SIPROTEC Compact 7SJ80 Multifunction Protection Relay

Fig. 5/56
SIPROTEC Compact 7SJ80 multifunction protection relay

Description

The SIPROTEC Compact 7SJ80 relays can be used for line/feeder protection of high and medium-voltage networks with grounded, low-resistance grounded, isolated or a compensated neutral point. The relays have all the required functions to be applied as a backup relay to a transformer differential relay.

The 7SJ80 features "flexible protection functions". 20 additional protection functions can be created by the user. For example, a rate of change of frequency function or a reverse power function can be created.

The relay provides circuit-breaker control, additional primary switching devices (grounding switches, transfer switches and isolating switches) can also be controlled from the relay. Automation or PLC logic functionality is also implemented in the relay. The integrated programmable logic (CFC) allows the user to add own functions, e.g. for the automation of switchgear (including: interlocking, transfer and load shedding schemes). The user is also allowed to generate user-defined messages.

The communication module is independent from the protection. It can easily be exchanged or upgraded to future communication protocols.

Highlights

Removable current and voltage terminals provide the ideal solution for fast and secure replacement of relays.

Binary input thresholds and current taps are software settings. There is thus no need to ever open the relay to adapt the hardware configuration to a specific application.

The relay provides 9 programmable function keys that can be used to replace pushbuttons, select switches and control switches.

The battery for event and fault recording memory can be exchanged from the front of the relay.

The relay is available with IEC 61850 for incredible cost savings in applications (e.g. transfer schemes with synch-check, bus interlocking and load shedding schemes).

This compact relay provides protection, control, metering and PLC logic functionality. Secure and easy to use one page matrix IO programming is now a standard feature.

The housing creates a sealed dust proof environment for the relay internal electronics. Heat build up is dissipated through the surface area of the steel enclosure. No dusty or corrosive air can be circulated over the electronic components. The relay thus will maintain its tested insulation characteristic standards per IEC, IEEE, even if deployed in harsh environment.

Function overview

Protection functions

- Time-overcurrent protection (50, 50N, 51, 51N)
- Directional time-overcurrent protection (67, 67N)
- Sensitive dir./non-dir. ground-fault detection (67Ns, 50Ns)
- Displacement voltage (64)
- High-impedance restricted ground fault (87N)
- Inrush restraint
- Undercurrent monitoring (37)
- Overload protection (49)
- Under-/overvoltage protection (27/59)
- Under-/overfrequency protection (81O/U)
- Breaker failure protection (50BF)
- Phase unbalance or negative-sequence protection (46)
- Phase-sequence monitoring (47)
- Synch-check (25)
- Auto-reclosure (79)
- Fault locator (21FL)
- Lockout (86)

Control functions/programmable logic

- Commands for the ctrl. of CB, disconnect switches (isolators/isolating switches)
- Control through keyboard, binary inputs, DIGSI 4 or SCADA system
- User-defined PLC logic with CFC (e.g. interlocking)

Monitoring functions

- Operational measured values *V, I, f*
- Energy metering values W_p, W_q
- Circuit-breaker wear monitoring
- Minimum and maximum values
- Trip circuit supervision (74TC)
- Fuse failure monitor
- 8 oscillographic fault records

Communication interfaces

- System/service interface
  - IEC 61850
  - IEC 60870-5-103
  - PROFIBUS-DP
  - DNP 3.0
  - MODBUS RTU
- Ethernet interface for DIGSI 4
- USB front interface for DIGSI 4

Hardware

- 4 current transformers
- 0/3 voltage transformers
- 3/7 binary inputs (thresholds configurable using software)
- 5/8 binary outputs (2 changeover/ Form C contacts)
- 1 live-status contact
- Pluggable current and voltage terminals

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Application

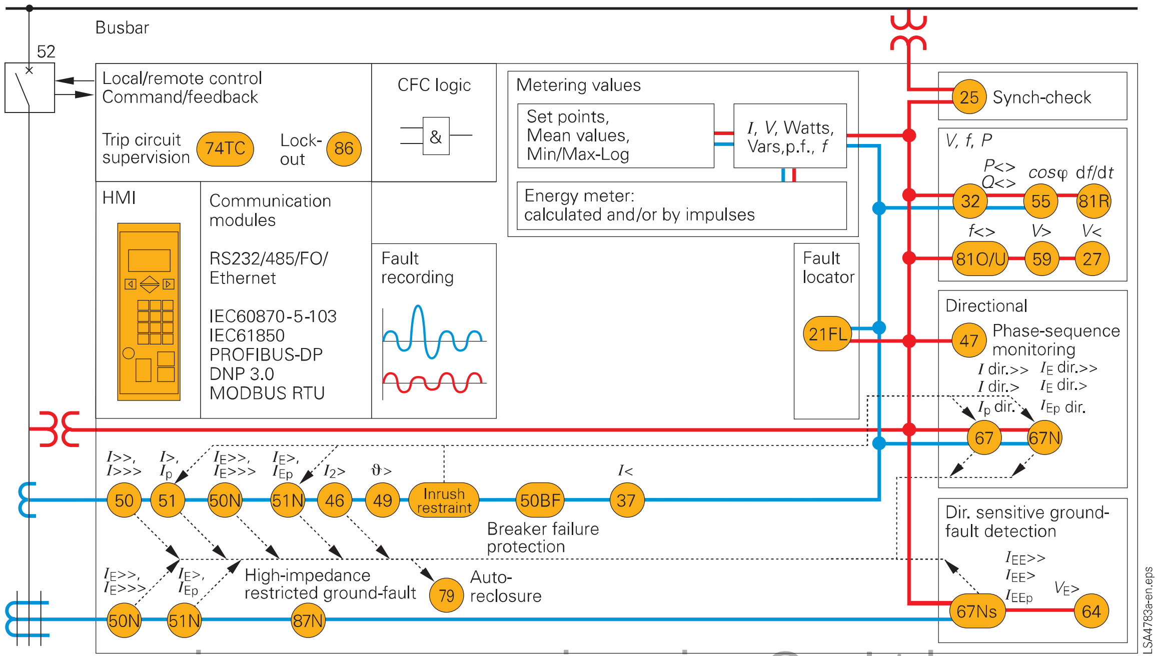


Fig. 5/57 Function diagram

The SIPROTEC Compact 7SJ80 unit is a numerical protection relay that can perform control and monitoring functions and therefore provide the user with a cost-effective platform for power system management, that ensures reliable supply of electrical power to the customers. The ergonomic design makes control easy from the relay front panel. A large, easy-to-read display was a key design factor.

Control

The integrated control function permits control of disconnect devices, grounding switches or circuit-breakers through the integrated operator panel, binary inputs, DIGSI 4 or the control or SCADA/automation system (e.g. SICAM, SIMATIC or other vendors automation system). A full range of command processing functions is provided.

Programmable logic

The integrated logic characteristics (CFC) allow the user to add own functions for automation of switchgear (e.g. interlocking) or switching sequence. The user can also generate user-defined messages. This functionality can form the base to create extremely flexible transfer schemes.

Line protection

The 7SJ80 units can be used for line protection of high and medium-voltage networks with grounded, low-resistance grounded, isolated or a compensated neutral point.

Transformer protection

The relay provides all the functions for backup protection for transformer differential protection. The inrush suppression effectively prevents unwanted trips that can be caused by inrush currents.

The high-impedance restricted ground-fault protection detects short-circuits and insulation faults on the transformer.

Backup protection

The 7SJ80 can be used as a stand alone feeder protection relay or as a backup to other protection relays in more complex applications.

Metering values

Extensive measured values (e.g. I, V), metered values (e.g. W_p, W_q) and limit values (e.g. for voltage, frequency) provide improved system management.

Reporting

The storage of event logs, trip logs, fault records and statistics documents are stored in the relay to provide the user or operator all the key data required to operate modern substations.

Switchgear cubicles for high/medium voltage

All units are designed specifically to meet the requirements of high/medium-voltage applications.

In general, no separate measuring instruments (e.g., for current, voltage, frequency, …) or additional control components are necessary.

Typically the relay provides all required measurements, thus negating the use of additional metering devices like amp, volt or frequency meters. No additional control switches are required either. The relay provides 9 function keys that can be configured to replace pushbuttons and select switches.

Application

ANSI No.	IEC	Protection functions
50, 50N	$I>$, $I>>$, $I>>>$, $I_E>$, $I_E>>$, $I_E>>>$	Instantaneous and definite time-overcurrent protection (phase/neutral)
51, 51N	I_p, I_{Ep}	Inverse time-overcurrent protection (phase/neutral)
67, 67N	$I_{dir}>$, $I_{dir}>>$, $I_{p\ dir}$ $I_{Edir}>$, $I_{Edir}>>$, $I_{Ep\ dir}$	Directional time-overcurrent protection (definite/inverse, phase/neutral), Directional comparison protection
67Ns/50Ns	$I_{EE}>$, $I_{EE}>>$, I_{EEp}	Directional/non-directional sensitive ground-fault detection
		Cold load pickup (dynamic setting change)
59N/64	V_E, $V_0>$	Displacement voltage, zero-sequence voltage
87N		High-impedance restricted ground-fault protection
50BF		Breaker failure protection
79		Auto-reclosure
25		Synch-check
46	$I_2>$	Phase-balance current protection (negative-sequence protection)
47	$V_2>$, phase-sequence	Unbalance-voltage protection and/or phase-sequence monitoring
49	$\vartheta>$	Thermal overload protection
37	$I<$	Undercurrent monitoring
27, 59	$V<$, $V>$	Undervoltage/overvoltage protection
32	$P<>$, $Q<>$	Forward-power, reverse-power protection
55	$\cos \varphi$	Power factor
81O/U	$f>$, $f<$	Overfrequency/underfrequency protection
81R	df/dt	Rate-of-frequency-change protection
21FL		Fault locator

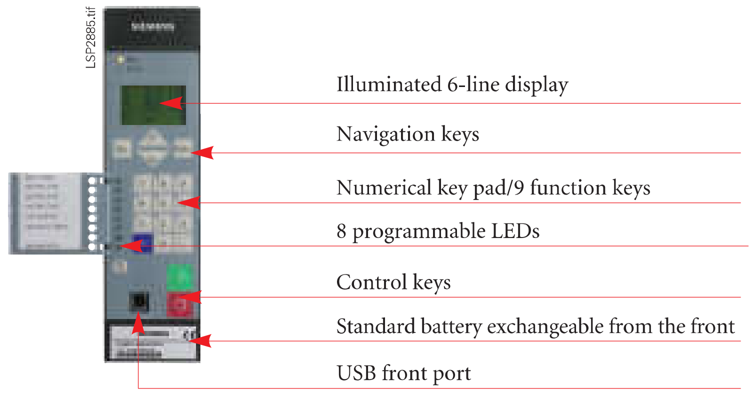
Construction and hardware

Connection techniques and housing with many advantages

The relay housing is 1/6 of a 19" rack. The housing is thus identical in size to the 7SJ50 and 7SJ60 relays that makes replacement very easy. The height is 244 mm (9.61").

Pluggable current and voltage terminals allow for pre-wiring and simplify the exchange of devices. CT shorting is done in the removable current terminal block. It is thus not possible to open-circuit a secondary current transformer.

All binary inputs are independent and the pick-up thresholds are settable using software settings (3 stages). The relay current transformer taps (1 A/5 A) are new software settings. Up to 9 function keys can be programmed for predefined menu entries, switching sequences, etc. The assigned function of the function keys can be shown in the display of the relay.



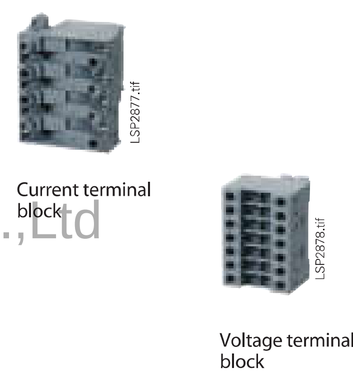


Fig. 5/58 7SJ80 Front view, rear view, terminals

Protection functions

Time-overcurrent protection (ANSI 50, 50N, 51, 51N)

This function is based on the phase-selective measurement of the three phase currents and the ground current (four transformers). Three definite-time overcurrent protection elements (DMT) are available both for the phase and the ground elements. The current threshold and the delay time can be set in a wide range. Inverse-time overcurrent protection characteristics (IDMTL) can also be selected and activated.

Reset characteristics

Time coordination with electromechanical relays are made easy with the inclusion of the reset characteristics according to ANSI C37.112 and IEC 60255-3 /BS 142 standards. When using the reset characteristic (disk emulation), the reset process is initiated after the fault current has disappeared. This reset process corresponds to the reverse movement of the Ferraris disk of an electromechanical relay (disk emulation).

Available inverse-time characteristics

Characteristics acc. to	ANSI/IEEE	IEC 60255-3
Inverse	•	•
Short inverse	•	
Long inverse	•	•
Moderately inverse	•	
Very inverse	•	•
Extremely inverse	•	•

Inrush restraint

The relay features second harmonic restraint. If second harmonic content is detected during the energization of a transformer, the pickup of non-directional and directional elements are blocked.

Cold load pickup/dynamic setting change

The pickup thresholds and the trip times of the directional and non-directional time-overcurrent protection functions can be changed via binary inputs or by setable time control.

Protection functions

Directional time-overcurrent protection (ANSI 67, 67N)

Directional phase and ground protection are separate functions. They operate in parallel to the non-directional overcurrent elements. Their pickup values and delay times can be set separately. Definite-time and inverse-time characteristics are offered. The tripping characteristic can be rotated by ± 180 degrees.

By making use of the voltage memory, the directionality can be determined reliably even for close-in (local) faults. If the primary switching device closes onto a fault and the voltage is too low to determine direction, the direction is determined using voltage from the memorized voltage. If no voltages are stored in the memory, tripping will be according to the set characteristic.

For ground protection, users can choose whether the direction is to be calculated using the zero-sequence or negative-sequence system quantities (selectable). If the zero-sequence voltage tends to be very low due to the zero-sequence impedance it will be better to use the negative-sequence quantities.

Directional comparison protection (cross-coupling)

It is used for selective instantaneous tripping of sections fed from two sources, i.e. without the disadvantage of time delays of the set characteristic. The directional comparison protection is suitable if the distances between the protection zones are not significant and pilot wires are available for signal transmission. In addition to the directional comparison protection, the directional coordinated time-overcurrent protection is used for complete selective backup protection.

(Sensitive) directional ground-fault detection (ANSI 64, 67Ns, 67N)

For isolated-neutral and compensated networks, the direction of power flow in the zero sequence is calculated from the zero-sequence current I_0 and zero-sequence voltage V_0.

For networks with an isolated neutral, the reactive current component is evaluated; for compensated networks, the active current component or residual resistive current is evaluated. For special network conditions, e.g. high-resistance grounded networks with ohmic-capacitive ground-fault current or low-resistance grounded networks with ohmic-inductive current, the tripping characteristics can be rotated approximately ± 45 degrees.

Two modes of ground-fault direction detection can be implemented: tripping or “signalling only mode”.

It has the following functions:

- TRIP via the displacement voltage V_E.
- Two instantaneous elements or one instantaneous plus one user-defined characteristic.
- Each element can be set to forward, reverse or non-directional.
- The function can also be operated in the insensitive mode as an additional short-circuit protection.

(Sensitive) ground-fault detection (ANSI 50Ns, 51Ns / 50N, 51N)

For high-resistance grounded networks, a sensitive input transformer is connected to a phase-balance neutral current transformer (also called core-balance CT).

The function can also be operated in the normal mode as an additional short-circuit protection for neutral or residual ground protection.

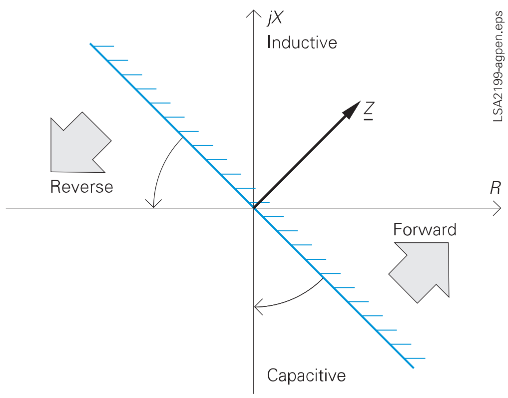


Fig. 5/59
Directional characteristic of the directional time-overcurrent protection

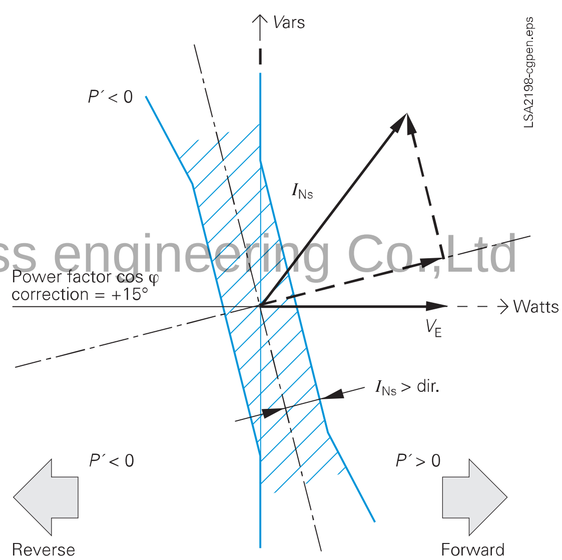


Fig. 5/60
Directional determination using cosine measurements for compensated networks

Protection functions

Phase-balance current protection (ANSI 46) (Negative-sequence protection)

By measuring current on the high side of the transformer, the two-element phase-balance current/negative-sequence protection detects high-resistance phase-to-phase faults and phase-to-ground faults on the low side of a transformer (e.g. Dy 5 or Delta/Star 150 deg.). This function provides backup protection for high-resistance faults through the transformer.

Breaker failure protection (ANSI 50BF)

If a faulted portion of the electrical circuit is not disconnected when a trip command is issued to a circuit-breaker, another trip command can be initiated using the breaker failure protection which trips the circuit-breaker of an upstream feeder. Breaker failure is detected if, after a trip command is issued and the current keeps on flowing into the faulted circuit. It is also possible to make use of the circuit-breaker position contacts (52a or 52b) for indication as opposed to the current flowing through the circuit-breaker.

High-impedance restricted ground-fault protection (ANSI 87N)

The high-impedance measurement principle is a simple and sensitive method to detect ground faults, especially on transformers. It can also be used on motors, generators and reactors when they are operated on a grounded network.

When applying the high-impedance measurement principle, all current transformers in the protected area are connected in parallel and operated through one common resistor of relatively high *R*. The voltage is measured across this resistor (see Fig. 5/61). The voltage is measured by detecting the current through the (external) resistor *R* at the sensitive current measurement input I_{EE}. The varistor *V* serves to limit the voltage in the event of an internal fault. It limits the high instantaneous voltage spikes that can occur at current transformer saturation. At the same time, this results to smooth the voltage without any noteworthy reduction of the average value. If no faults have occurred and in the event of external or through faults, the system is at equilibrium, and the voltage through the resistor is approximately zero. In the event of internal faults, an imbalance occurs which leads to a voltage and a current flowing through the resistor *R*.

The same type of current transformers must be used and must at least offer a separate core for the high-impedance restricted ground-fault protection. They must have the same transformation ratio and approximately an identical knee-point voltage. They should also have only minimal measuring errors.

Auto-reclosure (ANSI 79)

Multiple re-close cycles can be set by the user and lockout will occur if a fault is present after the last re-close cycle. The following functions are available:

- 3-pole ARC for all types of faults
- Separate settings for phase and ground faults
- Multiple ARC, one rapid auto-reclosure (RAR) and up to nine delayed auto-reclosures (DAR)
- Initiation of the ARC is dependant on the trip command selected (e.g. 46, 50, 51, 67)
- The ARC function can be blocked by activating a binary input
- The ARC can be initiated from external or by the PLC logic (CFC)
- The directional and non-directional elements can either be blocked or operated non-delayed depending on the auto-reclosure cycle
- If the ARC is not ready it is possible to perform a dynamic setting change of the directional and non-directional overcurrent elements

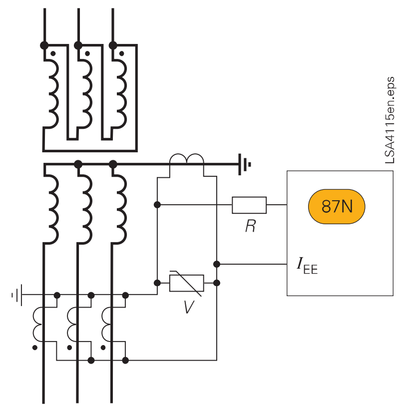


Fig. 5/61 High-impedance restricted ground-fault protection

Protection functions

Flexible protection functions

The 7SJ80 enables the user to easily add up to 20 additional protective functions. Parameter definitions are used to link standard protection logic with any chosen characteristic quantity (measured or calculated quantity) (Fig. 5/62). The standard logic consists of the usual protection elements such as the pickup set point, the set delay time, the TRIP command, a block function, etc. The mode of operation for current, voltage, power and power factor quantities can be three-phase or single-phase. Almost all quantities can be operated with ascending or descending pickup stages (e.g. under and over voltage). All stages operate with protection priority.

Protection functions/stages available are based on the available measured analog quantities:

Function	ANSI No.
$I>$, $I_E>$	50, 50N
$V<$, $V>$, $V_E>$	27, 59, 64
$3I_0>$, $I_1>$, $I_2>$, I_2/I_1 $3V_0>$, $V_1><$, $V_2><$	50N, 46 59N, 47
$P><$, $Q><$	32
$\cos\varphi$ (p.f.)><	55
$f><$	81O, 81U
$df/dt><$	81R

For example, the following can be implemented:

- Reverse power protection (ANSI 32R)
- Rate-of-frequency-change protection (ANSI 81R)

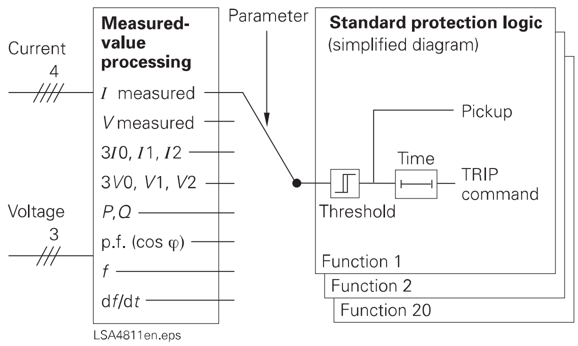


Fig. 5/62 Flexible protection functions

Synch-check (ANSI 25)

When closing a circuit-breaker, the units can check whether two separate networks are synchronized. Voltage-, frequency- and phase-angle-differences are checked to determine whether synchronous conditions exist.

Trip circuit supervision (ANSI 74TC)

One or two binary inputs can be used for monitoring the circuit-breaker trip coil including its incoming cables. An alarm signal is generated whenever the circuit is interrupted. The circuit breaker trip coil is monitored in the open and closed position. Interlocking features can be implemented to ensure that the beaker can only be closed if the trip coil is functional.

Lockout (ANSI 86)

All binary output statuses can be memorized. The LED reset key is used to reset the lockout state. The lockout state is also stored in the event of supply voltage failure. Reclosure can only occur after the lockout state is reset.

Thermal overload protection (ANSI 49)

To protect cables and transformers, an overload protection function with an integrated warning/alarm element for temperature and current can be used. The temperature is calculated using a thermal homogeneous body model (per IEC 60255-8), it considers the energy entering the equipment and the energy losses. The calculated temperature is constantly adjusted according to the calculated losses. The function considers loading history and fluctuations in load.

Settable dropout delay times

If the relays are used in conjunction with electromechanical relays, in networks with intermittent faults, the long dropout times of the electromechanical relay (several hundred milliseconds) can lead to problems in terms of time coordination/grading. Proper time coordination/grading is only possible if the dropout or reset time is approximately the same. This is why the parameter for dropout or reset times can be defined for certain functions such as time-overcurrent protection, ground short-circuit and phase-balance current protection.

Undercurrent monitoring (ANSI 37)

A sudden drop in current, which can occur due to a reduced load, is detected with this function. This may be due to shaft that breaks, no-load operation of pumps or fan failure.

Protection functions

Voltage protection

Overvoltage protection (ANSI 59)

The two-element overvoltage protection detects unwanted network and machine overvoltage conditions. The function can operate either with phase-to-phase, phase-to-ground, positive phase-sequence or negative phase-sequence voltage. Three-phase and single-phase connections are possible.

Undervoltage protection (ANSI 27)

The two-element undervoltage protection provides protection against dangerous voltage drops (especially for electric machines). Applications include the isolation of generators or motors from the network to avoid undesired operating conditions and a possible loss of stability. Proper operating conditions of electrical machines are best evaluated with the positive-sequence quantities. The protection function is active over a wide frequency range (45 to 55, 55 to 65 Hz). Even when falling below this frequency range the function continues to work, however, with decrease accuracy.

The function can operate either with phase-to-phase, phase-to-ground or positive phase-sequence voltage, and can be monitored with a current criterion. Three-phase and single-phase connections are possible.

Frequency protection (ANSI 81O/U)

Frequency protection can be used for overfrequency and underfrequency protection. Electric machines and parts of the system are protected from unwanted frequency deviations. Unwanted frequency changes in the network can be detected and the load can be removed at a specified frequency setting.

Frequency protection can be used over a wide frequency range (40 to 60 (for 50 Hz), 50 to 70 (for 60 Hz). There are four elements (individually set as overfrequency, underfrequency or OFF) and each element can be delayed separately. Blocking of the frequency protection can be performed by activating a binary input or by using an undervoltage element.

Fault locator (ANSI 21FL)

The integrated fault locator calculates the fault impedance and the distance to fault. The results are displayed in Ω, kilometers (miles) and in percent of the line length.

Customized functions (ANSI 51V, etc.)

Additional functions, which are not time critical, can be implemented using the CFC measured values. Typical functions include reverse power, voltage controlled overcurrent, phase angle detection, and zero-sequence voltage detection.

Control and automatic functions

Control

In addition to the protection functions, the SIPROTEC 4 and SIPROTEC Compact units also support all control and monitoring functions that are required for operating medium-voltage or high-voltage substations.

The main application is reliable control of switching and other processes.

The status of primary equipment or auxiliary devices can be obtained from auxiliary contacts and communicated to the 7SJ80 via binary inputs. Therefore it is possible to detect and indicate both the OPEN and CLOSED position or a fault or intermediate circuit-breaker or auxiliary contact position.

The switchgear or circuit-breaker can be controlled via:

– integrated operator panel
– binary inputs
– substation control and protection system
– DIGSI 4

Automation / user-defined logic

With integrated logic, the user can create, through a graphic interface (CFC), specific functions for the automation of switchgear or a substation. Functions are activated using function keys, a binary input or through the communication interface.

Switching authority

Switching authority is determined by set parameters or through communications to the relay. If a source is set to “LOCAL”, only local switching operations are possible. The following sequence for switching authority is available: “LOCAL”; DIGSI PC program, “REMOTE”.

There is thus no need to have a separate Local/Remote switch wired to the breaker coils and relay. The local/remote selection can be done using a function key on the front of the relay.

Command processing

This relay is designed to be easily integrated into a SCADA or control system. Security features are standard and all the functionality of command processing is offered. This includes the processing of single and double commands with or without feedback, sophisticated monitoring of the control hardware and software, checking of the external process, control actions using functions such as runtime monitoring and automatic command termination after output. Here are some typical applications:

- Single and double commands using 1, 1 plus 1 common or 2 trip contacts
- User-definable bay interlocks
- Operating sequences combining several switching operations such as control of circuit-breakers, disconnectors and grounding switches
- Triggering of switching operations, indications or alarm by combination with existing information

Assignment of feedback to command

The positions of the circuit-breaker or switching devices and transformer taps are acquired through feedback. These indication inputs are logically assigned to the corresponding command outputs. The unit can therefore distinguish whether the indication change is a result of switching operation or whether it is an undesired spontaneous change of state.

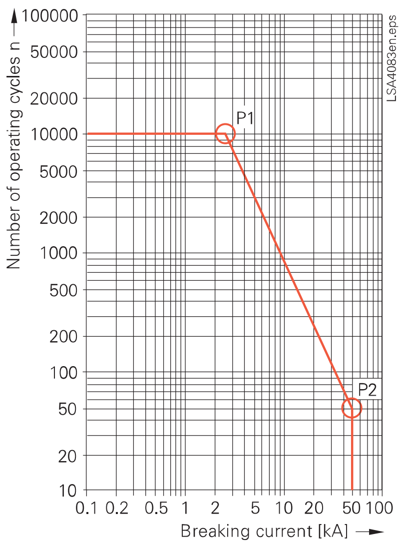


Fig. 5/63 CB switching cycle diagram

Chatter disable

The chatter disable feature evaluates whether, in a set period of time, the number of status changes of indication input exceeds a specified number. If exceeded, the indication input is blocked for a certain period, so that the event list will not record excessive operations.

Indication filtering and delay

Binary indications can be filtered or delayed.

Filtering serves to suppress brief changes in potential at the indication input. The indication is passed on only if the indication voltage is still present after a set period of time. In the event of an indication delay, there is a delay for a preset time. The information is passed on only if the indication voltage is still present after this time.

Indication derivation

User-definable indications can be derived from individual or a group of indications. These grouped indications are of great value to the user that need to minimize the number of indications sent to the system or SCADA interface.

Further functions

Measured values

The r.m.s. values are calculated from the acquired current and voltage along with the power factor, frequency, active and reactive power. The following functions are available for measured value processing:

- Currents I_{L1}, I_{L2}, I_{L3}, I_E, I_{EE} (67Ns)
- Voltages V_{L1}, V_{L2}, V_{L3}, V_{L1L2}, V_{L2L3}, V_{L3L1}
- Symmetrical components I_1, I_2, $3I_0$; V_1, V_2, V_0
- Power Watts, Vars, VA/P, Q, S (P, Q: total and phase selective)
- Power factor (cos φ), (total and phase selective)
- Frequency
- Energy ± kWh, ± kVarh, forward and reverse power flow
- Mean as well as minimum and maximum current and voltage values
- Operating hours counter
- Mean operating temperature of the overload function
- Limit value monitoring
  Limit values can be monitored using programmable logic in the CFC. Commands can be derived from this limit value indication.
- Zero suppression
  In a certain range of very low measured values, the value is set to zero to suppress interference.

Metered values

For internal metering, the unit can calculate an energy metered value from the measured current and voltage values. If an external meter with a metering pulse output is available, the 7SJ80 can obtain and process metering pulses through an indication input.

The metered values can be displayed and passed on to a control center as an accumulated value with reset. A distinction is made between forward, reverse, active and reactive energy.

Circuit-breaker wear monitoring

Methods for determining circuit-breaker contact wear or the remaining service life of a circuit-breaker (CB) allow CB maintenance intervals to be aligned to their actual degree of wear. The benefit lies in reduced maintenance costs.

There is no exact mathematical method to calculate the wear or the remaining service life of a circuit-breaker that takes arc-chamber's physical conditions into account when the CB opens. This is why various methods of determining CB wear have evolved which reflect the different operator philosophies. To do justice to these, the relay offers several methods:

- ΣI
- ΣI^x, with x = 1... 3
- Σi^2t

The devices also offer a new method for determining the remaining service life:

- Two-point method

The CB manufacturers double-logarithmic switching cycle diagram (see Fig. 5/63) and the breaking current at the time of contact opening serve as the basis for this method. After CB opening, the two-point method calculates the remaining number of possible switching cycles. Two points P1 and P2 only have to be set on the device. These are specified in the CB's technical data.

All of these methods are phase-selective and a limit value can be set in order to obtain an alarm if the actual value falls below or exceeds the limit value during determination of the remaining service life.

Commissioning

Commissioning could not be easier and is supported by DIGSI 4. The status of the binary inputs can be read individually and the state of the binary outputs can be set individually. The operation of switching elements (circuit-breakers, disconnect devices) can be checked using the switching functions of the relay. The analog measured values are represented as wide-ranging operational measured values. To prevent transmission of information to the control center during maintenance, the communications can be disabled to prevent unnecessary data from being transmitted. During commissioning, all indications with test tag for test purposes can be connected to a control and protection system.

Test operation

During commissioning, all indications can be passed to a control system for test purposes.

Communication

The relay offers flexibility with reference to its communication to substation automation systems and industrial SCADA or DCS systems. The communication module firmware can be changed to communicate using another protocol or the modules can be changed completely for a different connection or protocol. It will thus be possible to move to future communication protocols like popular Ethernet-based protocols with ease.

USB interface

There is an USB interface on the front of the relay. All the relay functions can be set using a PC and DIGSI 4 protection operation program. Commissioning tools and fault analysis are built into the DIGSI program and are used through this interface.

Interfaces

A number of communication modules suitable for various applications can be fitted at the bottom of the housing. The modules can be easily replaced by the user. The interface modules support the following applications:

- System/service interface
  Communication with a central control system takes place through this interface. Radial or ring type station bus topologies can be configured depending on the chosen interface. Furthermore, the units can exchange data through this interface via Ethernet and the IEC 61850 protocol and can also be accessed using DIGSI.
- Ethernet interface
  The Ethernet interface was implemented for access to a number of protection units using DIGSI.

System interface protocols (retrofittable)

IEC 61850 protocol

Since 2004, the Ethernet-based IEC 61850 protocol is a global standard for protection and control systems used by power utilities. Siemens was the first manufacturer to implement this standard. This protocol makes peer-to-peer communication possible. It is thus possible to set up masterless systems to perform interlocking or transfer schemes. Configuration is done using DIGSI.

IEC 60870-5-103 protocol

The IEC 60870-5-103 protocol is an international standard for the transmission of protective data and fault recordings. All messages from the unit and also control commands can be transferred by means of published, Siemens-specific extensions to the protocol. As a further option a redundant IEC 60870-5-103 module is available as well. With the redundant module it will be possible to read and change single parameters.

PROFIBUS-DP protocol

PROFIBUS-DP is a widespread protocol in industrial automation. Through PROFIBUS-DP, SIPROTEC units make their information available to a SIMATIC controller or receive commands from a central SIMATIC controller or PLC. Measured values can also be transferred to a PLC master.

MODBUS RTU protocol

This simple, serial protocol is mainly used in industry and by power utilities, and is supported by a number of relay manufacturers. SIPROTEC units function as MODBUS slaves, making their information available to a master or receiving information from it. A time-stamped event list is available.

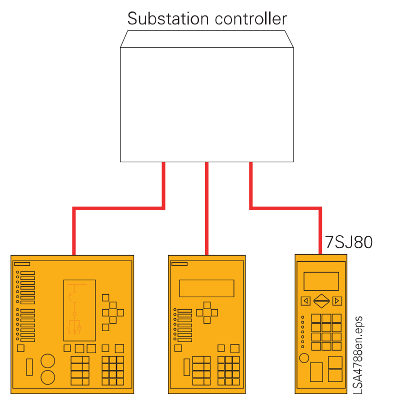


Fig. 5/64
IEC 60870-5-103: Radial fiber-optic connection

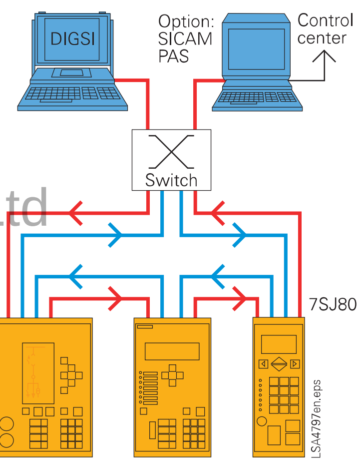


Fig. 5/65
Bus structure for station bus with Ethernet and IEC 61850, fiber-optic ring

Communication

DNP 3.0 protocol

Power utilities use the serial DNP 3.0 (Distributed Network Protocol) for the station and network control levels. SIPROTEC units function as DNP slaves, supplying their information to a master system or receiving information from it.

System solutions for protection and station control

Units featuring IEC 60870-5-103 interfaces can be connected to SICAM in parallel via the RS485 bus or radially by fiber-optic link. Through this interface, the system is open for the connection to other manufacturers systems (see Fig. 5/64).

Because of the standardized interfaces, SIPROTEC units can also be integrated into systems of other manufacturers or in SIMATIC. Electrical RS485 or optical interfaces are available. The best physical data transfer medium can be chosen thanks to opto-electrical converters. Thus, the RS485 bus allows low-cost wiring in the cubicles and an interference-free optical connection to the master can be established.

For IEC 61850, an interoperable system solution is offered with SICAM. Through the 100 Mbits/s Ethernet bus, the units are linked with SICAM electrically or optically to the station PC. The interface is standardized, thus also enabling direct connection to relays of other manufacturers and into the Ethernet bus. With IEC 61850, however, the relays can also be used in other manufacturers' systems (see Fig. 5/65).

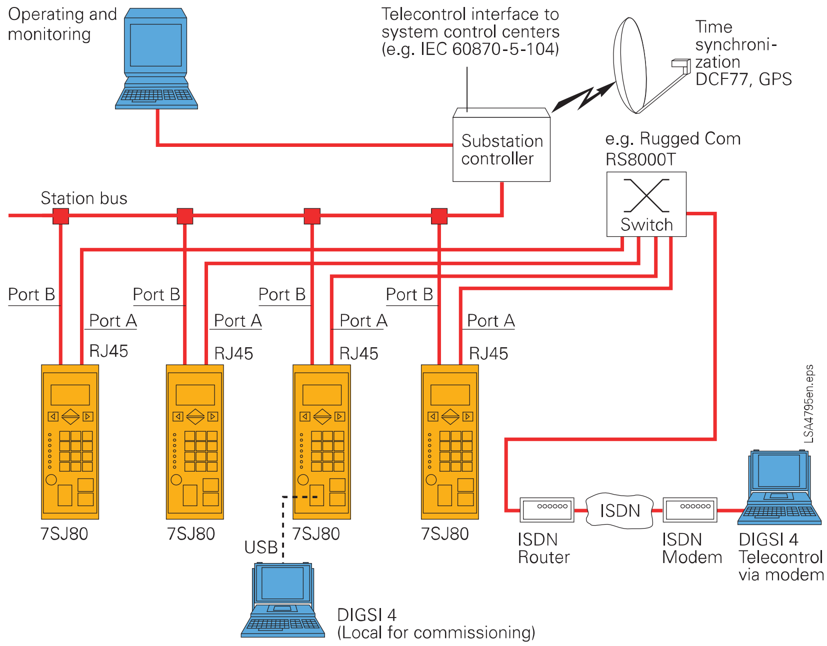


Fig. 5/66
System solution/communication

Fig. 5/67
Optical Ethernet communication module for IEC 61850 with integrated Ethernet-switch

5

Typical connections

Connection of current and voltage transformers

Standard connection

For grounded networks, the ground current is obtained from the phase currents by the residual current circuit.

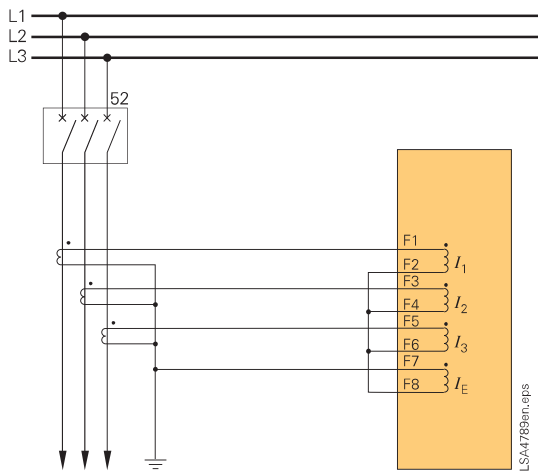


Fig. 5/68
Residual current circuit without directional element

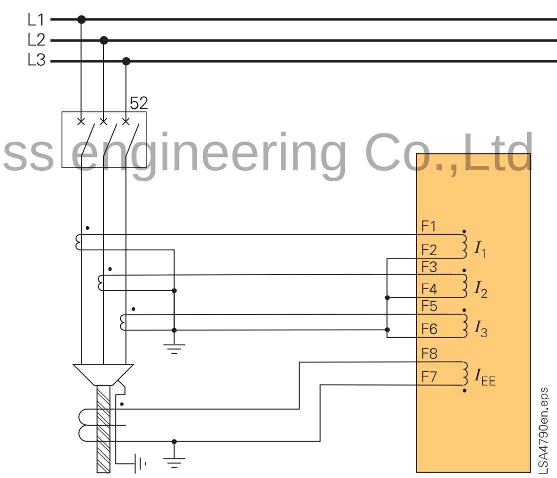


Fig. 5/69
Sensitive ground-current detection without directional element

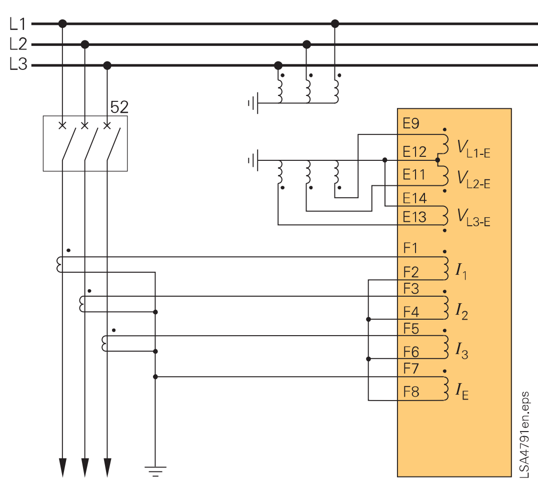


Fig. 5/70
Residual current circuit with directional element

5

Typical connections

Connection for compensated networks

The figure shows the connection of two phase-to-ground voltages and the V_E voltage of the broken delta winding and a phase-balance neutral current transformer for the ground current. This connection maintains maximum precision for directional ground-fault detection and must be used in compensated networks.

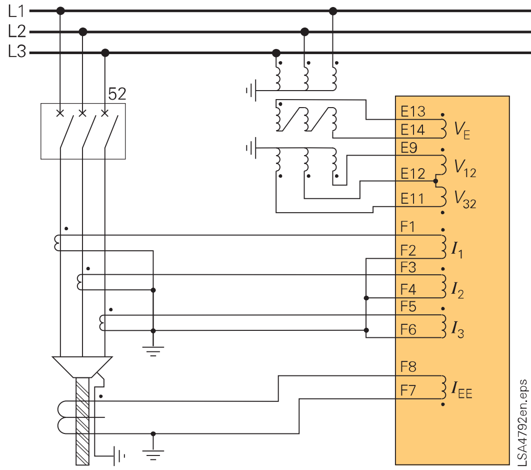


Fig. 5/71
Sensitive directional ground-fault detection with directional element for phases

Fig. 5/72 shows sensitive directional ground-fault detection.

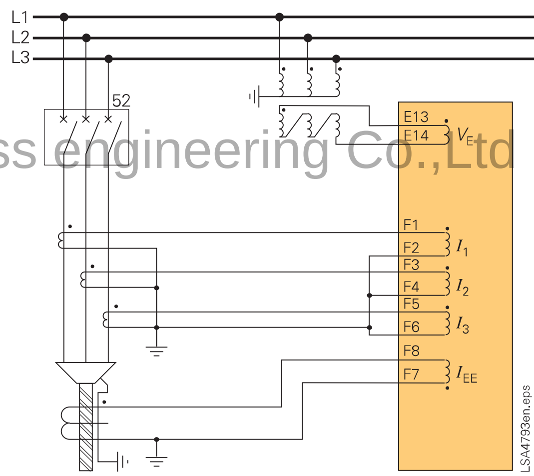


Fig. 5/72
Sensitive directional ground-fault detection

Connection for the synch-check function

Open delta voltages and residual I_N connection. Single-phase connection for synch-check.

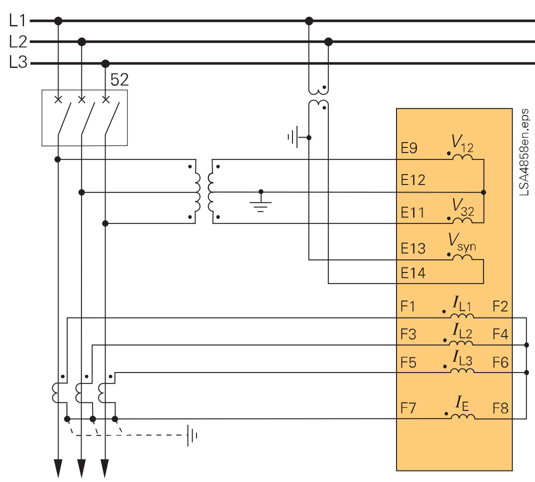


Fig. 5/73
Measuring of the busbar voltage and the outgoing feeder voltage for synchronization

Typical applications

Overview of connection types

Type of network	Function	Current connection	Voltage connection
(Low-resistance) grounded network	Time-overcurrent protection phase/ground non-directional	Residual circuit, with 3 phase-current transformers required, phase-balance neutral current transformer possible	–
(Low-resistance) grounded networks	Sensitive ground-fault protection	Phase-balance neutral current transformers required	–
Isolated or compensated networks	Time-overcurrent protection phases non-directional	Residual circuit, with 3 or 2 phase current transformers possible	–
(Low-resistance) grounded networks	Time-overcurrent protection phases directional	Residual circuit, with 3 phase-current transformers possible	Phase-to-ground connection or phase-to-phase connection
Isolated or compensated networks	Time-overcurrent protection phases directional	Residual circuit, with 3 or 2 phase-current transformers possible	Phase-to-ground connection or phase-to-phase connection
(Low-resistance) grounded networks	Time-overcurrent protection ground directional	Residual circuit, with 3 phase-current transformers required, phase-balance neutral current transformers possible	Phase-to-ground connection required
Isolated networks	Sensitive ground-fault protection	Residual circuit, if ground current > 0.05 I_N on secondary side, otherwise phase-balance neutral current transformers required	3 times phase-to-ground connection or phase-to-ground connection with broken delta winding
Compensated networks	Sensitive ground-fault protection cos φ measurement	Phase-balance neutral current transformers required	3 times phase-to-ground connection or phase-to-ground connection with broken delta winding

Technical data

General unit data

Analog current inputs

Rated frequency f_N	50 or 60 Hz (adjustable)
Rated current I_{nom}	1 or 5 A
Ground current, sensitive I_{Ns}	$\leq 1.6 \cdot I_{nom}$ linear range[1)]
Burden per phase and ground path at I_{nom} = 1 A at I_{nom} = 5 A for sensitive ground fault detection at 1 A	 Approx. 0.05 VA Approx. 0.3 VA Approx. 0.05 VA
Load capacity current path Thermal (rms) Dynamic (peak value)	 500 A for 1 s 150 A for 10 s 20 A continuous 1250 A (half-cycle)
Loadability input for sensitive ground-fault detection I_{Ns} [1)] Thermal (rms) Dynamic (peak value)	 300 A for 1 s 100 A for 10 s 15 A continuous 750 A (half-cycle)

Analog voltage inputs

Rated voltage	34 – 220 V
Measuring range	0 to 200 V
Burden at 100 V	Approx. 0.005 VA
Overload capacity in voltage path Thermal (rms)	 230 V continuous

Auxiliary voltage

<u>DC voltage</u>

Voltage supply via an integrated converter

Rated auxiliary voltage V_{aux}	DC	24 to 48 V	60 to 250 V
Permissible voltage ranges	DC	19 to 60 V	48 to 300 V
AC ripple voltage, peak-to-peak, IEC 60255-11		≤ 15 % of the auxiliary voltage	
Power input Quiescent Energized		 Approx. 5 W Approx. 12 W	
Bridging time for failure/ short-circuit, IEC 60255-11 (in the quiescent state)		≥ 50 ms at $V \geq$ 110 V DC ≥ 10 ms at $V <$ 110 V DC	

<u>AC voltage</u>

Voltage supply via an integrated converter

Rated auxiliary voltage V_{aux}	AC	115 V	230 V
Permissible voltage ranges	AC	92 to 132 V	184 to 265 V
Power input (at 115 V AC/230 V AC) Quiescent Energized		 Approx. 5 VA Approx. 12 VA	
Bridging time for failure/short-circuit (in the quiescent state)		≥ 10 ms at V = 115/230 V AC	

1) Only in models with input for sensitive ground-fault detection (see ordering data)

Binary inputs

Type	7SJ801/803	7SJ802/804
Number (marshallable)	3	7
Rated voltage range	24 to 250 V DC	
Current input, energized (independent of the control voltage)	Approx. 0.4 mA	
Secured switching thresholds	(adjustable)	
for rated voltages 24 to 125 V DC	V high > 19 V DC V low < 10 V DC	
for rated voltages 110 to 250 V DC	V high > 88 V DC V low < 44 V DC	
for rated voltages 220 and 250 V DC	V high > 176 V DC V low < 88 V DC	
Maximum permissible voltage	300 V DC	
Input interference suppression	220 V DC across 220 nF at a recovery time between two switching operations ≥ 60 ms	

Output relay

Type	7SJ801/803	7SJ802/804
NO contact	3	6
NO/NC selectable	2 (+ 1 live contact not allocatable)	2 (+ 1 live contact not allocatable)
Switching capability MAKE	Max. 1000 W/VA	
Switching capability BREAK	40 W or 30 VA at $L/R \leq$ 40 ms	
Switching voltage	250 V DC/AC	
Admissible current per contact (continuous)	5 A	
Permissible current per contact (close and hold)	30 A for 1 s (NO contact)	

Electrical tests

Specification

Standards	IEC 60255 (product standard) ANSI/ IEEE C37.90 see individual functions VDE 0435 for more standards see also individual functions

Insulation tests

Standards	IEC 60255-27 and IEC 60870-2-1
High-voltage test (routine test) All circuits except power supply, binary inputs, communication interface	2.5 kV, 50 Hz
High-voltage test (routine test) Auxiliary voltage and binary inputs	3.5 kV DC
High-voltage test (routine test) Only isolated communication interfaces (A and B)	500 V, 50 Hz
Impulse voltage test (type test) All process circuits (except communication interfaces) against the internal electronics	6 kV (peak value); 1.2/50 µs; 0.5 J; 3 positive and 3 negative impulses at intervals of 1 s

Technical data

Insulation tests (cont'd)	
Impulse voltage test (type test) All process circuits (except communication interfaces) against each other and against the productive conductor terminal class III	5 kV (peak value); 1.2/50 µs; 0.5 J; 3 positive and 3 negative impulses at intervals of 1 s

EMC tests for immunity; *type tests*	
Standards	IEC 60255-6 and -22 (product standard) IEC/EN 61000-6-2 VDE 0435 For more standards see individual functions
1 MHz check, class III IEC 60255-22-1; IEC 61000-4-18; IEEE C37.90.1	2.5 kV (peak); 1 MHz; τ =15 µs; 400 surges per s; test duration 2 s; R_i = 200 Ω
Electrostatic discharge, class IV IEC 60255-22-2 and IEC 61000-4-2	8 kV contact discharge; 15 kV air discharge; both polarities; 150 pF; R_i = 330 Ω
Radio frequency electromagnetic field, amplitude-modulated, class III IEC 60255-22-3; or IEC 61000-4-3	10 V/m; 80 MHz to 2.7 GHz; 80 % AM; 1 kHz
Fast transient disturbance variables/ burst, class IV IEC 60255-22-4 and IEC 61000-4-4, IEEE C37.90.1	4 kV; 5/50 ns; 5 kHz; burst length = 15 ms; repetition rate 300 ms; both polarities; R_i = 50 Ω; test duration 1 min
High-energy surge voltages (SURGE), Installation class III IEC 60255-22-5; IEC 61000-4-5	Impulse: 1.2/50 µs
Auxiliary voltage	Common mode: 4 kV; 12 Ω; 9 µF Diff. mode: 1 kV; 2 Ω; 18 µF
Measuring inputs, binary inputs and relay outputs	Common mode: 4 kV; 42 Ω; 0.5 µF Diff. mode: 1 kV; 42 Ω; 0.5 µF
HF on lines, amplitude-modulated, class III; IEC 60255-22-6; IEC 61000-4-6,	10 V; 150 kHz to 80 MHz; 80 % AM; 1 kHz
Power system frequency magnetic field IEC 61000-4-8, class IV	30 A/m continuous; 300 A/m for 3 s
Radiated electromagnetic interference ANSI/IEEE C37.90.2	20 V/m; 80 MHz to 1 GHz; 80 % AM; 1 kHz
Damped oscillations IEC 61000-4-18	2.5 (peak value) 100 kHz; 40 pulses per s; test duration 2 s; R_i = 200 Ω

EMC tests for noise emission; *type tests*	
Standard	IEC/EN 61000-6-4
Radio noise voltage to lines, only auxiliary voltage IEC/CISPR 11	150 kHz to 30 MHz, limit class A
Interference field strength IEC/CISPR 11	30 to 1000 MHz, limit class A

Mechanical stress tests

Vibration, shock stress and seismic vibration

During stationary operation	
Standards	IEC 60255-21 and IEC 60068
Oscillation IEC 60255-21-1, class II; IEC 60068-2-6	Sinusoidal 10 to 60 Hz: ± 0.075 mm amplitude; 60 to 150 Hz: 1 *g* acceleration Frequency sweep rate 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, class I; IEC 60068-2-27	Semi-sinusoidal 5 *g* acceleration, duration 11 ms; each 3 shocks (in both directions of 3 axes)
Seismic vibration IEC 60255-21-3, class II; IEC 60068-3-3	Sinusoidal 1 to 8 Hz: ± 7.5 mm amplitude (horizontal axis) 1 to 8 Hz: ± 3.5 mm amplitude (vertical axis) 8 to 35 Hz: 2 *g* acceleration (horizontal axis) 8 to 35 Hz: 1 *g* acceleration (vertical axis) Frequency sweep 1 octave/min 1 cycle in 3 orthogonal axes
During transportation	
Standards	IEC 60255-21 and IEC 60068
Vibration IEC 60255-21-1, class I; IEC 60068-2-6	Sinusoidal 5 to 7 Hz: ± 5 mm amplitude 7 to 150 Hz; 1 *g* acceleration Frequency sweep 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, class I; IEC 60068-2-27	Semi-sinusoidal 15 *g* acceleration, duration 11 ms, each 3 shocks (in both directions of the 3 axes)
Continuous shock IEC 60255-21-2, class I; IEC 60068-2-29	Semi-sinusoidal 10 *g* acceleration, duration 16 ms, each 1000 shocks (in both directions of the 3 axes)

Climatic stress tests

Temperatures	
Standards	IEC 60255-6
Type test (in acc. with IEC 60068-2-1 and -2, Test Bd for 16 h)	–25 °C to +85 °C or –13 °F to +185 °F
Permissible temporary operating temperature (tested for 96 h)	–20 °C to +70 °C or –4 °F to +158 °F (clearness of the display may be impaired from +55 °C or +131 °F)
Recommended for permanent operation (in acc. with IEC 60255-6)	–5 °C to +55 °C or +23 °F to +131 °F
Limit temperatures for storage	–25 °C to +55 °C or –13 °F to +131 °F
Limit temperatures for transport	–25 °C to +70 °C or –13 °F to +158 °F
Storage and transport with factory packaging	
Humidity	
Permissible humidity	Mean value per year ≤ 75 % relative humidity; on 56 days of the year up to 93 % relative humidity; condensation must be avoided!

It is recommended that all devices be installed such that they are not exposed to direct sunlight, nor subject to large fluctuations in temperature that may cause condensation to occur.

Unit design		
Type	7SJ80**-*B	7SJ80**-*/E
Housing	7XP20	
Dimensions	See dimension drawings	
Housing width	1/6	1/6
Weight in kg		
Surface-mounting	4.5 kg (9.9 lb)	
Flush-mounting	4 kg (8.8 lb)	

Technical data

Unit design *(cont'd)*	
Degree of protection acc. to EN 60529	
For equipment in the surface-mounting housing	IP 50
For equipment in the flush-mounting housing	Front IP 51 Back IP 50
For operator protection	IP 2x for current terminal IP 1x for voltage terminal
Degree of pollution, IEC 60255-27	2

Communication interfaces	
Operating interface *(front of unit)*	
Terminal	USB, type B
Transmission speed	Up to 12 Mbit/s
Bridgeable distance	5 m
Ethernet service interface (Port A)	
Ethernet electrical for DIGSI	
Operation	With DIGSI
Terminal	At the bottom part of the housing, mounting location "A", RJ45 socket, 100BaseT in acc. with IEEE 802.3 LED yellow: 10/100 Mbit/s (ON/OFF) LED green: connection/no connection (ON/OFF)
Test voltage	500 V/50 Hz
Transmission speed	10/100 Mbit/s
Bridgeable distance	20 m (66 ft)
Service interface for DIGSI 4/modem (Port B)	
Isolated RS 232/RS 485	
Terminal	At the bottom part of the housing, 9-pin subminiature connector (SUB-D)
Test voltage	500 V/50 Hz
Transmission rate	Min. 1200 Bd, max. 115200 Bd
Bridgeable distance RS232	Max. 15 m/49.2 ft
Bridgeable distance RS485	Max. 1 km/3300 ft
Fiber optic (FO)	
Terminal	At the bottom part of the housing, ST connector
Optical wavelength	λ = 820 nm
Permissible path attenuation	Max. 8 dB, for glass fiber 62.5/125 µm
Bridgeable distance	Max. 1.5 km/0.9 miles
System interface (Port B)	
IEC 60870-5-103 protocol, single	
RS 232/RS 485	
Terminal	At the bottom part of the housing, mounting location "B", 9-pin subminiature connector (SUB-D)
Test voltage	500 V/50 Hz
Transmission rate	Min. 1200 Bd, max. 115000 Bd, factory setting 9600 Bd
Bridgeable distance RS232	15 m/49.2 ft
Bridgeable distance RS485	1 km/3300 ft

System interface	
IEC 60870-5-103 protocol, single *(continued)*	
Fiber optic	
Connection fiber-optic cable	ST connector
Terminal	At the bottom part of the housing, mounting location "B"
Optical wavelength	λ = 820 nm
Permissible path attenuation	Max. 8 dB, for glass fiber 62.5/125 µm
Bridgeable distance	Max. 1.5 km/0.9 miles
IEC 60870-5-103 protocol, redundant	
RS485, isolated	
Terminal	At the bottom part of the housing, mounting location "B", RJ45 socket
Test voltage	500 V/50 Hz
Transmission rate	Min. 2400 Bd, max. 57600 Bd; factory setting 19200 Bd
Bridgeable distance RS485	Max. 1 km/3300 ft
IEC 61850 protocol	
Ethernet, electrical (EN100) for IEC 61850 and DIGSI	
Terminal	At the bottom part of the housing, mounting location "B", two RJ45 connectors, 100BaseT in acc. with IEEE 802.3
Test voltage	500 V/50 Hz
Transmission rate	100 Mbit/s
Bridgeable distance	Max. 20 m/65.6 ft
Ethernet, optical (EN100) for IEC 61850 and DIGSI	
Terminal	At the bottom part of the housing, mounting location "B", ST connector, 100BaseT in acc. with IEEE 802.3
Transmission rate	100 Mbit/s
Optical wavelength	λ = 1300 nm
Bridgeable distance	max. 2 km/1.24 miles
PROFIBUS DP	
RS485, isolated	
Terminal	At the bottom part of the housing, mounting location "B", 9-pin subminiature connector (SUB-D)
Test voltage	500 V/50 Hz
Transmission rate	Up to 1.5 Mbaud
Bridgeable distance	1000 m/3300 ft ≤ 93.75 kbaud; 500 m/1640 ft ≤ 187.5 kbaud; 200 m/656 ft ≤ 1.5 Mbaud
Fiber optic	
Connection fiber-optic cable	ST connector, double ring
Terminal	At the bottom part of the housing, mounting location "B"
Optical wavelength	λ = 820 nm
Permissible path attenuation	Max. 8 dB, for glass fiber 62.5/125 µm
Bridgeable distance	Max. 2 km/1.24 miles
MODBUS RTU, DNP 3.0	
RS485	
Terminal	At the bottom part of the housing, mounting location "B", 9-pin subminiature connector (SUB-D)
Test voltage	500 V/50 Hz

5

Technical data

System interface (cont'd)	
Transmission rate	Up to 19200 baud
Bridgeable distance	Max. 1 km/3300 ft
Fiber optic	
Connection fiber-optic cable	ST connector transmitter/receiver
Terminal	At the bottom part of the housing, mounting location "B"
Optical wavelength	λ = 820 nm
Permissible path attenuation	Max. 8 dB, for glass fiber 62.5/125 µm
Bridgeable distance	Max. 1.5 km/0.9 miles

Functions

Definite-time overcurrent protection, directional/non-directional (ANSI 50, 50N, 67, 67N)	
Operating modes	3-phase (standard) or 2-phase A (L1) and C (L3)
Number of elements (stages)	50-1, 50-2, 50-3 (I>, I>>, I>>>) (phases) 50N-1, 50N-2, 50N-3 (I_E>, I_E>>, I_E>>>) (ground)
Setup setting ranges	
Pickup current 50-1, 50-2, 50-3 (phases)	0.5 to 175 A or ∞[1] (in steps of 0.01 A)
Pickup current 50N-1, 50N-2, 50N-3 (ground)	0.25 to 175 A or ∞[1] (in steps of 0.01 A)
Delay times T	0 to 60 s or ∞ (in steps of 0.01 s)
Dropout delay time 50/50N $T_{DROPOUT (DO)}$	0 to 60 s (in steps of 0.01 s)
Times	
Pickup times (without inrush restraint, with inrush restraint + 10 ms)	
With twice the setting value With ten times the setting value	Approx. 30 ms Approx. 20 ms
Dropout time	Approx. 30 ms
Dropout ratio	Approx. 0.95 for $I/I_{nom} \geq 0.3$
Tolerances	
Pickup Delay times T, T_{DO}	3 % of setting value or 75 mA[1] 1 % or 10 ms

Inverse-time overcurrent protection, directional/non-directional (ANSI 51, 51N, 67, 67N)	
Operating mode	3-phase (standard) or 2-phase A (L1) and C (L3)
Setting ranges	Voltage-independent Voltage-controlled Voltage-dependent
Pickup currents 51 (phases)/(I_P) Pickup currents 51N (ground)/(I_{Ep}) Time multiplier T for 51, 51N (I_P, I_{Ep}) (IEC characteristics)	0.5 to 20 A[1] (in steps of 0.01 A) 0.25 to 20 A[1] (in steps of 0.01 A) 0.05 to 3.2 s or ∞ (in steps of 0.01 s)
Time multiplier D for 51, 51N (ANSI characteristics)	0.50 to 15 s or ∞ (in steps of 0.01 s)
Trip characteristics	
IEC acc. to IEC 60255-3 or BS 142	Inverse (type A), very inverse (type B), extremely inverse (type C), long inverse (type B)
ANSI/IEEE	Inverse, short inverse, long inverse, moderately inverse, very inverse, extremely inverse, definite inverse
Dropout characteristics with disk emulation	
IEC acc. to IEC 60255-3 or BS 142	Inverse (type A), very inverse (type B), extremely inverse (type C), long inverse (type B)
ANSI/IEEE	Inverse, short inverse, long inverse, moderately inverse, very inverse, extremely inverse, definite inverse
Pickup threshold IEC and ANSI	Approx. 1.1 · I_p
Dropout setting IEC and ANSI	
Without disk emulation	Approx. 1.05 · I_p setting value for $I_p/I_{nom} \geq 0.3$, corresponds to approx. 0.95 · pickup value
With disk emulation	Approx. 0.9 · I_p setting value
Tolerances	
Pickup/dropout thresholds I_p, I_{Ep}	3 % of setting value or 75 mA[1]
Trip time for $2 \leq I/I_p \leq 20$	5 % of reference (calculated) value + 2 % current tolerance or 30 ms
Dropout time for $I/I_p \leq 0.9$	5 % of reference (calculated) value + 2 % current tolerance or 30 ms

1) At I_{nom} = 1 A, all limits divided by 5.

Determination of direction	
For phase faults	
Polarization/type	With cross-polarized voltages With voltage memory (memory depth 2 seconds) for measurement voltages that are too low
Forward range Rotation of reference voltage $V_{ref,rot}$	$V_{ref,rot}$ ± 86 ° –180 ° to 180 ° (in steps of 1 °)
Directional sensitivity	For one and two-phase faults unlimited For three-phase faults dynamically unlimited Steady-state approx. 7 V phase-to-phase
For ground faults	
Polarization/type	With zero-sequence quantities $3V_0$, $3I_0$ or with negative-sequence quantities $3V_2$, $3I_2$
Forward range Rotation of reference voltage $V_{ref,rot}$	$V_{ref,rot}$ ± 86 ° –180 ° to 180 ° (in steps of 1 °)
Directional sensitivity	
Zero-sequence quantities $3V_0$, $3I_0$	$V_N \approx 2.5$ V displacement voltage, measured $3V_0 \approx 5$ V displacement voltage, calculated
Negative-sequence quantities $3V_2$, $3I_2$	$3V_2 \approx 5$ V negative-sequence voltage $3I_2 \approx 225$ mA negative-sequence current[1]
Times	
Pickup times (without inrush restraint; with inrush restraint + 10 ms) 50-1, 50-2, 50N-1, 50N-2	
With twice the setting value With ten times the setting value	Approx. 45 ms Approx. 40 ms
Dropout time 50-1, 50-2, 50N-1, 50N-2	Approx. 40 ms
Tolerances	
Angle faults for phase and earth faults	± 3 ° electrical

Technical data

Inrush restraint	
Controlled functions	Time-overcurrent elements, $I>$, $I_E>$, I_p, I_{Ep} (directional, non-directional) 50-1, 50N-1, 51, 51N, 67-1, 67N-1
Lower function limit	At least one phase current (50 Hz and 100 Hz) ≥ 125 mA for I_{nom} = 5 A, ≥ 50 mA for I_{nom} = 1 A
Upper function limit (setting range)	1.5 to 125 A[1] (in steps of 0.01 A)
Setting range, stabilization factor I_{2f}/I	10 to 45 % (in steps of 1 %)
Crossblock $I_{A(L1)}$, $I_{B(L2)}$, $I_{C(L3)}$	ON/OFF
Cold-load pickup/dynamic setting change	
Controllable functions	Directional and non-directional time-overcurrent protection (separated acc. to phases and ground)
Initiation criteria	Current criterion "BkrClosed/MIN" CB position via aux. contacts, binary input, auto-reclosure ready
Time control	3 time elements ($T_{CB\ Open}$, T_{Active}, T_{Stop})
Current control	Current threshold "BkrClosed/MIN" (reset on dropping below threshold; monitoring with timer)
Setting ranges	
Current control	0.2 to 5 A[1] (in steps of 0.01 A)
Time until changeover to dynamic setting $T_{CB\ Open}$	0 to 21600 s (= 6 h) (in steps of 1 s)
Period dynamic settings are effective after a reclosure T_{Active}	1 to 21600 s (= 6 h) (in steps of 1 s)
Fast reset time T_{Stop}	1 to 600 s (= 10 min.) or ∞ (fast reset inactive) (in steps of 1 s)
Dynamic settings or pickup currents and time delays or time multipliers	Adjustable within the same ranges and with the same steps (increments) as the directional and non-directional time-overcurrent protection
Single-phase overcurrent protection	
Current elements	
High-set current elements 50-2 ($I>>$)	0.005 to 8 A (in steps of 0.001 A) or ∞ [1] (disabled)
Definite-time current element 50-1 ($I>$)	0.005 to 8 A or ∞ [1] (disabled) (in steps of 0.001 A)
T_{50-1}, T_{50-2} ($T_I>/T_I>>$)	0 to 60 s or ∞ (no trip) (in steps of 0.01 s)
Operating times	
Minimum	14 ms
Typical	30 ms
Dropout time	Approx. 25 ms
Dropout ratios	
Current elements	Approx. 0.95 for I/I_{nom} ≥ 0.5
Tolerances	
Currents	5 % of setting value or 1 mA
Times	1 % of setting value or 10 ms
***Voltage protection** (ANSI 27, 59)*	
***Undervoltages** 27-1, 27-2 (V<, V<<)*	
Measured quantity used with	
Three-phase connection	Positive-sequence system of the voltages Lowest phase-to-phase voltage Lowest phase-to-ground voltage
Single-phase connection	Connected single-phase-to-ground voltage

1) At I_{nom} = 1 A, all limits divided by 5. 2) $r = V_{dropout}/V_{pickup}$.

Setting ranges	
Connection of phase-to-ground voltage	10 to 120 V (in steps of 1 V)
Connection of phase-to-phase voltage	10 to 120 V (in steps of 1 V)
Connection of single phase	10 to 120 V (in steps of 1 V)
Dropout ratio[2] r for 27-1, 27-2 ($V<$, $V<<$)	1.01 to 3 (in steps of 0.01)
Dropout threshold for $r \cdot$ 27-1 ($V<$)	Max. 130 V for phase-to-phase voltage
$r \cdot$ 27-2 ($V<<$)	Max. 225 V for phase-to-ground volt.
Hysteresis	Min. 0.6 V
Time delays T27-1($V<$), T27-2 ($V<<$)	0 to 100 s (in steps of 0.01 s) or ∞ (disabled)
Current criterion "BkrClosed/MIN"	0.2 to 5 A[1] (in steps of 0.01 A)
***Overvoltages** 59-1, 59-2 (V>, V>>)*	
Measured quantity used with	
Three-phase connection	Positive-sequence system of the voltages Negative-sequence system of the voltages Highest phase-to-phase voltage Highest phase-to-ground voltage
Single-phase connection	Connected single-phase-to-ground voltage
Setting ranges	
Connection of phase-to-ground voltage:	
Evaluation of phase-to-ground voltages	20 to 150 V (in steps of 1 V)
Evaluation of phase-to-phase voltages	20 to 260 V (in steps of 1 V)
Evaluation of positive-sequence system	20 to 150 V (in steps of 1 V)
Evaluation of negative-sequence system	2 to 150 V (in steps of 1 V)
Connection of phase-to-phase voltages:	
Evaluation of phase-to-phase voltage	20 to 150 V (in steps of 1 V)
Evaluation of positive-sequence system	20 to 150 V (in steps of 1 V)
Evaluation of negative-sequence system	2 to 150 V (in steps of 1 V)
Connection single phase	20 to 150 V (in steps of 1 V)
Dropout ratio r for 59-1, 59-2 ($V>$, $V>>$)	0.90 to 0.99 (in steps of 0.01 V)
Dropout threshold for $r \cdot$ 59-1 ($V>$)	Max. 150 V for phase-to-phase voltage
$r \cdot$ 59-2 ($V>>$)	Max. 260 V for phase-to-ground volt.
Hysteresis	Min. 0.6 V
Time delay T59-1, T59-2 ($V>$, $V>>$)	0 to 100 s (in steps of 0.01 s) or ∞ (disabled)
Times	
Pickup times	
Undervoltage 27-1, 27-2 ($V<$, $V<<$) 27-1 V_1, 27-2 V_1	Approx. 50 ms
Overvoltage 59-1, 59-2 ($V>$, $V>>$)	Approx. 50 ms
Overvoltage 59-1 V_1, 59-2 V_1, 59-1 V_2, 59-2 V_2	Approx. 60 ms
Dropout times	
Undervoltage 27-1, 27-2 ($V<$, $V<<$) 27-1 V_1, 27-2 V_1	Approx. 50 ms
Overvoltage 59-1, 59-2 ($V>$, $V>>$)	Approx. 50 ms
Overvoltage 59-1 V_1, 59-2 V_1, 59-1 V_2, 59-2 V_2	Approx. 60 ms
Tolerances	
Pickup voltage limits	3 % of setting value or 1 V
Delay times T	1 % of setting value or 10 ms

Technical data

Negative-sequence protection (ANSI 46)

Definite-time characteristic (ANSI 46-1 and 46-2)

Setting ranges	
Unbalanced load tripping element 46-1, 46-2 (I_2>, I_2>>)	0.5 to 15 A or ∞ (disabled)[1] (in steps of 0.01 A)
Delay times 46-1, 46-2 (T_{I2}>, T_{I2}>>)	0 to 60 s or ∞ (disabled)[1] (in steps of 0.01 s)
Dropout delay times 46 $T_{Dropout}$	0 to 60 s (in steps of 0.01 s)
Functional limit	All phase currents ≤ 50 A[1]
Times	
Pickup times	Approx. 35 ms
Dropout times	Approx. 35 ms
Dropout ratio	
Characteristic 46-1, 46-2/I_2>, I_2>>	Approx. 0.95 for I_2/I_{nom} ≥ 0.3
Tolerances	
Pickup values 46-1, 46-2/I_2>, I_2>>	3 % of the set value or 75 mA[1]
Delay times	1 % or 10 ms

Inverse-time characteristic (ANSI 46-TOC)

Setting ranges	
Pickup value 46-TOC/I_{2p}	0.5 to 10 A[1] (in steps of 0.01 A)
Time multiplier T_{I2p} (IEC)	0.05 to 3.2 s or ∞ (disabled) (in steps of 0.01 s)
Time multiplier D_{I2p} (ANSI)	0.5 to 15 s or ∞ (disabled) (in steps of 0.01 s)
Functional limit	All phase currents ≤ 50 A[1]
Trip characteristics acc. to	
IEC	Inverse, very inverse, extremely inverse
ANSI	Inverse, moderately inverse, very inverse, extremely inverse
Pickup threshold IEC and ANSI	Approx. 1.10 · I_{2p}
Tolerances	
Pickup threshold I_{2p}	3 % of the setting value or 75 mA[1]
Time for 2 ≤ I/I_{2p} ≤ 20	5 % of reference (calculated) value + 2 % current tolerance or 30 ms
Dropout characteristic with disk emulation acc. to ANSI	Inverse, moderately inverse, very inverse, extremely inverse
Dropout value	
IEC and ANSI without disk emulation	Approx. 1.05 · I_{2p} setting value, corresponds to approx. 0.95 · pickup
ANSI with disk emulation	Approx. 0.90 · I_{2p} setting value
Tolerances	
Dropout value I_{2p}	3 % of the set value or 75 mA[1]
Time for 2 ≤ I_2/I_{2p} ≤ 0.90	5 % of reference (calculated) value +2 % current tolerance, or 30 ms

Frequency protection (ANSI 81O/U)

Number of frequency elements	4, each can be set to *f*> or *f*<
Setting ranges	
Pickup values *f*> or *f*< for f_{nom} = 50 Hz	40 to 60 Hz (in steps of 0.01 Hz)
Pickup values *f*> or *f*< for f_{nom} = 60 Hz	50 to 70 Hz (in steps of 0.01 Hz)
Delay times *T*	0 to 100 s or ∞ (disabled) (in steps of 0.01 s)
Undervoltage blocking, with positive-sequence voltage V_1	10 to 150 V (in steps of 1 V)
Times	
Pickup times *f* >, *f*<	Approx. 80 ms
Dropout times *f* >, *f*<	Approx. 80 ms
Dropout difference	
Δ *f* = |pickup value – dropout value|	0.02 to 1 Hz
Dropout	
Ratio undervoltage blocking	Approx. 1.05
Tolerances	
Pickup thresholds	
Frequency 81O/U *f* >, *f*<	15 mHz (with $V = V_{nom}$, $f = f_{nom}$)
Undervoltage blocking	3 % of setting value or 1 V
Delay times	1 % of the setting value or 10 ms

1) At I_{nom} = 1 A, all limits divided by 5.

Thermal overload protection (ANSI 49)

Setting ranges	
Factor k	0.1 to 4 (in steps of 0.01)
Time constant	1 to 999.9 min (in steps of 0.1 min)
Current warning stage I_{Alarm}	0.5 to 20 A (in steps of 0.01 A)
Extension factor when stopped $k_τ$ factor	1 to 10 with reference to the time constant with the machine running (in steps of 0.1)
Dropout ratios	
$Θ/Θ_{Trip}$	Drops out with $Θ_{Alarm}$
$Θ/Θ_{Alarm}$	Approx. 0.99
I/I_{Alarm}	Approx. 0.97
Tolerances	
With reference to k · I_{nom}	3 % or 75 mA[1] 2 % class acc. to IEC 60255-8
With reference to tripping time	3 % or 1 s for $I/(k \cdot I_{nom})$ > 1.25 3 % class acc. to IEC 60255-8

(Sensitive) ground-fault protection (ANSI 64, 50Ns, 51Ns, 67Ns)

Displacement voltage element for all types of ground fault (ANSI 64)

Setting ranges	
Displacement voltage (measured)	V_0> 1.8 to 200 V (in steps of 0.1 V)
Displacement voltage (calculated)	$3V_0$> 10 to 225 V (in steps of 0.1 V)
Delay time $T_{Delay\ pickup}$	0.04 to 320 s or ∞ (in steps of 0.01 s)
Additional trip delay $T_{V\ Delay}$	0.1 to 40,000 s or ∞ (in steps of 0.01 s)
Operating time	Approx. 50 ms
Dropout ratio	0.95 or (pickup value –0.6 V)
Tolerances (measurement)	
Pickup threshold V_0 (measured)	3 % of setting value or 0.3 V
Pickup threshold $3V_0$ (calculated)	3 % of setting value or 3 V
Delay times	1 % of setting value or 10 ms

Phase detection for ground fault in an ungrounded system

Measuring principle	Voltage measurement (phase-to-ground)
Setting ranges	
$V_{ph\ min}$ (ground-fault phase)	10 to 100 V (in steps of 1 V)
$V_{ph\ max}$ (healthy phases)	10 to 100 V (in steps of 1 V)
Tolerance	
Measurement tolerance acc. to VDE 0435, Part 303	3 % of setting value or 1 V