.

Corrections/Suggestions

Substantial alterations against previous issue:

Complete revision with regard to firmware version V3.2

Subject to technical alteration

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