SIEMENS

Protection Systems

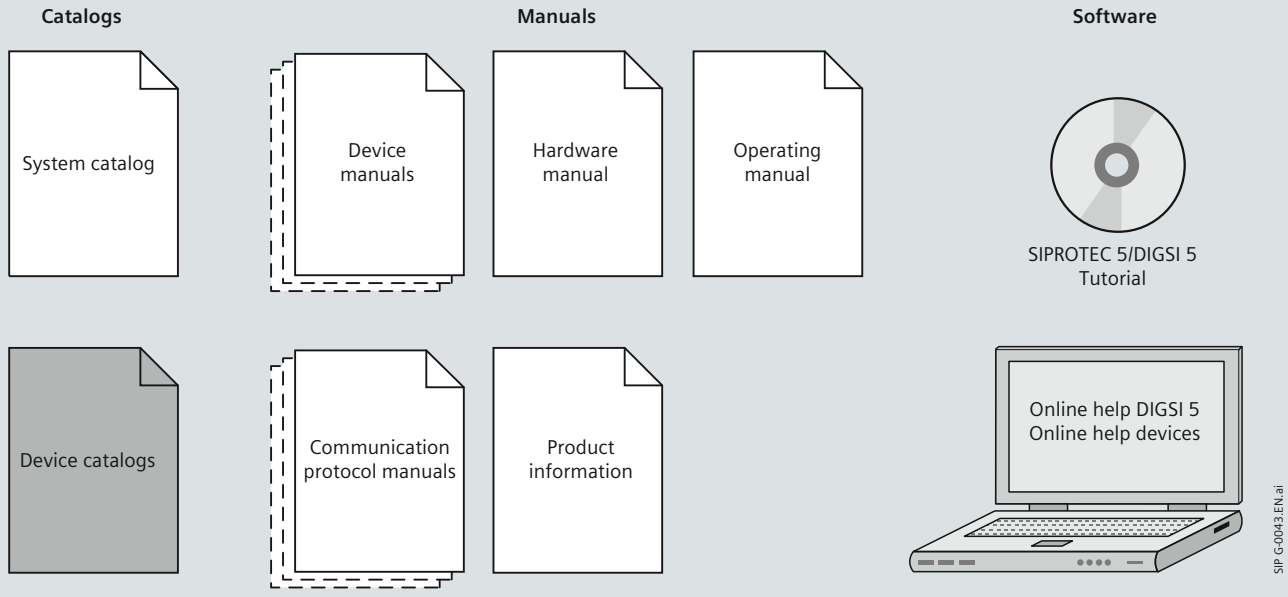
SIPROTEC 5 – Line Protection Devices 7SA8, 7SD8, 7SL8, 7VK8, 7SJ86

Catalog SIPROTEC 5.02 · Edition 2

Answers for infrastructure.

SIEMENS

siemens-russia.com



Overview of documentation for the SIPROTEC 5 system

System catalog

The system catalog describes the SIPROTEC 5 system features.

Device catalogs

The device catalogs describe device-specific features such as functional scope, hardware and applications.

Device manuals

The device manuals describe the functions and applications of a specific SIPROTEC 5 device. The printed manual and the online help for the device have the same informational structure.

Hardware manual

The hardware manual describes the hardware components and device combinations of the SIPROTEC 5 device family.

Operating manual

The operating manual describes the basic principles and procedures for operating and assembling the devices of the SIPROTEC 5 device family.

Communication protocol manuals

The communication protocol manuals include a description of specific protocols for communication within the SIPROTEC 5 device family and to higher-level control centers.

Product information

The product information includes general information about device installation, technical data, limiting values for input and output modules, and conditions when preparing for operation. This document is delivered with each SIPROTEC 5 device.

DIGSI 5 online help

The DIGSI 5 online help contains a help package for DIGSI 5 and CFC. The help package for DIGSI 5 includes a description of the basic operation of software, the DIGSI principles and editors. The help package for CFC includes an introduction to CFC programming, basic examples of CFC handling, and a reference chapter with all CFC blocks available for the SIPROTEC 5 device family.

Online help devices

The online help for devices has the same information structure as the device manual.

SIPROTEC 5 / DIGSI 5 Tutorial

The tutorial on the DVD contains brief information about important product features, more detailed information about the individual technical areas, as well as operating sequences with tasks based on practical operation and a brief explanation.

SIPROTEC 5 – Line Protection Devices 7SA8, 7SD8, 7SL8, 7VK8, 7SJ86

Energy Automation

Catalog SIPROTEC 5.02 · Edition 2

Invalid: Catalog SIP 5.02 · V1.0

ISO 9001
ISO 14001
DNV
Certified Company

OHSAS 18001
DNV
Certified Company

The products and systems described in this catalog are manufactured and sold according to a certified management system (acc. to ISO 9001, ISO 14001 and BS OHSAS 18001).
DNV Certificate No.: 92113-2011-AHSO-GER-TGA and Certificate No.: 87028-2010-AHSO-GER-TGA.

Editorial

SIPROTEC has been a recognized brand leader in digital protection and field devices on the energy market for decades. The Siemens high-performance SIPROTEC devices cover the entire power spectrum and can be implemented in a wide range of fields – from power generation to very high voltage transmission and distribution network applications.

"Smart automation for transmission grids" is the Siemens response to the present and future challenges to achieve a reliable and efficient energy supply. SIPROTEC 5 is an active component of the energy-efficient smart grid and an important building block in the complex distributed energy supply systems and networks solutions.

The next generation of SIPROTEC devices, SIPROTEC 5, is based on the proven features of SIPROTEC 4 to provide you with a new, modern platform including both hardware and software. This platform offers an excellent solution to the challenges associated with evolving grid structures and workflows. The quality, reliability and proven functions of the former system have been preserved. Innovative approaches including holistic workflow, safety and security, and network stability monitoring (PMU functionality) have been added.

The pioneering system architecture places you in full control of switchgear communications. A powerful, reliable communication infrastructure, combined with the flexible engineering capabilities serves as the basis for monitoring and controlling of distributed, decentralized systems. Seamless communications is the central component of the SIPROTEC 5 system architecture to provide flexibility, safety and security in the automated distributed network solutions.

With SIPROTEC 5, you are at the beginning of a new generation of intelligent, digital multifunction field devices. The new operating tool DIGSI 5 offers individual support for you – handles your specific workflow requirements, from system design to device selection and testing, covering the entire device lifecycle. The new tool offers cost savings over the entire lifecycle without compromising safety and system availability.

With the new SIPROTEC 5 generation, you are well equipped to meet the growing economic and reliability demands imposed on your networks. The philosophy of SIPROTEC 5 is reflected in the modularity and flexibility of its hardware and software components. Perfectly tailored fit – the custom fit for your switchgear and specifications for the application and standardization of energy automation.

Ingo Erkens

General Manager
Infrastructure and Cities Sector
Smart Grid Division
Energy Automation

SIPROTEC 5 – Line protection devices

SIPROTEC 5 line protection devices are part of the modular system of SIPROTEC 5. They support all SIPROTEC 5 system features, and can be used individually as well as universally in the framework of system solutions. In the following, the specific properties of the SIPROTEC 5 line protection devices are described. The description of the SIPROTEC 5 system features is found in the system catalog.

In the system catalog, the following properties of SIPROTEC 5 are introduced in detail:

- The SIPROTEC 5 system
- Areas of use
- Hardware
- Engineering
- Communication
- IEC 61850 – Simply usable
- Test and diagnostics
- Safety concept
- DIGSI 5

The system catalog can be ordered free of charge from your Siemens contact partner under order number E50001-K4605-A011-A1-7600.

SIPROTEC 5 system catalog
Order No. E50001-K4605-A011-A1-7600

SIPROTEC 5 line protection devices are based on the distance protection and differential protection principles. They protect overhead lines and cables of all voltage levels with the highest possible degree of selectivity and security. A large number of additional protection and automation functions makes use in all areas of line protection possible.

The devices also contain important auxiliary functions that are necessary for safe network operation today. This includes functions for control, measurement and monitoring. The large number of communication interfaces and communication protocols satisfies the requirements of communication-based selective protection, as well as automated operation.

Commissioning and maintenance work can be completed safely, quickly and thus cost-effectively with high-performance test functions. Because of a modular structure design, SIPROTEC 5 line protection devices can always be flexibly adapted to specific requirements.

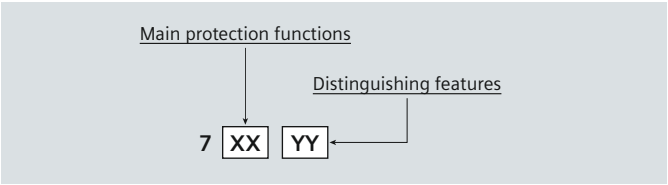
Line Protection Devices

Overview

Features

The device types are defined by their main protection functions and by essential distinguishing features.

Definition of device types based on designation



7	XX	YY	
Main protection:			
7	SA		Distance protection
7	SD		Differential protection
7	SL		Distance and differential protection
7	SJ		Overcurrent protection
7	VK		Circuit-breaker management
Essential distinguishing features:			
7		84	– exclusively 3-pole tripping – Hardware quantity structure fixed
7		86	– exclusively 3-pole tripping – Hardware quantity structure flexibly configurable
7		87	– 1- and 3-pole tripping – Hardware quantity structure flexibly configurable

For devices with flexible configurability of the hardware quantity structure, you can select various standard variants when ordering. Expandability through supplemental modules allows for individual adaptation to specific applications such as more analog channels for breaker-and-a-half schemes, or more binary contacts (see "Overview of the standard variants", page 58).

Function library and application templates

A common function library makes all protection, automation, monitoring and auxiliary functions for the SIPROTEC 5 line protection devices available. Thus, the same functions are truly the same for all devices. Once established, configurations can be transferred from device to device. This results in substantially reduced engineering effort.

On the following pages of this catalog, the selection of functions available from the library is shown in table format. Pre-defined templates are available in DIGSI for standard applications. These templates contain basic configurations, required functions and default settings for standard applications.

Type designation	7SA84	7SA86	7SA87	7SD84	7SD86	7SD87	7SL86	7SL87	7VK87	7SJ86
Distance protection	■	■	■				■	■		
Differential protection				■	■	■	■	■		
Overcurrent protection for overhead line	■	■	■	■	■	■	■	■		■
Circuit-breaker management									■	
3-pole trip command	■	■		■	■		■			■
1-/3-pole trip command			■			■		■	■	
Flexibly configurable hardware		■	■		■	■	■	■	■	■

Table 1 Overview of the various distinguishing features of the main protection types

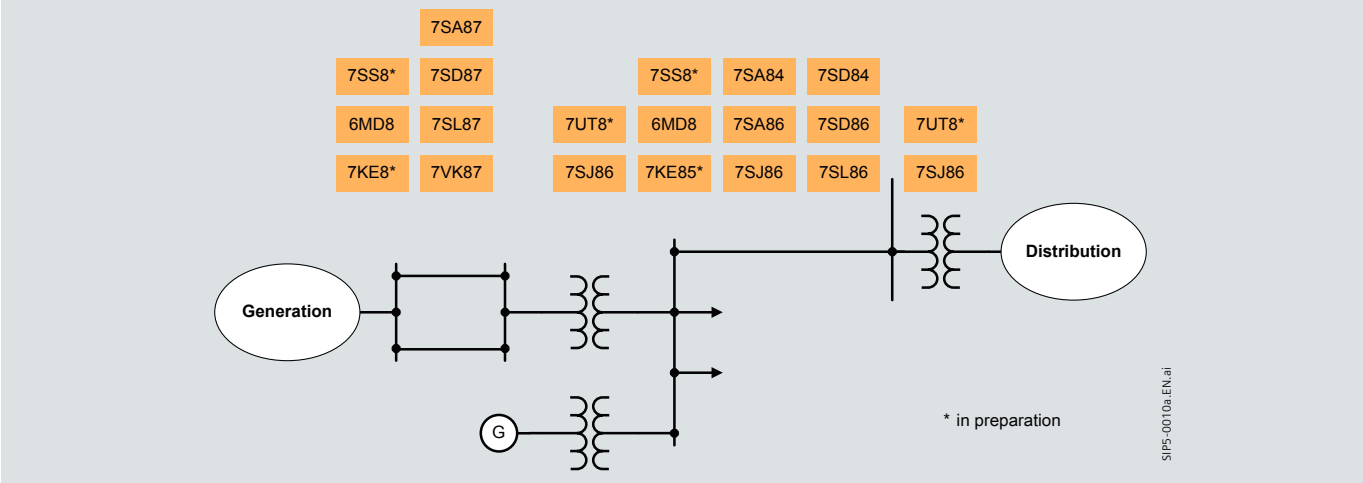


Fig. 1 Areas of application of the SIPROTEC 5 devices in the power transmission system

Properties

Main protection function:	Distance protection
Tripping:	3-pole, min. tripping time 25 ms
Inputs and outputs:	4 current transformers, 4 voltage transformers, 5 binary inputs, 8 binary outputs (1 standard, 7 fast relays). The I/O quantity structure for 7SA84 is fixed; it cannot be changed with other modules of the SIPROTEC 5 modular system
Width of housing:	1/3×19"

- Line protection for all voltage levels with 3-pole tripping
- Selective protection of overhead lines and cables with single- and multi-ended feeders
- Time-graded backup protection for differential protection equipment
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Main protection function: 6-system distance protection
- Various additional functions
- Protection of lines with capacitive series compensation
- Suitable for protection of long and short lines
- Adaptive power-swing blocking
- Detection of CT saturation for fast tripping and high accuracy at the same time
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The distance protection 7SA84 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds as well as time-graded backup protection for comparison protection schemes. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 2 on page 9 shows all functions that are available in the 7SA84. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 2 Distance protection 7SA84

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 2 on page 9 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SA84 basic distance protection

- Distance protection with 3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection as emergency or backup function
- Teleprotection functions
- Fault locator.

7SA84 distance protections for compensated/isolated systems with AR

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines and cables in networks with compensated and isolated neutral point.

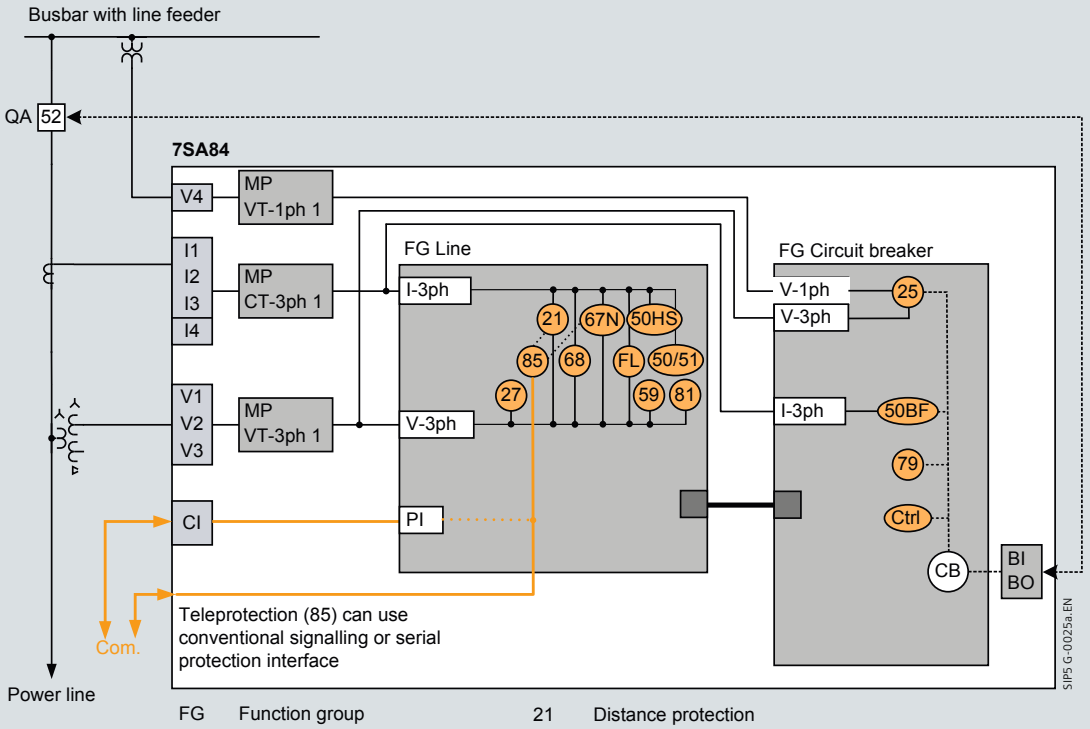
7SA84 distance protection for overhead line for grounded systems, with AR

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point (Fig. 3).

7SA84 distance protection with MHO distance zone characteristics for overhead line for grounded systems, with AR

- Comprises the basic functions with MHO distance zone characteristics as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point.

Distance protection 7SA84 – Application examples



FG	Function group	21	Distance protection
MP	Measuring point	25	Synchrocheck, synchronizing function
PI	Protection interface	27	Undervoltage protection
CI	Communication interface	50/51	Overcurrent protection, phases, ground
CB	Circuit breaker	50HS	High speed instantaneous overcurrent protection
BI	Binary input	50BF	Circuit-breaker failure protection
BO	Binary output	59	Overvoltage protection
		67N	Directional overcurrent protection for ground-faults
		68	Power-swing blocking
		79	Automatic reclosing
		81	Frequency protection
		85	Teleprotection schemes
		Ctrl	Control
		FL	Fault locator

Fig. 3 Application example: Distance protection for overhead line

Distance protection 7SA84 – Functions, application templates

ANSI	Function	Abbr.	Application templates				
			Available in 7SA84	DIS Basic	DIS comp./isol. systems, with AR	DIS overhead line, grounded systems	DIS MHO, overhead line, grounded systems
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■
21, 21N	Distance protection	Z<	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■			■	■
27	Undervoltage protection, 3-phase	V<	■		■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■				
27	Undervoltage protection, 1-phase, V_x *	Vx<	■				
32, 37	Power protection active/reactive power	P<>, Q<>	■				
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■				
49	Thermal overload protection	θ, I²t	■		■	■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	■
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■				
59	Overvoltage protection, compounding	V1comp>	■				
59	Overvoltage protection, negative-sequence system	V2>	■				
59N	Overvoltage protection, zero-sequence system	V0>	■				
59	Overvoltage protection, 1-phase, V_x *	Vx>	■				
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■				
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■			■	■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■		■		
68	Power-swing blocking	ΔZ/Δt	■			■	■
74TC	Trip-circuit supervision	TCS	■				
78	Out-of-step protection	ΔZ/Δt	■				
79	Automatic reclosing	AR	■		■	■	■
81O	Overfrequency protection	f>	■		■	■	■
81U	Underfrequency protection	f<	■		■	■	■
85/21	Teleprotection for distance protection		■	■	■	■	■
85/27	Weak or no infeed: Echo and tripping	WI	■	■	■	■	■
85/67N	Teleprotection for directional ground-fault protection		■	■	■	■	■
86	Lockout		■				
FL	Fault locator	FL	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■				
PMU	Synchrophasor measurement	PMU	■				
	Operational measured values, standard		■	■	■	■	■
	Measured values, extended: Min, Max, Avg (function points per type)		■				
	Switching-statistic counters		■	■	■	■	■
	CFC standard		■	■	■	■	■
	CFC arithmetic		■				
	CFC switching sequences		■				
	Inrush current detection		■				
	External trip initiation		■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■				
	Fault recording of analog and binary signals		■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■
	Protection interface, serial		■	■	■	■	■
	Function points:			0	125	225	225

* Currently under development

Table 2 7SA84 functions, application templates

Distance protection 7SA86 – Applications

Properties

Main protection function:	Distance protection
Tripping:	3-pole, min. tripping time 9 ms
Inputs and outputs: Hardware flexibility:	12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 × 19" to 1/1 × 19"

- Line protection for all voltage levels with 3-pole tripping
- Very short tripping time
- Also used in switchgear with breaker-and-a-half scheme
- Selective protection of overhead lines and cables with single- and multi-ended feeders
- Time-graded backup protection for differential protection equipment
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Main protection function: 6-system distance protection
- Various additional functions
- Protection of lines with capacitive series compensation
- Suitable for the protection of long and short lines
- Adaptive power-swing blocking
- Detection of CT saturation for fast tripping and high accuracy at the same time
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple test and commissioning.

Applications

The distance protection 7SA86 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective, fast protection equipment for overhead lines and cables with single- and multi-ended infeeds as well as time-graded backup protection for comparison protection schemes. The device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 3 on page 13 shows all functions that are available in the 7SA86. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 4 Distance protection 7SA86

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 3 on page 13 shows the functional scope and the function point requirement for the application templates described. The following templates are available:

7SA86 basic distance protection

- Distance protection with 3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection as emergency or backup function
- Teleprotection functions
- Fault locator.

7SA86 distance protections for compensated/isolated systems with AR

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines and cables in networks with compensated and isolated neutral point.

7SA86 distance protection for overhead line for grounded systems, with AR

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point (Fig. 5).

7SA86 distance protection with MHO distance zone characteristics for overhead line for grounded systems, with AR

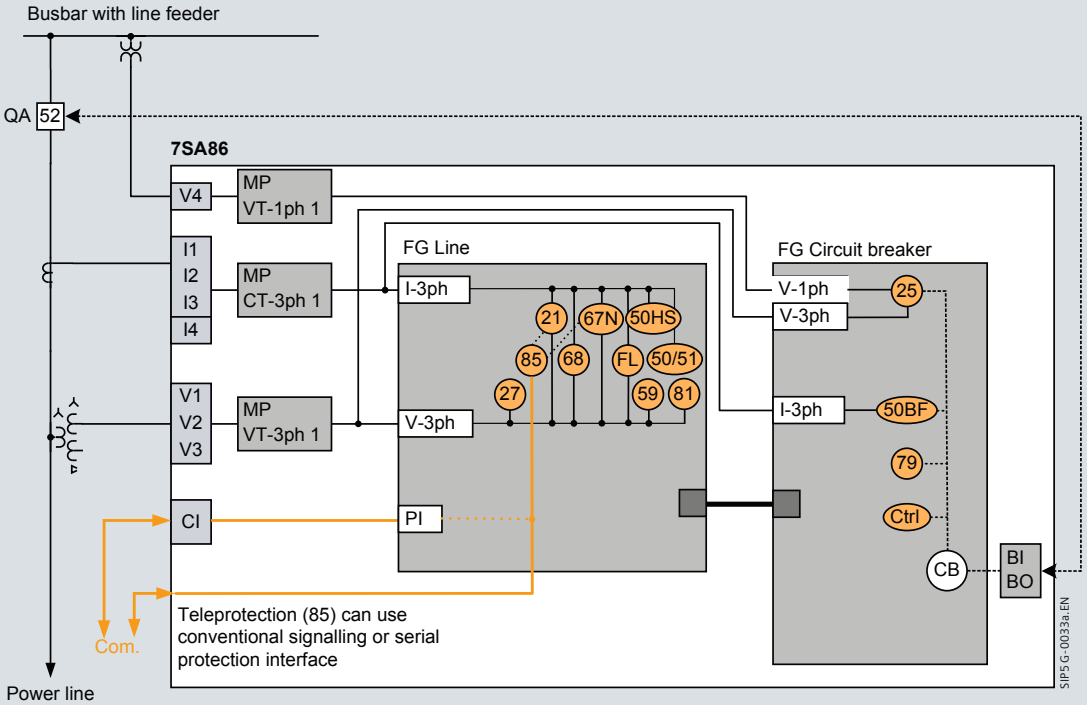
- Comprises the basic functions with MHO distance zone characteristics as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point

7SA86 distance protection for overhead line for grounded systems, with AR for applications with breaker-and-a-half scheme

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point; prepared for applications with breaker-and-a-half schemes (Fig. 6).

7SA86 distance protection with MHO distance zone characteristics for overhead line for grounded systems, with AR for applications with breaker-and-a-half schemes

- Comprises the basic functions with MHO distance zone characteristics as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point; prepared for applications with breaker-and-a-half schemes (Fig. 6).

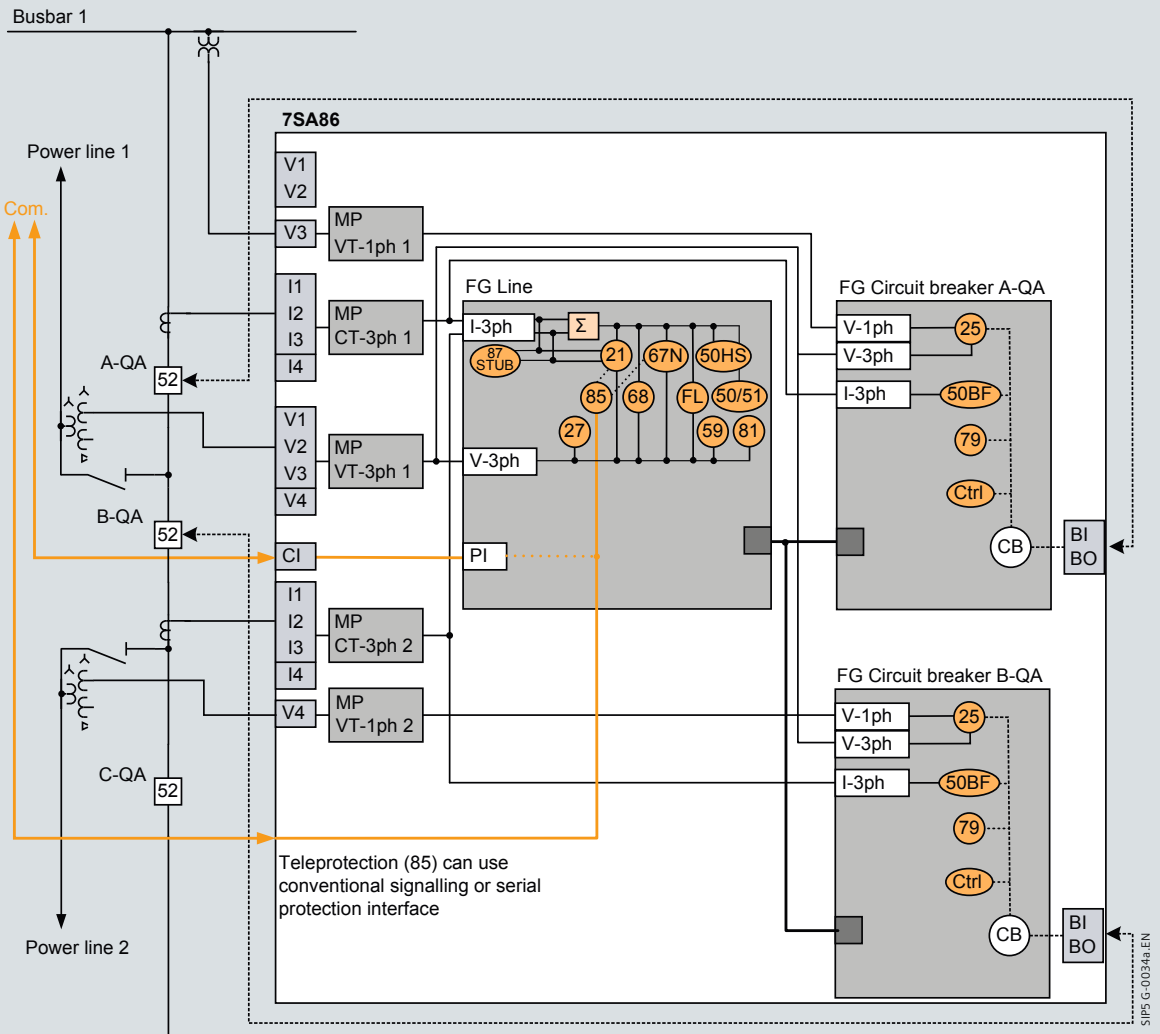


FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

21	Distance protection
25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
67N	Directional overcurrent protection for ground-faults
68	Power-swing blocking
79	Automatic reclosing
81	Frequency protection
85	Teleprotection schemes
Ctrl	Control
FL	Fault locator

Fig. 5 Application example: Distance protection for overhead line

Distance protection 7SA86 – Application examples



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
Σ	Summation of currents
BI	Binary input
BO	Binary output

21	Distance protection
25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
67N	Directional overcurrent protection for ground-faults
68	Power-swing blocking
79	Automatic reclosing
81	Frequency protection
85	Teleprotection schemes
87STUB	STUB Differential protection
Ctrl	Control
FL	Fault locator

Fig. 6 Application example: Distance protection for overhead line with breaker-and-a-half scheme

Distance protection 7SA86 – Functions, application templates

ANSI	Function	Abbr.	Application templates						
			Available in 7SA86	DIS Basic	DIS comp./isol. systems, with AR	DIS overhead line, grounded systems	DIS MHO, overhead line, grounded systems	DIS overhead line, grounded systems breaker-and-a-half	DIS MHO, overhead line, grounded systems breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■	■	■	■
21, 21N	Distance protection	Z<	■	■	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■			■	■	2	2
27	Undervoltage protection, 3-phase	V<	■		■	■	■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■						
27	Undervoltage protection, 1-phase, V_x *	Vx<	■						
32, 37	Power protection active/reactive power	P<>, Q<>	■						
46	Negative-sequence system overcurrent protection with direction	I2>, U2/I2	■						
49	Thermal overload protection	θ	■		■	■	■	■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	■	2	2
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■						
59	Overvoltage protection, compounding	V1comp>	■						
59	Overvoltage protection, negative-sequence system	V2>	■						
59N	Overvoltage protection, zero-sequence system	V0>	■						
59	Overvoltage protection, 1-phase, V_x *	Vx>	■						
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■						
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■			■	■	■	■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■		■				
68	Power-swing blocking	ΔZ/Δt	■			■	■	■	■
74TC	Trip-circuit supervision	TCS	■						
78	Out-of-step protection	ΔZ/Δt	■						
79	Automatic reclosing	AR	■		■	■	■	2	2
81O	Overfrequency protection	f>	■		■	■	■	■	■
81U	Underfrequency protection	f<	■		■	■	■	■	■
85/21	Teleprotection for distance protection		■	■	■	■	■	■	■
85/27	Weak or no infeed: Echo and tripping	WI	■	■	■	■	■	■	■
85/67N	Teleprotection for directional ground-fault protection		■	■	■	■	■	■	■
86	Lockout		■						
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■					■	■
FL	Fault locator	FL	■	■	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■						
PMU	Synchrophasor measurement	PMU	■						
	Operational measured values, standard		■	■	■	■	■	■	■
	Measured values, expanded: Min, Max Middle (function points per type)		■						
	Switching-statistic counters		■	■	■	■	■	■	■
	CFC standard		■	■	■	■	■	■	■
	CFC arithmetic		■						
	CFC switch sequences		■						
	Inrush current detection		■						
	External trip initiation		■	■	■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■						
	Fault recording of analog and binary signals		■	■	■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■	■	■
	Protection interface, serial		■						
	Function points:			0	125	225	225	375	375

* Currently under development

Table 3 7SA86 functions, application templates

Distance protection 7SA87 – Applications

Properties

Main protection function:	Distance protection
Tripping:	1- and 3-pole, min. tripping time 9 ms
Inputs and outputs: Hardware flexibility:	12 predefined standard variations with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 × 19" to 1/1 × 19"

- Line protection for all voltage levels with 1- and 3-pole tripping
- Very short tripping time
- Also used in switchgear with breaker-and-a-half schemes
- Selective protection of overhead lines and cables with single- and multi-ended feeders
- Time-graded backup protection for differential protection equipment
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Main protection function: 6-system distance protection
- Various additional functions
- Protection of lines with capacitive series compensation
- Suitable for protection of long and short lines
- Adaptive power-swing blocking
- Detection of CT saturation for fast tripping and high accuracy at the same time
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The distance protection 7SA87 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective, fast protection equipment for overhead lines and cables with single- and multi-ended infeeds as well as time-graded backup protection for comparison protection schemes. The device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 4 on page 17 shows all functions that are available in the 7SA87. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 7 Distance protection 7SA87

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 4 on page 17 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SA87 basic distance protection

- Distance protection with 1-/3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection as emergency or backup function
- Teleprotection functions
- Fault locator.

7SA87 distance protection for compensated/isolated systems with AR

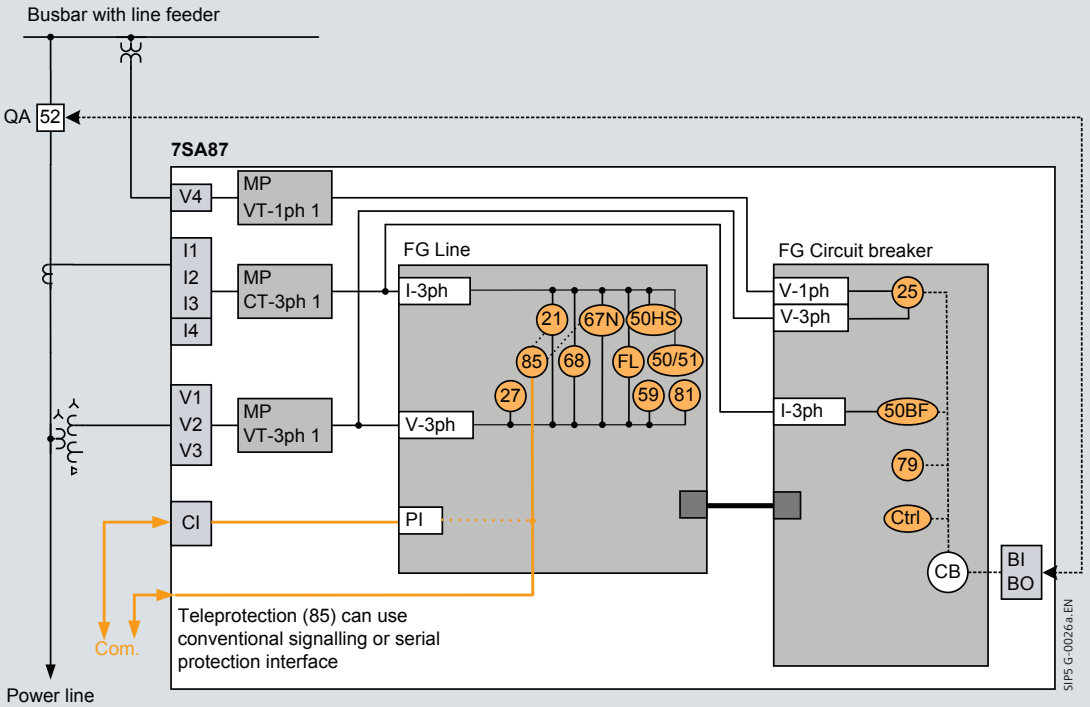
- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with compensated and isolated neutral point.

7SA87 distance protection for overhead line for grounded systems, with AR

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point (Fig. 8).

7SA87 distance protection for overhead line in grounded systems, with AR for applications with breaker-and-a-half schemes

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point; prepared for applications with breaker-and-a-half schemes (Fig. 9).

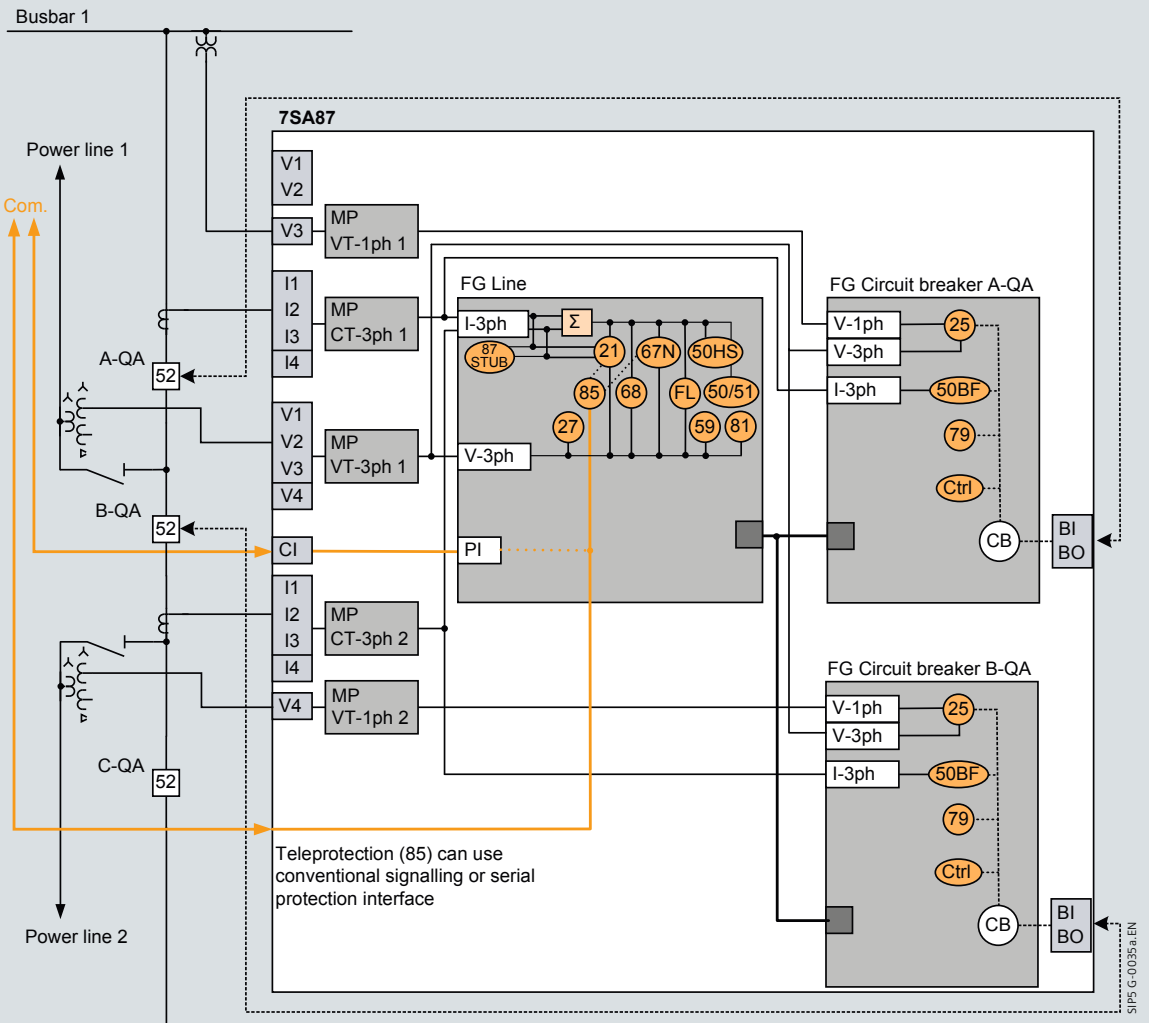


FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

21	Distance protection
25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
67N	Directional overcurrent protection for ground-faults
68	Power-swing blocking
79	Automatic reclosing
81	Frequency protection
85	Teleprotection schemes
Ctrl	Control
FL	Fault locator

Fig. 8 Application example: Distance protection for overhead line

Distance protection 7SA87 – Application examples



FG	Function group	21	Distance protection
MP	Measuring point	25	Synchrocheck, synchronizing function
PI	Protection interface	27	Undervoltage protection
CI	Communication interface	50/51	Overcurrent protection, phases, ground
CB	Circuit breaker	50HS	High speed instantaneous overcurrent protection
Σ	Summation of currents	50BF	Circuit-breaker failure protection
BI	Binary input	59	Overvoltage protection
BO	Binary output	67N	Directional overcurrent protection for ground-faults
		68	Power-swing blocking
		79	Automatic reclosing
		81	Frequency protection
		85	Teleprotection schemes
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 9 Application example: Distance protection for overhead line with breaker-and-a-half scheme

Distance protection 7SA87 – Functions, application templates

ANSI	Function	Abbr.	Application templates				
			Available in 7SA87	DIS Basic	DIS comp./isol. systems, with AR	DIS overhead line, grounded systems	DIS overhead line, grounded systems breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■
	Protection functions for 1-pole tripping	1-pole	■	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■	■
21, 21N	Distance protection	Z<	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■			■	2
27	Undervoltage protection, 3-phase	V<	■		■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■				
27	Undervoltage protection, 1-phase, V_x *	Vx<	■				
32, 37	Power protection active/reactive power	P<>, Q<>	■				
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■				
49	Thermal overload protection	θ, I²t	■		■	■	■
50 HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	2
50/51	Overcurrent protection, phases	I>, I_p	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■				
59	Overvoltage protection, compounding	V1comp>	■				
59	Overvoltage protection, negative-sequence system	V2>	■				
59N	Overvoltage protection, zero-sequence system	V0>	■				
59	Overvoltage protection, 1-phase, V_x *	Vx>	■				
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■				
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■			■	■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■		■		
68	Power-swing blocking	ΔZ/Δt	■			■	■
74TC	Trip-circuit supervision	TCS	■				
78	Out-of-step protection	ΔZ/Δt	■				
79	Automatic reclosing	AR	■		■	■	2
81O	Overfrequency protection	f>	■		■	■	■
81U	Underfrequency protection	f<	■		■	■	■
85/21	Teleprotection for distance protection		■	■	■	■	■
85/27	Weak or no infeed infeed: Echo and tripping	WI	■	■	■	■	■
85/67N	Teleprotection for directional ground-fault protection		■	■	■	■	■
86	Lockout		■				
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■				■
FL	Fault locator	FL	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■				
PMU	Synchrophasor measurement	PMU	■				
	Operational measured values, standard		■	■	■	■	■
	Measured values, extended: Min, Max, Avg (function points per type		■				
	Switching-statistic counters		■	■	■	■	■
	CFC standard		■	■	■	■	■
	CFC arithmetic		■				
	CFC switching sequences		■				
	Inrush current detection		■				
	External trip initiation		■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■				
	Fault recording of analog and binary signals		■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■
	Protection interface, serial		■				
	Function points:			0	150	250	425

* Currently under development

Table 4 7SA87 functions, application templates

Differential protection 7SD84 – Applications

Properties

Main protection function:	Differential protection
Tripping:	3-pole, min. tripping time 14 ms
Inputs and outputs:	4 current transformers, 4 voltage transformers, 5 binary inputs, 8 binary outputs (1 standard, 7 fast relays) The I/O quantity structure for 7SD84 is fixed; it cannot be changed with the other modules of the SIPROTEC 5 modular system.
Width of housing:	1/3 × 19"

- Line protection for all voltage levels with 3-pole tripping
- Phase-selective protection of overhead lines and cables with single- and multi-ended infeeds of all lengths with 2 line ends
- Transformers and compensating coils in the protection zone are possible
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Protection of lines with capacitive series compensation
- Main protection function is differential protection with adaptive algorithm for maximum sensitivity and stability even at different CT errors, CT saturation and capacitive charging currents
- Directional backup protection and various additional functions
- Secure serial protection data communication, also over great distances, and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The differential protection device 7SD84 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds with two ends. Transformers and compensating coils in the protection zone are also possible. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 5 on page 20 shows all functions that are available in the 7SD84. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 10 Differential protection device 7SD84

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 5 on page 20 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SD84 basic differential protection

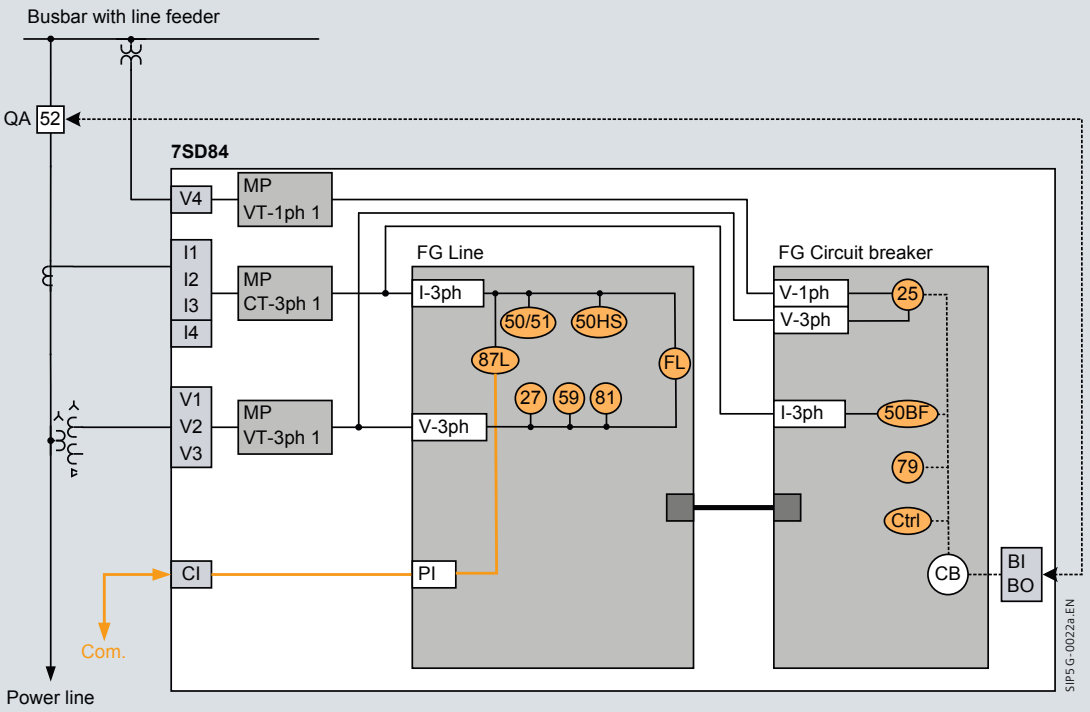
- Phase-selective differential protection with 3-pole tripping
- Non-directional overcurrent protection as emergency or backup function
- Fault locator.

7SD84 differential protection for overhead line

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection (Fig. 11).

7SD84 differential protection for overhead line with transformer in the protection range

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection
- Considers a transformer in the protection range.



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
79	Automatic reclosing
81	Frequency protection
87L	Differential protection, line
Ctrl	Control
FL	Fault locator

Fig. 11 Application example: Line differential protection for overhead line

Differential Protection 7SD

Differential protection 7SD84 – Functions, application templates

ANSI	Function	Abbr.	Application templates: Available in 7SD84	DIFF Basic	DIFF Overhead line	DIFF Overhead line with transformer
	Protection functions for 3-pole tripping	3-pole	■	■	■	■
87L	Differential protection, line	ΔI	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		■	■
27	Undervoltage protection, 3-phase	V<	■		■	■
27	Undervoltage protection, positive-sequence system	V1<	■			
27	Undervoltage protection, 1-phase, V_x *	Vx<	■			
32, 37	Power protection active/reactive power	P<>, Q<>	■			
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■			
49	Thermal overload protection	θ, I²t	■		■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■
59	Overvoltage protection, positive-sequence system	V1>	■			
59	Overvoltage protection, compounding	V1comp>	■			
59	Overvoltage protection, negative-sequence system	V2>	■			
59N	Overvoltage protection, zero-sequence system	V0>	■			
59	Overvoltage protection, 1-phase, V_x *	Vx>	■			
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■			
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■			
74TC	Trip-circuit supervision	TCS	■			
79	Automatic reclosing	AR	■		■	■
81O	Overfrequency protection	f>	■		■	■
81U	Underfrequency protection	f<	■		■	■
86	Lockout		■			
87L/87T	Option for line differential protection: including power transformer	ΔI	■			■
	Option for line differential protection:charging-current compensation		■			
	Broken-wire detection for differential protection		■			
FL	Fault locator	FL	■	■	■	■
FL	Fault locator, two-ended measurement *	FL-two	■			
PMU	Synchrophasor measurement	PMU	■			
	Operational measured values, standard		■	■	■	■
	Measured values, extended: Min, Max, Avg (function points per type)		■			
	Switching-statistic counters		■	■	■	■
	CFC standard		■	■	■	■
	CFC arithmetic		■			
	CFC switching sequences		■			
	Inrush current detection		■			
	External trip initiation		■	■	■	■
	Control for 4 switching devices		■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■			
	Fault recording of analog and binary signals		■	■	■	■
	Monitoring and supervision		■	■	■	■
	Protection interface, serial		■	■	■	■
	Function points:			0	175	275

* Currently under development

Table 5 7SA84 functions, application templates

Properties

Main protection function:	Differential protection
Tripping:	3-pole, min. tripping time 9 ms
Inputs and outputs:	12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 × 19" to 1/1 × 19"

- Line protection for all voltage levels with 3-pole tripping
- Phase-selective protection of overhead lines and cables with single- and multi-ended infeeds of all lengths with up to 6 line ends
- Also used in switchgear with breaker-and-a-half schemes
- Transformers and compensating coils in the protection zone are possible
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Protection of lines with capacitive series compensation
- Main protection function is differential protection with adaptive algorithm for maximum sensitivity and stability even at different CT errors, CT saturation and capacitive charging currents
- Directional backup protection and various additional functions
- Secure serial protection data communication, also over great distances, and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The differential protection device 7SD86 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds with up to 6 ends. Transformers and compensating coils in the protection zone are also possible. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 6 on page 24 shows all functions that are available in the 7SD86. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 12 Differential protection device 7SD86

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 6 on page 24 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SD86 basic differential protection

- Phase-selective differential protection with 3-pole tripping
- Non-directional overcurrent protection as emergency or backup function
- Fault locator.

7SD86 differential protection for overhead line

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection (Fig. 13).

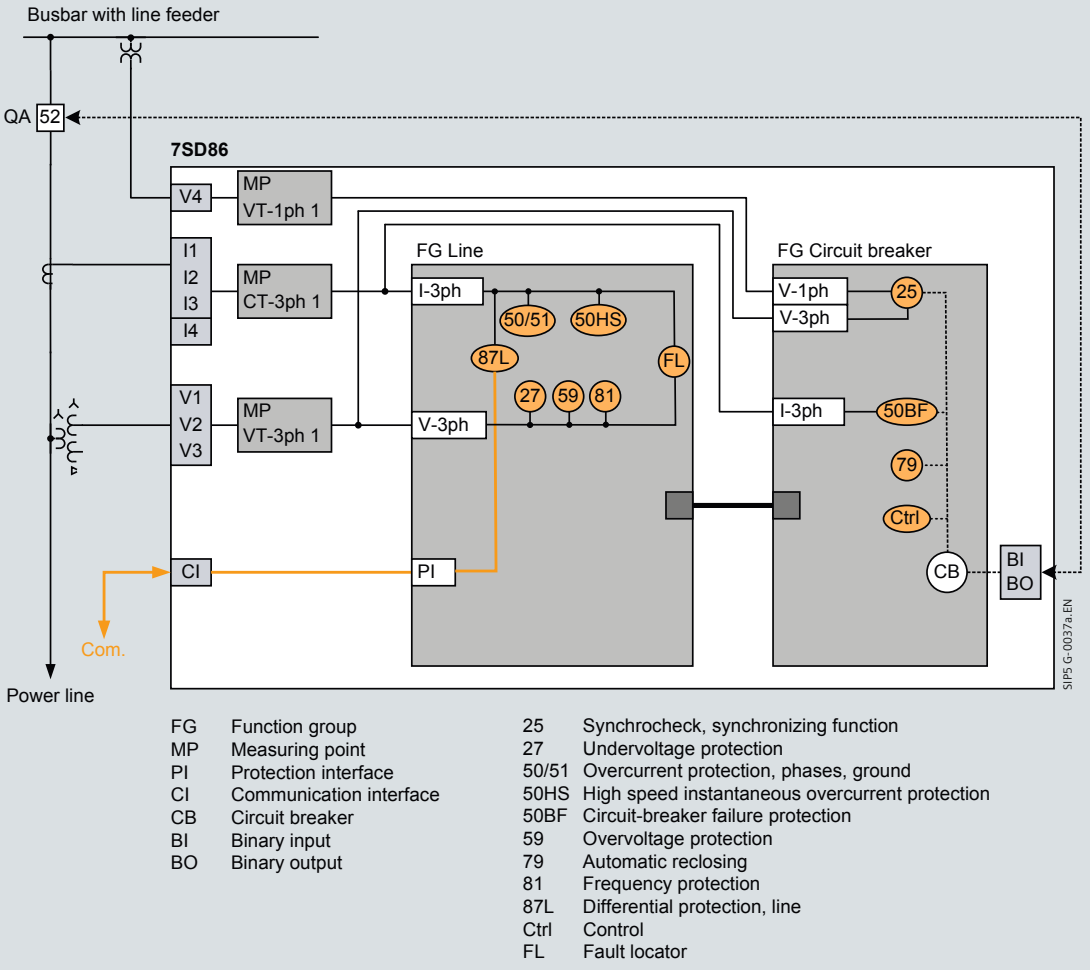
7SD86 differential protection for overhead line with transformer in the protection range

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection.
- Considers a transformer in the protection range.

Differential protection 7SD86 – Application examples

7SD86 differential protection for overhead line, for applications with breaker-and-a-half schemes

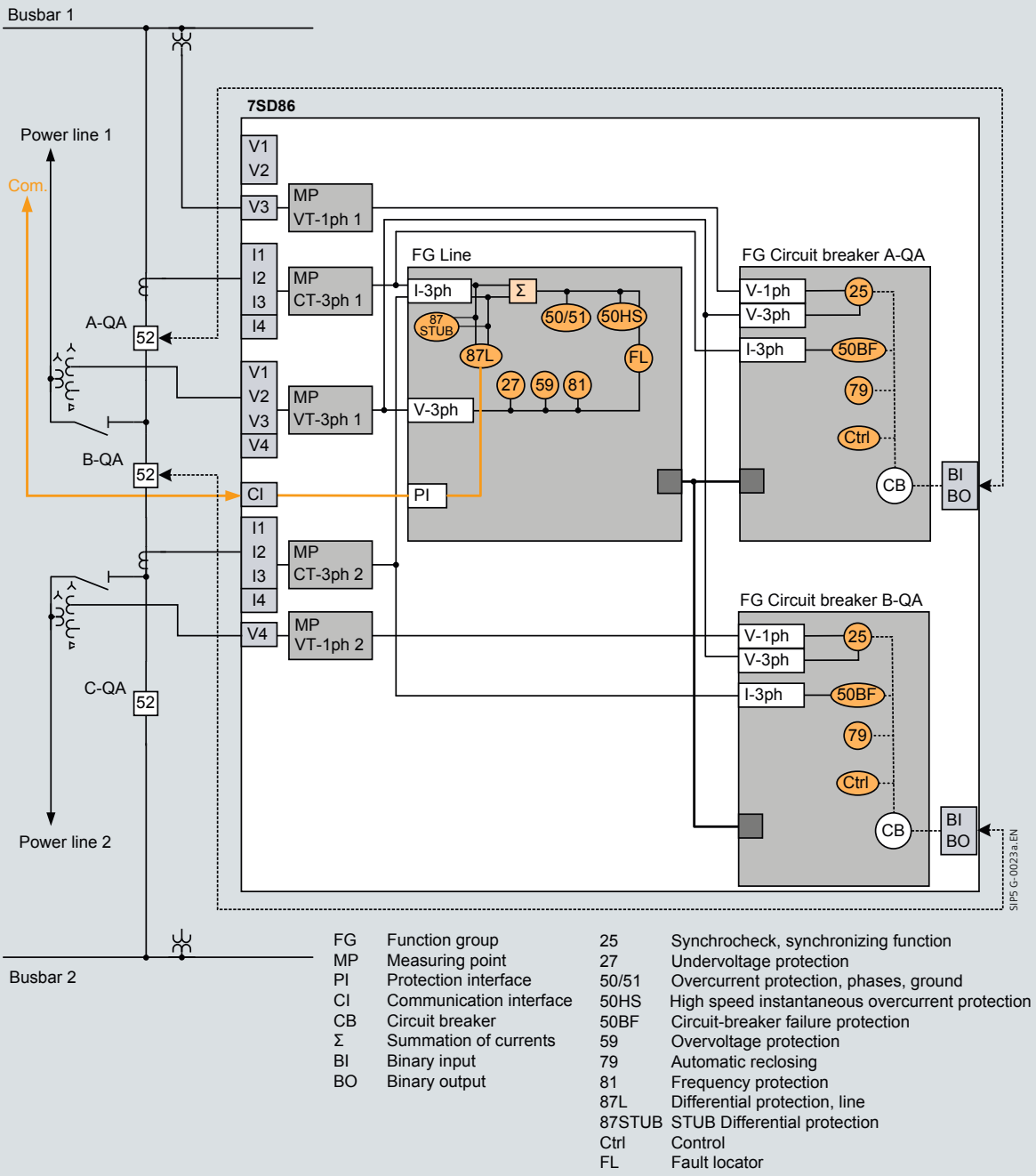
- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection.
- Prepared for applications with breaker-and-a-half schemes (Fig. 14).



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
79	Automatic reclosing
81	Frequency protection
87L	Differential protection, line
Ctrl	Control
FL	Fault locator

Fig. 13 Application example: Line differential protection for overhead line



FG	Function group	25	Synchrocheck, synchronizing function
MP	Measuring point	27	Undervoltage protection
PI	Protection interface	50/51	Overcurrent protection, phases, ground
CI	Communication interface	50HS	High speed instantaneous overcurrent protection
CB	Circuit breaker	50BF	Circuit-breaker failure protection
Σ	Summation of currents	59	Overvoltage protection
BI	Binary input	79	Automatic reclosing
BO	Binary output	81	Frequency protection
		87L	Differential protection, line
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 14 Application example: Line differential protection for overhead line with breaker-and-a-half scheme

Differential protection 7SD86 – Functions, application templates

ANSI	Function	Abbr.	Application templates				
			Available in 7SD86	DIFF Basic	DIFF Overhead line	DIFF Overhead line with transformer	DIFF Overhead line, breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■	■
87L	Line differential protection for 2 line ends	Z<	■	■	■	■	■
87L	Line differential protection for 3 to 6 line ends	ΔI	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		■	■	2
27	Undervoltage protection, 3-phase	V<	■		■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■				
27	Undervoltage protection, 1-phase, V_x *	Vx<	■				
32, 37	Power protection active/reactive power	P<>, Q<>	■				
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■				
49	Thermal overload protection	θ, I²t	■		■	■	■
50 HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	2
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■				
59	Overvoltage protection, compounding	V1comp>	■				
59	Overvoltage protection, negative-sequence system	V2>	■				
59N	Overvoltage protection, zero-sequence system	V0>	■				
59	Overvoltage protection, 1-phase, V_x *	Vx>	■				
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■				
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■				
74TC	Trip-circuit supervision	TCS	■				
79	Automatic reclosing	AR	■		■	■	2
81O	Overfrequency protection	f>	■		■	■	■
81U	Underfrequency protection	f<	■		■	■	■
86	Lockout		■				
87L/87T	Option for line differential protection: including power transformer	ΔI	■			■	
	Option for line differential protection:charging-current compensation		■				
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■				■
	Broken-wire detection for differential protection		■				
FL	Fault locator	FL	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■				
PMU	Synchrophasor measurement	PMU	■				
	Operational measured values, standard		■	■	■	■	■
	Measured values, expanded: Min, Max, Avg (function points per type)		■				
	Switching-statistic counters		■	■	■	■	■
	CFC standard		■	■	■	■	■
	CFC arithmetic		■				
	CFC switching sequences		■				
	Inrush current detection		■				
	External trip initiation		■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■				
	Fault recording of analog and binary signals		■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■
	Protection interface, serial		■	■	■	■	■
	Function points:			0	175	275	325

* Currently under development

Table 6 7SD86 functions, application templates

Properties

Main protection function:	Differential protection
Tripping:	1- and 3-pole, min. tripping time 9 ms
Inputs and outputs:	12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 ×19" to 1/1 ×19"

- Line protection for all voltage levels with 1- and 3-pole tripping
- Phase-selective protection of overhead lines and cables with single- and multi-ended infeeds of all lengths with up to 6 line ends
- Also used in switchgear with breaker-and-a-half schemes
- Transformers and compensating coils in the protection zone are possible
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Protection of lines with capacitive series compensation
- Main protection function is differential protection with adaptive algorithm for maximum sensitivity and stability even in the most varied transformer errors, CT saturation and capacitive charging currents
- Directional backup protection and various additional functions
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The differential protection device 7SD87 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system. Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds with up to 6 ends. Transformers and compensating coils in the protection zone are also possible. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 7 on page 28 shows all functions that are available in the 7SD87. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 15 Differential protection device 7SD87

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 7 on page 28 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SD87 basic differential protection

- Phase-selective differential protection with 1- and 3-pole tripping
- Non-directional overcurrent protection as emergency or backup function
- Fault locator.

7SD87 differential protection for overhead line

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, synchronization function, voltage and frequency protection, thermal overload protection (Fig. 16).

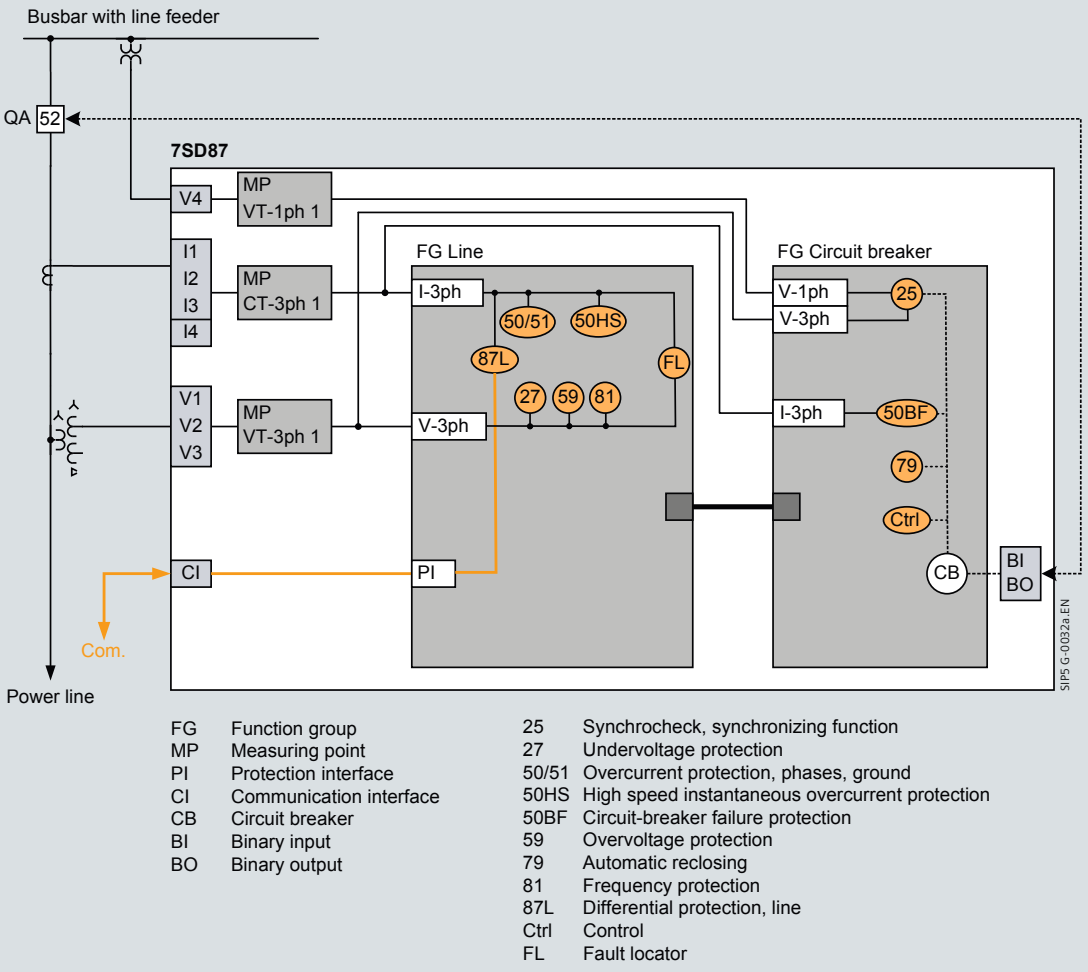
7SD87 differential protection for overhead line with transformer in the protection range

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection.
- Considers a transformer in the protection range.

Differential protection 7SD87 – Application examples

7SD87 differential protection for overhead line, for applications with breaker-and-a-half schemes

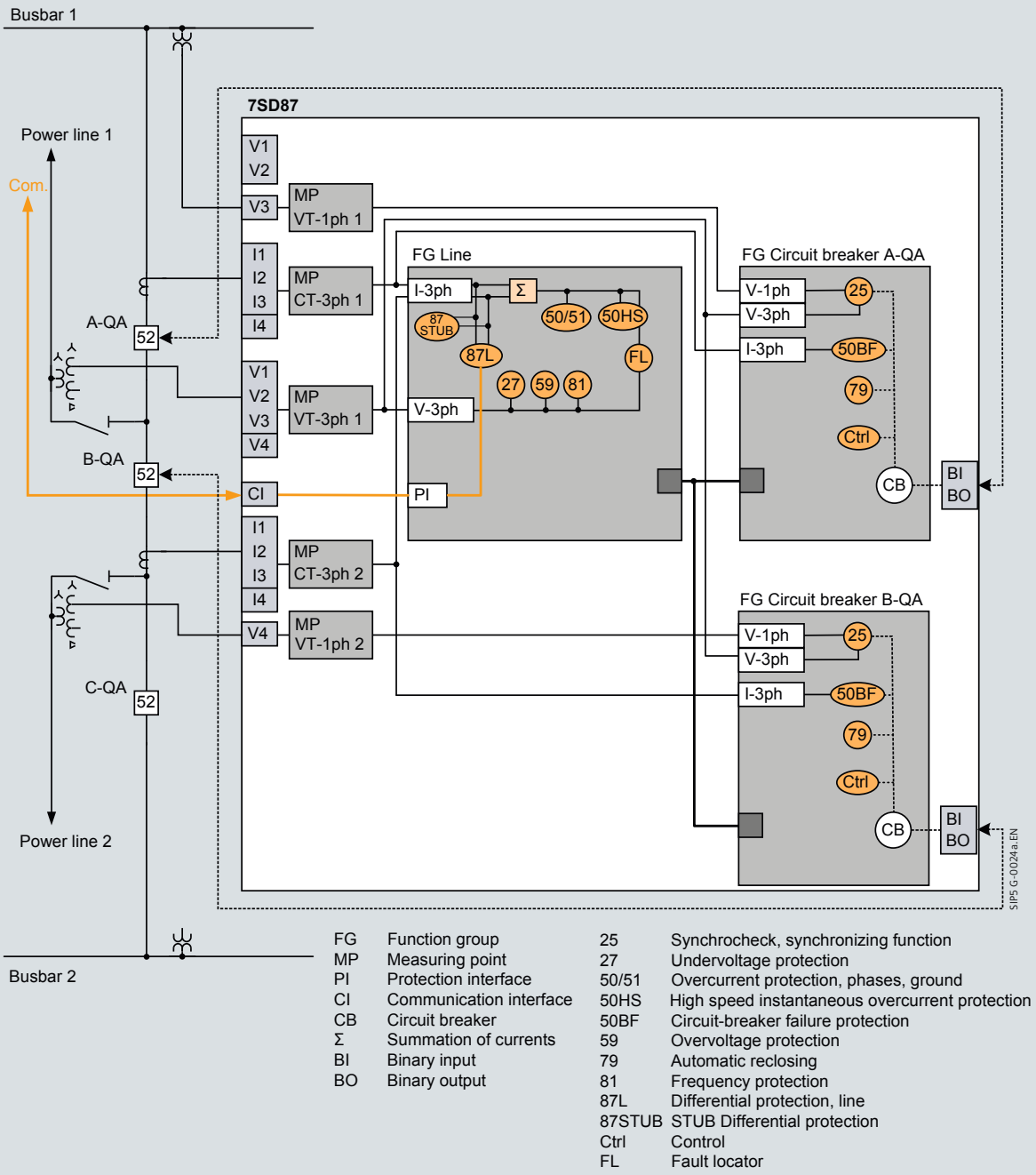
- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection.
- Prepared for applications with breaker-and-a-half schemes (Fig. 17).



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
79	Automatic reclosing
81	Frequency protection
87L	Differential protection, line
Ctrl	Control
FL	Fault locator

Fig. 16 Application example: Line differential protection for overhead line



FG	Function group	25	Synchrocheck, synchronizing function
MP	Measuring point	27	Undervoltage protection
PI	Protection interface	50/51	Overcurrent protection, phases, ground
CI	Communication interface	50HS	High speed instantaneous overcurrent protection
CB	Circuit breaker	50BF	Circuit-breaker failure protection
Σ	Summation of currents	59	Overvoltage protection
BI	Binary input	79	Automatic reclosing
BO	Binary output	81	Frequency protection
		87L	Differential protection, line
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 17 Application example: Line differential protection for overhead line with breaker-and-a-half scheme

Differential Protection 7SD

Differential protection 7SD87 – Functions, application templates

ANSI	Function	Abbr.	Available in 7SD87	Application templates: DIFF Basic	DIFF Overhead line	DIFF Overhead line with transformer	DIFF Overhead line, breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■
	Protection functions for 1-pole tripping	1-pole	■	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■	■
87L	Line differential protection for 2 line ends	ΔI	■	■	■	■	■
87L	Line differential protection for 3 to 6 line ends	ΔI	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		■	■	2
27	Undervoltage protection, 3-phase	V<	■		■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■				
27	Undervoltage protection, 1-phase, V_x *	Vx<	■				
32, 37	Power protection active/reactive power	P<>, Q<>	■				
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■				
49	Thermal overload protection	θ, I²t	■		■	■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	2
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■				
59	Overvoltage protection, compounding	V1comp>	■				
59	Overvoltage protection, negative-sequence system	V2>	■				
59N	Overvoltage protection, zero-sequence system	V0>	■				
59	Overvoltage protection, 1-phase, V_x *	Vx>	■				
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■				
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■				
74TC	Trip-circuit supervision	TCS	■				
79	Automatic reclosing	AR	■		■	■	2
81O	Overfrequency protection	f>	■		■	■	■
81U	Underfrequency protection	f<	■		■	■	■
86	Lockout		■		■	■	■
87L/87T	Option for line protection: including power transformer	ΔI	■			■	
	Option for line differential protection: charging-current compensation		■				
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■				■
	Broken-wire detection for differential protection		■				
FL	Fault locator	FL	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■				
PMU	Synchrophasor measurement	PMU	■				
	Operational measured values, standard		■	■	■	■	■
	Measured values, expanded: Min, Max, Avg (function points per type)		■				
	Switching-statistic counters		■	■	■	■	■
	CFC standard		■	■	■	■	■
	CFC arithmetic		■				
	CFC switching sequences		■				
	Inrush current detection		■	■	■	■	■
	External trip initiation		■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■				
	Fault recording of analog and binary signals		■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■
	Protection interface, serial		■	■	■	■	■
	Function points:			0	175	275	350

* Currently under development

Table 7 7SD87 functions, application templates

Differential protection and distance protection 7SL86 – Applications

Properties

Main protection function:	Differential protection and distance protection
Tripping:	3-pole, min. tripping time 9 ms
Inputs and outputs:	• 12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or
Hardware flexibility:	• flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 ×19" to 1/1 ×19"

- Line protection for all voltage levels with 3-pole tripping
- Phase-selective protection of overhead lines and cables with single- and multi-ended infeeds
- Used on lines of all lengths with up to 6 line ends
- Also used in switchgear with breaker-and-a-half schemes
- Transformers and compensating coils in the protection zone are possible
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Protection of lines with capacitive series compensation
- Two independent main protection functions with various protection algorithms
- Main 1 protection: Differential protection with very short tripping time. The adaptive algorithm guarantees maximum sensitivity and stability, even in case of different CT errors, CT saturation and capacitive charging currents.
- Main 2 protection: 6-system distance protection with very short tripping time and high accuracy also when detecting CT saturation.
- Adaptive power-swing blocking
- Various additional functions
- Secure serial protection data communication, also over great distances, and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The combined differential and distance protection 7SL86 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system.

Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds of all lengths with up to 6 ends. Transformers and compensating coils in the protection zone are also possible. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Fig. 18 Differential protection and distance protection 7SL86

Functions

Table 8 on page 32 shows all functions that are available in the 7SL86. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 8 on page 32 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SL86 basic differential and distance protection

- Phase-selective differential protection with 3-pole tripping
- Distance protection with 3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection as emergency or backup function
- Teleprotection functions
- Fault locator.

7SL86 differential and distance protection for overhead line in grounded systems

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection.

Differential protection and distance protection 7SL86 – Application examples

7SL86 differential and distance protection with MHO distance zone characteristic for overhead line in grounded systems

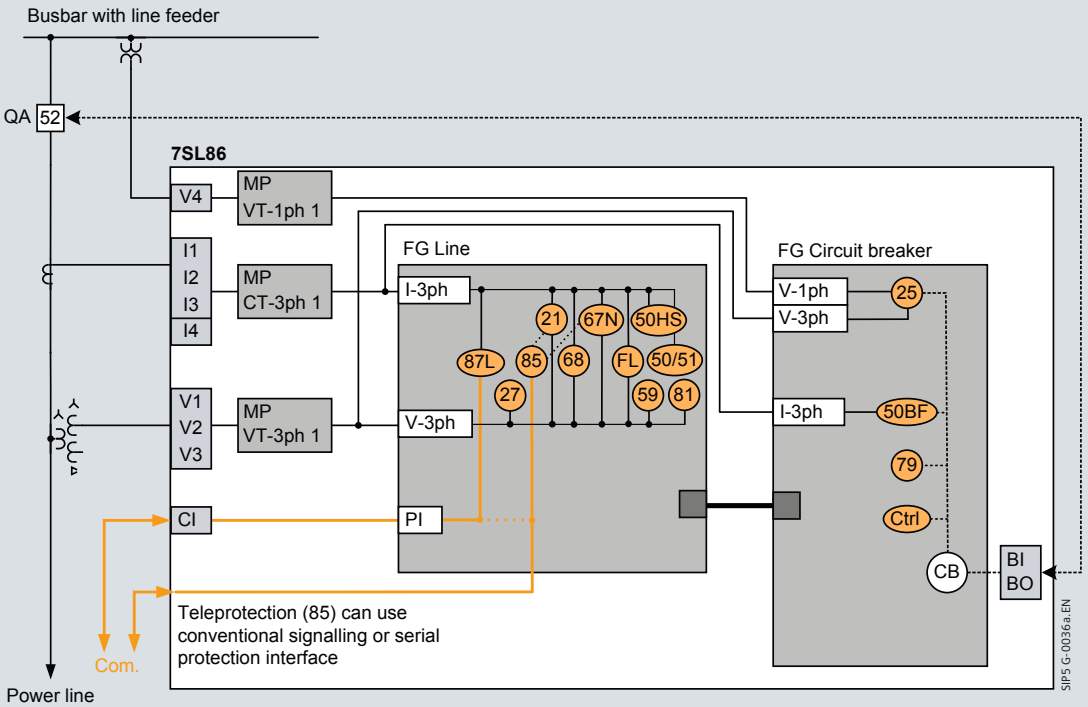
- Comprises the basic functions with MHO distance zone characteristics as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point (Fig. 19).

7SL86 differential and distance protection for overhead line in grounded systems, with AR for applications with breaker-and-a-half schemes

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point
- Prepared for applications with breaker-and-a-half schemes (Fig. 20).

7SL86 differential and distance protection with MHO distance zone characteristics for overhead line in grounded systems, with AR for applications with breaker-and-a-half schemes

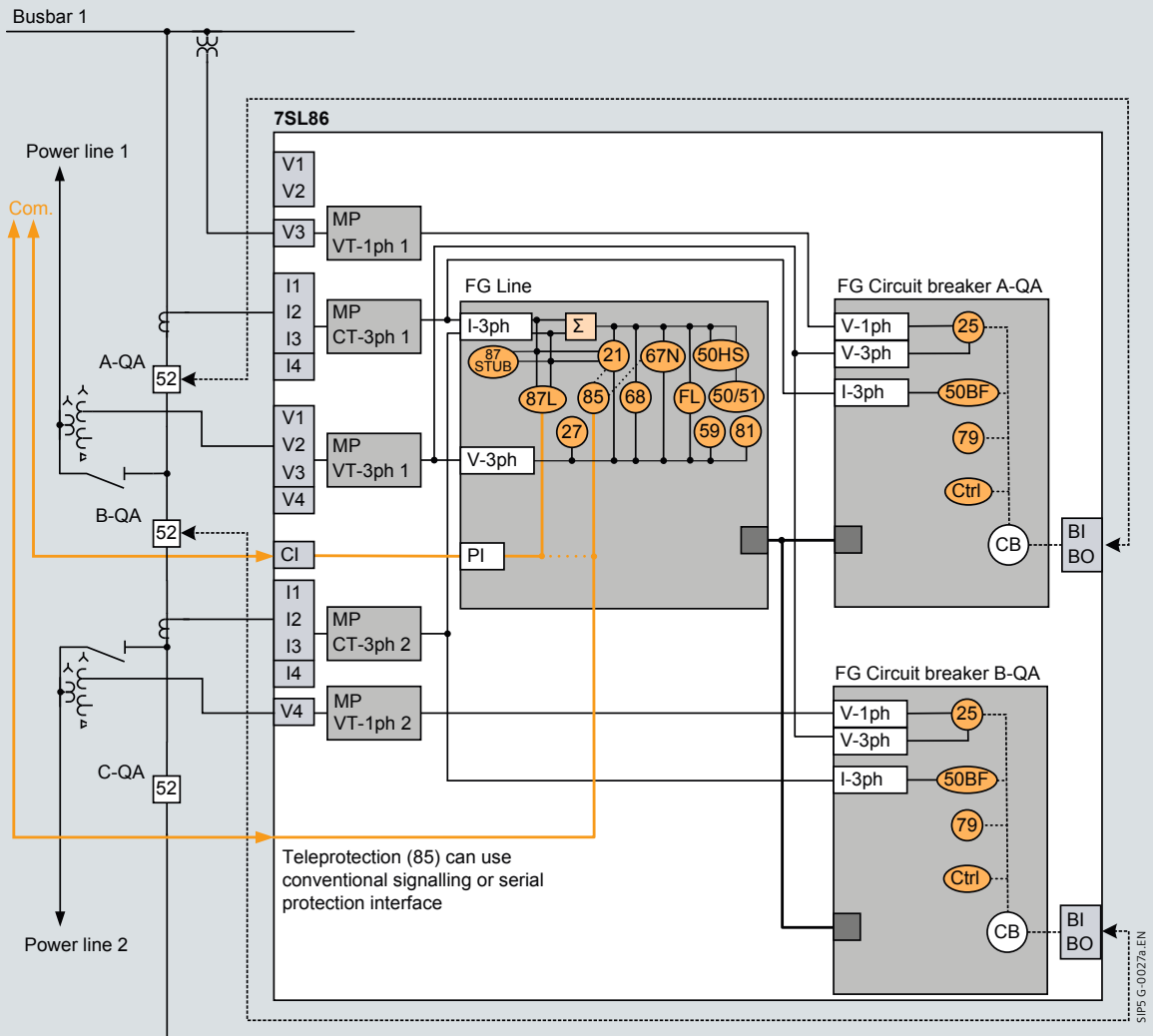
- Comprises the basic functions with MHO distance zone characteristics as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point
- Prepared for applications with breaker-and-a-half schemes (Fig. 20).



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

21	Distance protection
25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
67N	Directional overcurrent protection for ground-faults
68	Power-swing blocking
79	Automatic reclosing
81	Frequency protection
85	Teleprotection schemes for 21 and/or 67 N
Ctrl	Control
FL	Fault locator

Fig. 19 Application example: Combined line differential and distance protection for overhead line



FG	Function group	21	Distance protection
MP	Measuring point	25	Synchrocheck, synchronizing function
PI	Protection interface	27	Undervoltage protection
CI	Communication interface	50/51	Overcurrent protection, phases, ground
CB	Circuit breaker	50HS	High speed instantaneous overcurrent protection
Σ	Summation of currents	50BF	Circuit-breaker failure protection
BI	Binary input	59	Overvoltage protection
BO	Binary output	67N	Directional overcurrent protection for ground-faults
		68	Power-swing blocking
		79	Automatic reclosing
		81	Frequency protection
		85	Teleprotection schemes for 21 and/or 67N
		87L	Differential protection, line
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 20 Application example: Combined line differential and distance protection for overhead line with breaker-and-a-half scheme

Differential protection and distance protection 7SL86 – Functions, application templates

ANSI	Function	Abbr.	Available in 7SL86	Application templates: DIFF/DIS Basic	DIFF/DIS overhead line, grounded systems	DIFF/DIS MHO, overhead line, grounded systems	DIFF/DIS overhead line, grounded syst. breaker-and-a-half	DIFF/DIS MHO, overhead line, grounded breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■	■	■
21, 21N	Distance protection	Z<	■	■	■	■	■	■
87L	Line differential protection for 2 line ends	ΔI	■	■	■	■	■	■
87L	Line differential protection for 3 to 6 line ends	ΔI	■	■	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		■	■	2	2
27	Undervoltage protection, 3-phase	V<	■		■	■	■	■
27	Undervoltage protection, positive-sequence system	V1<	■					
27	Undervoltage protection, 1-phase, V_x *	Vx<	■					
32, 37	Power protection active/reactive power	P<>, Q<>	■					
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■					
49	Thermal overload protection	θ, I²t	■		■	■	■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	■	2	2
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■	■	■
59	Overvoltage protection, positive-sequence system	V1>	■					
59	Overvoltage protection, compounding	V1comp>	■					
59	Overvoltage protection, negative-sequence system	V2>	■					
59N	Overvoltage protection, zero-sequence system	V0>	■					
59	Overvoltage protection, 1-phase, V_x *	Vx>	■					
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■					
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■		■	■	■	■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■					
68	Power-swing blocking	ΔZ/Δt	■		■	■	■	■
74TC	Trip-circuit supervision	TCS	■					
78	Out-of-step protection	ΔZ/Δt	■					
79	Automatic reclosing	AR	■		■	■	2	2
81O	Overfrequency protection	f>	■		■	■	■	■
81U	Underfrequency protection	f<	■		■	■	■	■
85/21	Teleprotection for distance protection		■	■	■	■	■	■
85/27	Weak or no infeed: Echo and tripping	WI	■	■	■	■	■	■
85/67N	Teleprotection for directional ground-fault protection		■	■	■	■	■	■
86	Lockout		■					
87L/87T	Option for line differential protection: including power transformer	ΔI	■					
	Option for line differential protection: charging-current compensation		■					
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■				■	■
	Broken-wire detection for differential protection		■					
FL	Fault locator	FL	■	■	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■					
PMU	Synchrophasor measurement	PMU	■					
	Operational measured values, standard		■	■	■	■	■	■
	Measured values, expanded: Min, Max, Avg (function points per type)		■					
	Switching-statistic counters		■	■	■	■	■	■
	CFC standard		■	■	■	■	■	■
	CFC arithmetic		■					
	CFC switching sequences		■					
	Inrush current detection		■					
	External trip initiation		■	■	■	■	■	■
	Control for 4 switching devices		■	■	■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■					
	Fault recording of analog and binary signals		■	■	■	■	■	■
	Monitoring and supervision		■	■	■	■	■	■
	Protection interface, serial		■	■	■	■	■	■
	Function points:			0	225	225	375	375

*Currently under development

Table 8 7SL86 functions, application templates

Differential protection and distance protection 7SL87 – Applications

Properties

Main protection function:	Distance and differential protection
Tripping:	1- and 3-pole, min. tripping time 9 ms
Inputs and outputs: Hardware flexibility:	12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 ×19" to 1/1 ×19"

- Line protection for all voltage levels with 1- and 3-pole tripping
- Phase-selective protection of overhead lines and cables with single- and multi-ended infeeds
- Used on lines of all lengths with up to 6 line ends
- Also used in switchgear with breaker-and-a-half schemes
- Transformers and compensating coils in the protection zone are possible
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Protection of lines with capacitive series compensation
- Two independent main protection functions with various protection algorithms
- Main 1 protection: Differential protection with very short tripping time. The adaptive algorithm guarantees maximum sensitivity and stability, also in case of the most varied transformer errors, CT saturation and capacitive charging currents
- Main 2 protection: 6-system distance protection with very short tripping time and high accuracy also when detecting CT saturation
- Adaptive power-swing blocking
- Various additional functions
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The combined differential and distance protection 7SL87 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system.

Due to its high flexibility, it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds of all lengths with up to 6 ends. Transformers and compensating coils in the protection zone are also possible. The device is delivered with the aforementioned number of analog and binary inputs and outputs. Apart from that, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Fig. 21 Differential protection and distance protection 7SL87

Functions

Table 9 on page 36 shows all functions that are available in the 7SL87. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 9 on page 36 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

7SL87 basic differential and distance protection

- Phase-selective differential protection with 1- and 3-pole tripping
- Distance protection with 1- and 3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection as emergency or backup function
- Teleprotection functions
- Fault locator.

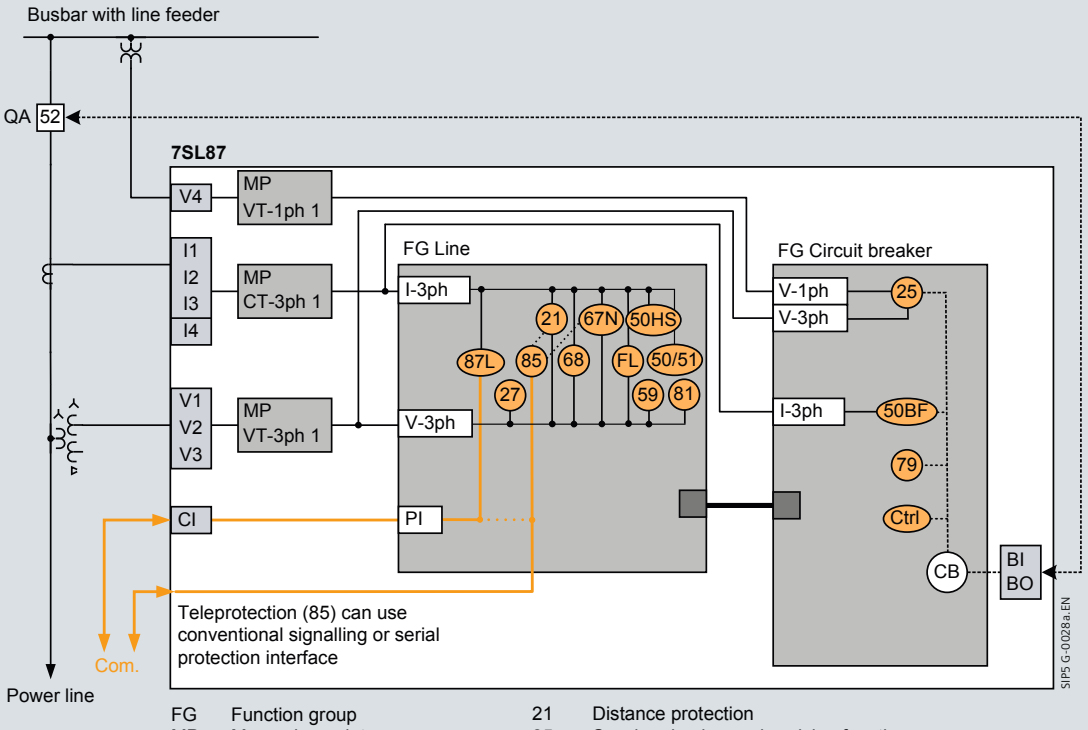
Differential protection and distance protection 7SL87 – Application examples

7SL87 differential and distance protection for overhead line in grounded systems

- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point: Circuit-breaker failure protection, AR, synchronization function, voltage and frequency protection, thermal overload protection (Fig. 22).

7SL87 differential and distance protection for overhead line in grounded systems for applications with breaker-and-a-half schemes

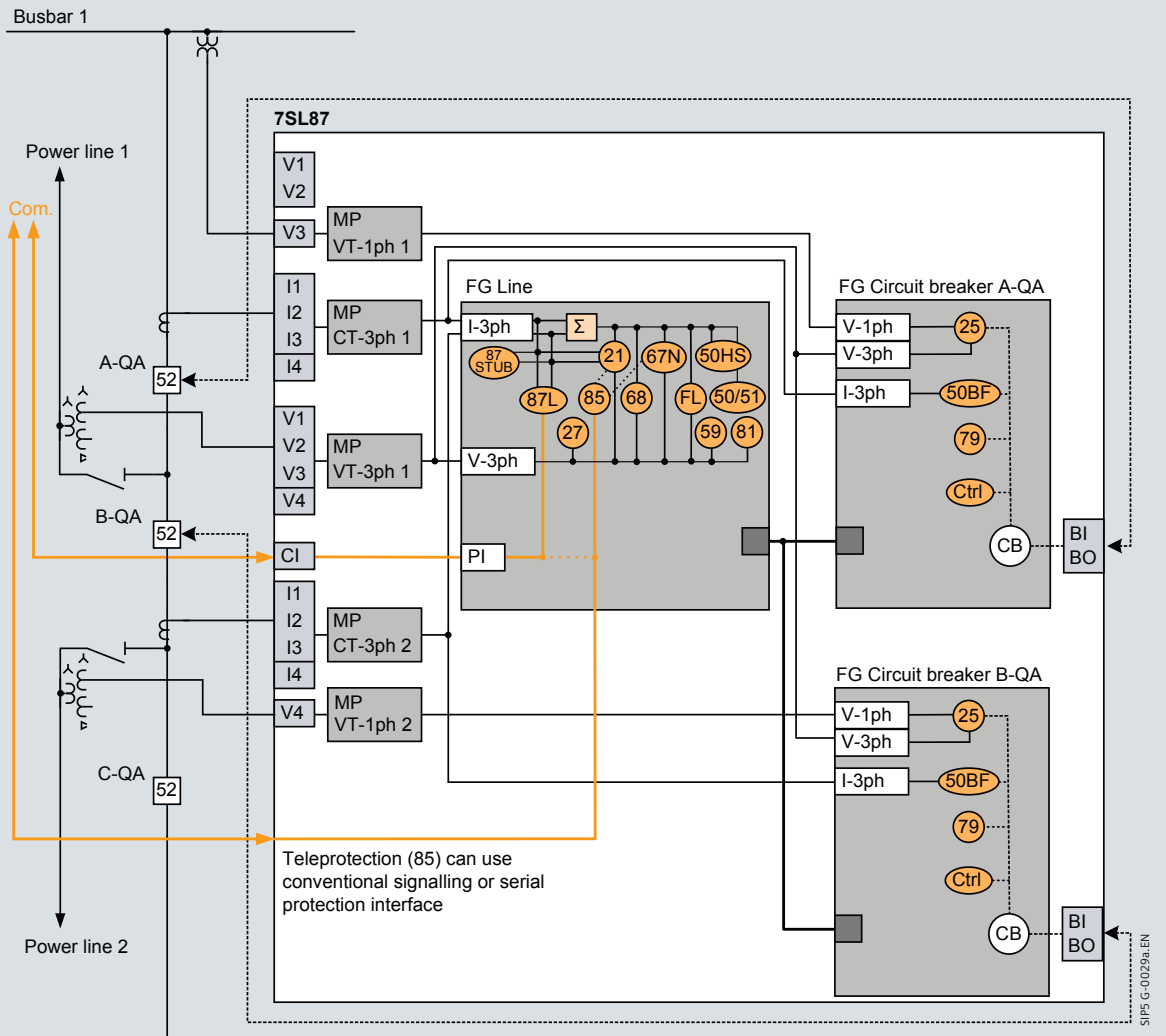
- Comprises the basic functions as well as additional functions that are typically required for the protection of overhead lines in networks with grounded neutral point.
- Prepared for applications with breaker-and-a-half schemes (Fig. 23).



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

21	Distance protection
25	Synchrocheck, synchronizing function
27	Undervoltage protection
50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
50BF	Circuit-breaker failure protection
59	Overvoltage protection
67N	Directional overcurrent protection for ground-faults
68	Power-swing blocking
79	Automatic reclosing
81	Frequency protection
85	Teleprotection schemes
Ctrl	Control
FL	Fault locator

Fig. 22 Application example: Combined line differential and distance protection for overhead line



FG	Function group	21	Distance protection
MP	Measuring point	25	Synchrocheck, synchronizing function
PI	Protection interface	27	Undervoltage protection
CI	Communication interface	50/51	Overcurrent protection, phases, ground
CB	Circuit breaker	50HS	High speed instantaneous overcurrent protection
Σ	Summation of currents	50BF	Circuit-breaker failure protection
BI	Binary input	59	Overvoltage protection
BO	Binary output	67N	Directional overcurrent protection for ground-faults
		68	Power-swing blocking
		79	Automatic reclosing
		81	Frequency protection
		85	Teleprotection schemes for 21 and/or 67N
		87L	Differential protection, line
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 23 Application example: Combined line differential and distance protection for overhead line with breaker-and-a-half scheme

Differential protection and distance protection 7SL87 – Functions, application templates

ANSI	Function	Abbr.	Application templates: Available in 7SL87	DIFF/DIS Basic	DIFF/DIS overhead line, grounded systems	DIFF/DIS overhead line, ground. syst. breaker-and-a-half
	Protection functions for 3-pole tripping	3-pole	■	■	■	■
	Protection functions for 1-pole tripping	1-pole	■	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■	■
21, 21N	Distance protection	Z<	■	■	■	■
87L	Line differential protection for 2 line ends	ΔI	■	■	■	■
87L	Line differential protection for 3 to 6 line ends	ΔI	■	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		■	2
27	Undervoltage protection, 3-phase	V<	■		■	■
27	Undervoltage protection, positive-sequence system	V1<	■			
27	Undervoltage protection, 1-phase, V_x *	Vx<	■			
32, 37	Power protection active/reactive power	P<>, Q<>	■			
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■			
49	Thermal overload protection	θ, I²t	■		■	■
50HS	High speed instantaneous overcurrent protection	I>>>	■	■	■	■
50BF	Circuit-breaker failure protection	CBFP	■		■	2
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■	■
59	Overvoltage protection, 3-phase	V>	■		■	■
59	Overvoltage protection, positive-sequence system	V1>	■			
59	Overvoltage protection, compounding	V1comp>	■			
59	Overvoltage protection, negative-sequence system	V2>	■			
59N	Overvoltage protection, zero-sequence system	V0>	■			
59	Overvoltage protection, 1-phase, V_x *	Vx>	■			
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■			
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■		■	■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■			
68	Power-swing blocking	ΔZ/Δt	■		■	■
74TC	Trip-circuit supervision	TCS	■			
78	Out-of-step protection	ΔZ/Δt	■			
79	Automatic reclosing	AR	■		■	2
81O	Overfrequency protection	f>	■		■	■
81U	Underfrequency protection	f<	■		■	■
85/21	Teleprotection for distance protection		■	■	■	■
85/27	Weak or no infeed: Echo and tripping	WI	■	■	■	■
85/67N	Teleprotection for directional ground-fault protection		■	■	■	■
86	Lockout		■			
87L/87T	Option for line differential protection: including power transformer	ΔI	■			
	Option for line differential protection: charging-current compensation		■			
87STUB	STUB differential protection (for breaker-and-a-half schemes)	ΔI	■			■
	Broken-wire detection for differential protection		■			
FL	Fault locator	FL	■	■	■	■
FL	Fault locator, two-ended measurement*	FL-two	■			
PMU	Synchrophasor measurement	PMU	■			
	Operational measured values, standard		■	■	■	■
	Measured values, expanded: Min, Max, Avg (function points per type)		■			
	Switching-statistic counters		■	■	■	■
	CFC standard		■	■	■	■
	CFC arithmetic		■			
	CFC switching sequences		■			
	Inrush current detection		■			
	External trip initiation		■	■	■	■
	Control for 4 switching devices		■	■	■	■
	Control for more than 4 switching devices (function points per switching device)		■			
	Fault recording of analog and binary signals		■	■	■	■
	Monitoring and supervision		■	■	■	■
	Protection interface, serial		■	■	■	■
	Function points:			0	250	425

* Currently under development

Table 9 7SL87 functions, application templates

Circuit-breaker management device 7VK87 – Applications

Properties

Main protection function:	Automatic reclosing, synchrocheck, circuit-breaker failure protection
Tripping:	1- and 3-pole or 3-pole
Inputs and outputs:	12 predefined standard variants with 4/4 or 8/8 current/voltage transformers, 5 to 31 binary inputs, 8 to 46 binary outputs or
Hardware flexibility:	flexibly adjustable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 × 19" to 1/1 × 19"

- Automatic reclosing function and synchrocheck for line protection applications with 1- and 3-pole tripping
- Circuit-breaker failure protection with 2 stages for 1- and 3-pole tripping
- Various additional functions
- Secure serial protection data communication, also over great distances and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The circuit-breaker management device 7VK87 is a universal automation, protection and control device on the basis of the SIPROTEC 5 system.

The device is used for automatic reclosing after 1- or 3-pole tripping of the circuit breaker after a short circuit. Before automatic reclosing after 3-pole tripping, the reliability of the reclosure can be checked by synchronization check.

The 7VK87 can also be used as a 2-stage circuit-breaker failure protection after 1- or 3-pole tripping by the main protection.

The device can work together with conventional and digital protection equipment requiring only the pertinent pickup and tripping operations. The start and output signals can be connected via contacts or digital communication. Otherwise, the device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 10 on page 39 shows all functions that are available in the 7VK87. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 24 Circuit-breaker management device 7VK87

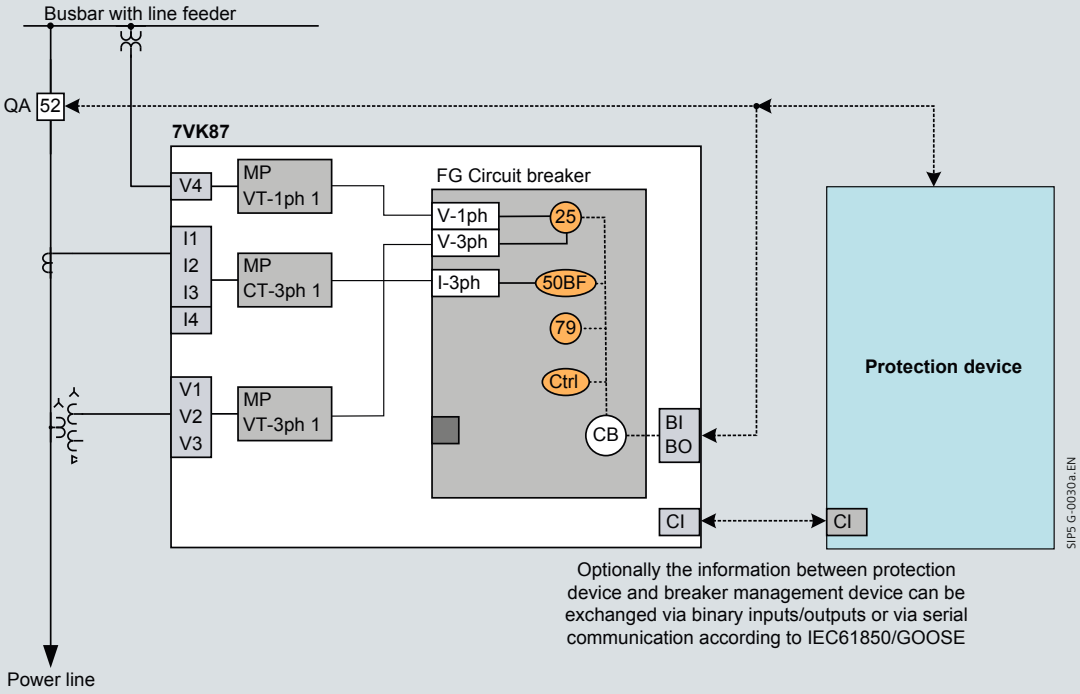
Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 10 on page 39 shows the functional scope. For 7VK87, the following application template exists:

7VK87 basic circuit-breaker management device

- Automatic reclosing after 1-pole or 3-pole tripping
- Synchronization function
- Circuit-breaker failure protection for 1- and 3-pole tripping (Fig. 25).

Circuit-breaker management device 7VK87 – Application examples



FG	Function group	25	Synchrocheck, synchronizing function
MP	Measuring point	50BF	Breaker failure protection
CI	Communication interface	79	Automatic reclosing
CB	Circuit breaker	Ctrl	Control
BI	Binary input		
BO	Binary output		

Fig. 25 Application example: Circuit-breaker management device

Circuit-breaker management device 7VK87 – Functions, application templates

ANSI	Function	Abbr.	Application templates: Available in 7VK87	Application templates: Basic (AR, Sync., Circuit-breaker failure protection
	Protection functions for 3-pole tripping	3-pole	■	■
	Protection functions for 1-pole tripping	1-pole	■	■
	Hardware quantity structure expandable	I/O	■	■
25	Synchrocheck, synchronizing function	Sync	■	■
27	Undervoltage protection, 3-phase	V<	■	
27	Undervoltage protection, positive-sequence system	V1<	■	
27	Undervoltage protection, 1-phase, V_x *	Vx<	■	
32, 37	Power protection active/reactive power	P<>, Q<>	■	
50HS	High speed instantaneous overcurrent protection	I>>>	■	
50BF	Circuit-breaker failure protection	CBFP	■	■
50/51	Overcurrent protection, phases	I>, I_p>	■	
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	
59	Overvoltage protection, 3-phase	V>	■	
59	Overvoltage protection, positive-sequence system	V1>	■	
59	Overvoltage protection, compounding	V1comp>	■	
59	Overvoltage protection, negative-sequence system	V2>	■	
59N	Overvoltage protection, zero-sequence system	V0>	■	
59	Overvoltage protection, 1-phase, V_x *	Vx>	■	
67	Directional overcurrent protection, phases	I>, $I_p\angle$ (V,I)	■	
74TC	Trip-circuit supervision	TCS	■	
79	Automatic reclosing	AR	■	■
81O	Overfrequency protection	f>	■	
81U	Underfrequency protection	f<	■	
86	Lockout		■	
PMU	Synchrophasor measurement	PMU	■	
	Operational measured values, standard		■	■
	Measured values, expanded: Min, Max, Avg (function points per type)		■	
	Switching-statistic counters		■	■
	CFC standard		■	■
	CFC arithmetic		■	
	CFC switching sequences		■	
	Inrush current detection		■	
	External trip initiation		■	■
	Control for 4 switching devices		■	■
	Control for more than 4 switching devices (function points per switching device)		■	
	Fault recording of analog and binary signals		■	■
	Monitoring and supervision		■	■
	Protection interface, serial		■	
	Function points:			0

* Currently under development

Table 10 7KL87 functions, application templates

Overcurrent protection 7SJ86 – Applications

Properties

Main protection function:	Overcurrent protection
Tripping:	3-pole
Inputs and outputs:	3 predefined standard variants with 4/4 current/voltage transformers, 11 to 23 binary inputs, 9 to 25 binary outputs or
Hardware flexibility:	flexibly adjustable and expandable I/O quantity structure within the scope of the SIPROTEC 5 modular system
Width of housing:	1/3 × 19" to 1/1 × 19"

- Overcurrent protection for all voltage levels with 3-pole tripping
- Also used in switchgear with breaker-and-a-half-schemes
- Selective protection of overhead lines and cables with single- and multi-ended feeders for use of protection data communication
- Suitable for radial, ring or any type of meshed systems of any voltage level with grounded, compensated or isolated neutral point
- Main protection: Directional and non-directional overcurrent protection for phasor- and ground-fault
- Overcurrent protection also configurable as emergency function
- Additional functions
- Secure serial protection data communication, also over great distances, and all available physical media (fiber-optic cable, 2-wire connections and communication networks)
- Control of switching devices
- Measurement of operating values and synchrophasors
- Powerful fault recording
- Consistent monitoring concept
- Auxiliary functions for simple tests and commissioning.

Applications

The overcurrent protection 7SJ86 is a universal protection, control and automation device on the basis of the SIPROTEC 5 system.

It is especially designed for the protection of lines and therefore it is optimally suitable for reserve or emergency protection for the line protection devices.

Due to its high flexibility in using of protection-data communication it is suitable as selective protection equipment for overhead lines and cables with single- and multi-ended infeeds. The device supports all SIPROTEC 5 system characteristics. It enables future-oriented system solutions with high investment security and low operating costs.

Functions

Table 11 on page 42 shows all functions that are available in the 7SJ86. Basically, all functions can be configured freely with DIGSI 5. For the application of some of the functions, you require the appropriate number of free function points within the device. The function point calculator in the online configurator provides support in determining the required number of function points for your device.

Fig. 26 Overcurrent protection 7SJ86

Application templates

Application templates are available in DIGSI for standard applications. They comprise all basic configurations and default settings. Table 11 on page 42 shows the functional scope and the function point requirement for the application templates described. The following application templates are available:

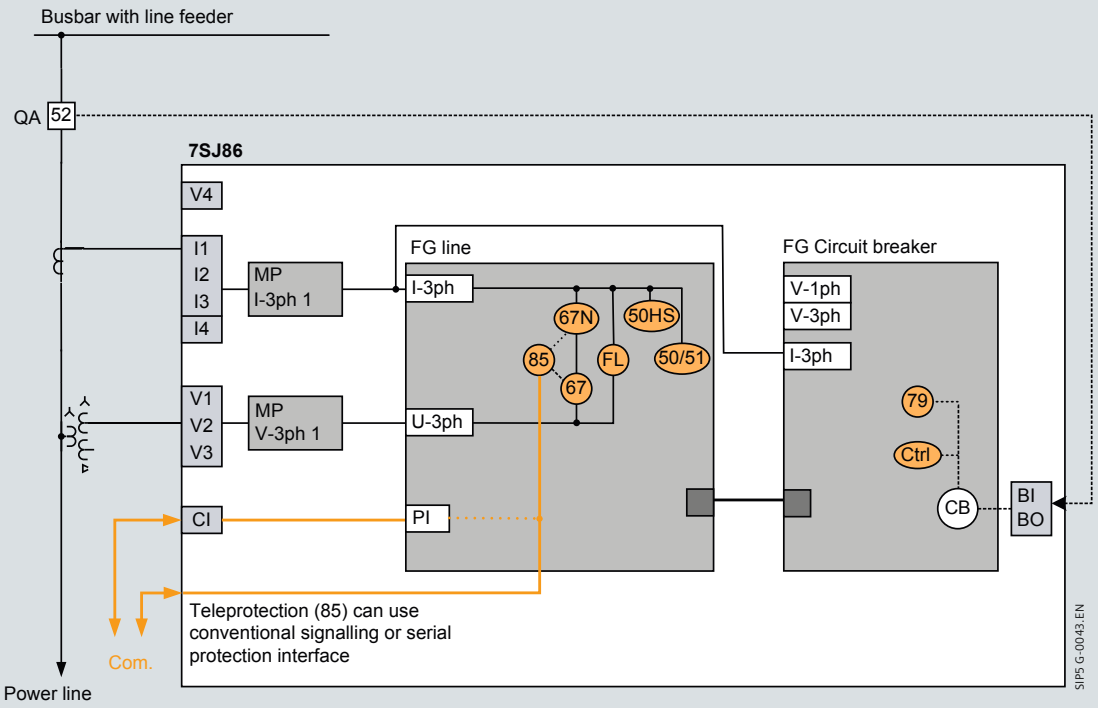
7SJ86 non-directional overcurrent protection

- Distance protection with 3-pole tripping for networks with all kinds of neutral point treatment
- Non-directional overcurrent protection also configurable as emergency function
- Circuit-breaker control.

7SJ86 directional overcurrent protection

- Comprises the functions of the non-directional overcurrent protection
- Directional overcurrent protection for phases and ground, also configurable as emergency function
- Measuring-voltage failure detection.

Figure 26 shows an application example for directional protection for overhead line. The functional scope is based on the application template directional overcurrent protection. In addition the functions fault locator and automatic reclosing were loaded from the DIGSI 5 library.



FG	Function group
MP	Measuring point
PI	Protection interface
CI	Communication interface
CB	Circuit breaker
BI	Binary input
BO	Binary output

50/51	Overcurrent protection, phases, ground
50HS	High speed instantaneous overcurrent protection
67	Directional overcurrent protection, Phase
67N	Directional overcurrent protection for ground-faults
79	Automatic reclosing
85	Teleprotection schemes
Ctrl	Control
FL	Fault locator

Fig. 27 Application example: directional overcurrent protection for overhead line

Overcurrent Protection for Line 7SJ86

Overcurrent protection 7SJ86 – Functions, application templates

ANSI	Functions	Abbr.	Application templates: Available in 7SJ86	Non-directional overcurrent	Directional overcurrent
	Protection functions for 3-pole tripping	3-pole	■	■	■
	Hardware quantity structure expandable	I/O	■	■	■
25	Synchrocheck, synchronizing function	Sync	■		
27	Undervoltage protection, 3-phase	V<	■		
27	Undervoltage protection, positive-sequence system	V1<	■		
27	Undervoltage protection, 1-phase, V_x *	Vx<	■		
32, 37	Power protection active/reactive power	P<>, Q<>	■		
46	Negative-sequence system overcurrent protection with direction	I2>, ∠(V2,I2)	■		
49	Thermal overload protection	θ, I^2t	■		
50HS	High speed instantaneous overcurrent protection	I>>>	■		
50BF	Circuit-breaker failure protection	CBFP	■		
50/51	Overcurrent protection, phases	I>, I_p>	■	■	■
50N/51N	Overcurrent protection, ground faults	I_N>, I_{NP}>	■	■	■
59	Overvoltage protection, 3-phase	V>	■		
59	Overvoltage protection, positive-sequence system	V1>	■		
59	Overvoltage protection, compounding	V1comp>	■		
59	Overvoltage protection, negative-sequence system	V2>	■		
59N	Overvoltage protection, zero-sequence system	V0>	■		
59	Overvoltage protection, 1-phase, V_x *	Vx>	■		
67	Directional overcurrent protection, phases	I>, I_p∠ (V,I)	■		■
67N	Directional overcurrent protection for ground faults	I_N>, I_{NP} ∠ (V,I)	■		■
67Ns	Sensitive ground-fault detection for systems with resonant or isolated neutral *	I_N>, ∠ (V,I)	■		
74TC	Trip-circuit supervision	TCS	■		
79	Automatic reclosing	AR	■		
81O	Overfrequency protection	f>	■		
81U	Underfrequency protection	f<	■		
85/67N	Teleprotection for directional ground-fault protection		■		
86	Lockout		■		
FL	Fault locator	FL	■		
FL	Fault locator, two-ended measurement *	FL-two	■		
PMU	Synchrophasor measurement	PMU	■		
	Operational measured values, standard		■	■	■
	Measured values, extended: Min, Max, Avg (function points per type)		■		
	Switching-statistic counters		■	■	■
	CFC standard		■	■	■
	CFC arithmetic		■		
	CFC switching sequences		■		
	Inrush current detection		■		
	External trip initiation		■		
	Control for 4 switching devices		■	■	■
	Function points:			0	35

*Currently under development

Table 11 7SJ86 Functions, application templates

Functional integration

Due to the modular design of its hardware and software and the powerful engineering tool DIGSI 5, SIPROTEC 5 is ideally suited for protection, automation, measurement and monitoring tasks in the electrical power systems. The devices are not only pure protection and control equipment, their performance enables them to assure functional integration of desired depth and scope. For example, they can also serve to perform monitoring, phasor measurement, fault recording, a wide range of measurement functions and much more, concurrently, and they have been designed to facilitate future functionality expansion.

SIPROTEC 5 provides an extensive, precise data acquisition and bay level recording for these functions. By combining device functionality with communication flexibility, SIPROTEC 5 has the ability to meet a wide range of today's applications and specific project specifications as well as the functional expansion capability to adapt to changing needs in the future.

With SIPROTEC 5 you can improve the safety and reliability of your application. Fig. 28 shows the possible functional expansion of a SIPROTEC 5 device.

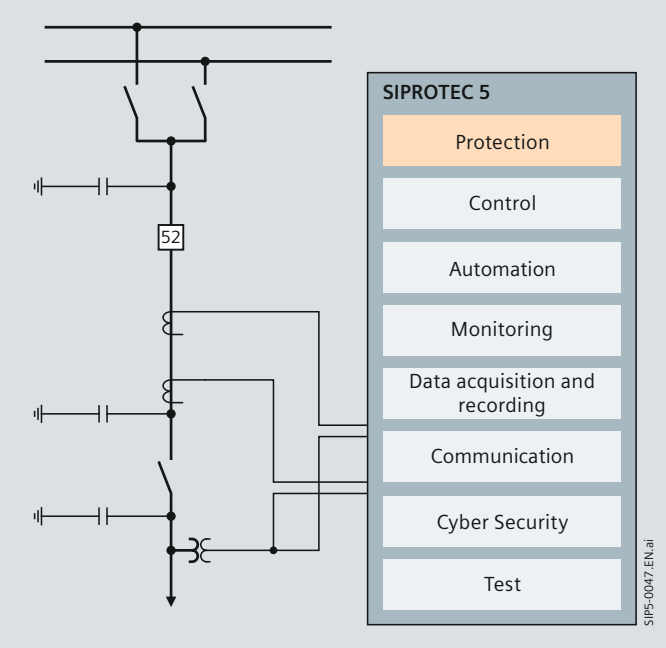


Fig. 28 SIPROTEC 5: possible device construction

Protection

SIPROTEC 5 provides all the necessary protection functions to address reliability and security of power transmission systems. System configurations with multiple busbars and breaker-and-a-half schemes are both supported. The functions are based on decades of experience in putting systems into operation, including feedback and suggestions from our customers.

The modular, functional structure of SIPROTEC 5 allows exceptional flexibility and enables the creation of a protection functionality that is specific to the conditions of the system while also being capable of further changes in the future.

Faster results with application templates

Application templates allow you to fast track your solution. A library of application templates is available that can be tailored to specific functional scope for typical applications. For each device a table gives an overview of the respective protection functions and pre-configured application templates.

Optimizing the application template for your specific application

You can adapt the application templates to your application and create your own in-house standards.

The required number of protection stages or zones can be increased without difficulty. Additional functions can be loaded into the device directly from an extensive function library. Since the functions conform to a common design structure throughout the SIPROTEC 5 system, protection functions and even entire function groups including parameterization can be copied from one device to another.

Line differential protection (ANSI 87L, 87T)

Line differential protection is a selective short-circuit protection for overhead lines, cables, and busbars with single-side and multi-side infeed in radial, looped, or meshed systems. It can be used at all voltage levels. Line differential protection works strictly phase-selectively and allows instantaneous tripping of 1- or 3-phase short circuits at up to six line ends. Depending on the device variation 1-/3-pole (7SD87/7SL87) or only 3-pole tripping (7SD84/7SD86/7SL86) is possible. The devices in a differential protection topology communicate with each other via protection interfaces (protection-data communication). The flexible use of available communication media saves investment in communication infrastructure and guarantees the protection of lines of all lengths.

Adaptive measurement

An adaptive measurement method ensures a maximum of sensitivity to detect internal faults under all conditions. To guarantee highest stability any measurement and communication errors are taken into account. Simple settings and supervision features shorten time of engineering and commissioning.

- A sensitive measurement stage ($I_{Diff>}$) offers the detection of high resistive faults. Special algorithms guarantee high stability even with high-level DC components in the short-circuit current.
- A high-set differential stage ($I_{Diff>>}$) offers high-speed fault clearance with very short tripping times.
- Different CT ratios at the line ends are handled inside the relay. No external matching transformers are needed.
- With the setting of CT-error data the differential protection device automatically calculates the restraint current and adapts its permissible sensitivity according to the CT's data. Thus no protection characteristic has to be parameterized. Only $I_{Diff>}$ (sensitive stage) and $I_{Diff>>}$ (high-set current differential stage) must be set according to the charging current of the line/cable.
- Enhanced communication features guarantee stability and accuracy even under disturbed or interrupted communication on all kinds of media like optical fibers, pilot wires or communication networks.
- Differential and restraint currents are monitored continuously during normal operation and are displayed as operational measurements.

Adaptive measurement (contin.)

- High stability during external faults even with different current transformer saturation levels.
- When long lines or cables get switched on, transient charging currents load the line. To avoid higher settings and less sensitivity of the $I_{Diff>>}$ stage, the set point may be increased $I_{Diff>}$ for a settable time. This offers higher sensitivity under normal load conditions.

Charging current compensation

Particularly with long cables and long lines, distributed capacitances can cause considerable, permanently flowing capacitive load currents. These have to be taken into account by the pickup values of the differential protection stages.

- The charging current compensation serves to improve the sensitivity so that maximum sensitivity can be protected even at high charging currents.
- Charging current compensation requires that local voltage transformers are connected.
- The principle of distributed compensation guarantees maximum availability, since with local failure of measuring voltages of a device, the remaining devices continue to guarantee their part of the compensation.

Transformer in the protection range

Apart from normal lines, line differential protection can also protect lines with a transformer in block connection. The current transformers selectively delimit the protection range.

- A separate transformer protection device can therefore be omitted, since line differential protection acts as a transformer protection with measuring points that may lie far away from one another.

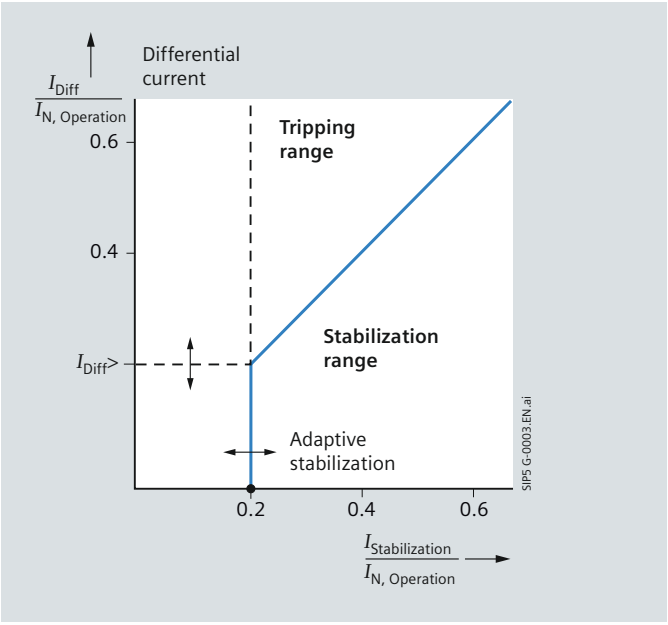


Fig. 29 Triggering characteristic

- With few additional transformer parameters such as rated apparent power, primary voltages, vector groups and any neutral-point groundings of the respective windings, there is no need for external matching transformers.
- The sensitivity of differential protection can be further increased by capturing the earth currents of grounded neutral-point windings.
- The inrush current detectionstabilizes the differential protection against tripping due to transformer inrush currents. This can occur phase-selectively or in 3-phase by means of the crossblock function.

Breaker-and-a-half schemes

Differential protection can be integrated easily into breaker-and-a-half schemes. With corresponding hardware extension (see standard variants), two 3-phase current inputs per device are configurable. Thus ultimately topologies of up to 12 measurement points with 6 devices can be configured. The protection of a STUB-BUS can be assumed by the separate STUB differential protection.

Improved communication features

The line differential protection uses the protection interfaces in the "Differential protection" configuration (Type 1, see Protection-data communication). Different communication modules and external converters allow the interfacing and use of all available communication media.

- Direct fiber-optic data transmission is immune to electromagnetic interference and offers highest performance.
- Using the external communication converters via existing pilot wires or communication networks is possible.

The data required for the differential calculations is cyclically exchanged in full-duplex mode in the form of synchronous, serial telegrams between the protection units. Enhanced supervision features ensure stability in operation in any communication environment:

- Telegrams are secured with CRC checksums to detect transmission errors. Only valid telegrams get operated by the differential protection.
- Supervision of all communication paths between the units without additional equipment.
- Unambiguous identification of each unit is ensured by the assignment of settable communication addresses for each unit within a differential protection topology.
- Detection of reflected telegrams in the communication networks.
- Detection of time delay changes in the communication networks.
- Dynamic compensation of delay time in the differential measurement and supervision of the maximum permissible signal-transit time.
- Generation of alarms on disturbed communication connection. Faulty telegram counters are available as operational measurement.

Improved communication features (contin.)

- Switched communication networks can lead to unsymmetrical delay times in receive and transmit directions. The resulting differential current is compensated by the adaptive measuring techniques of the differential protection.
- With a high-precision 1 s pulse from a GPS receiver the relays can be synchronized with an absolute, exact time at each line end. In this way, delay times in receive and transmit path can be measured exactly. Thus the differential protection can be used in communication networks with a maximum of sensitivity even under massive unsymmetrical delay conditions.

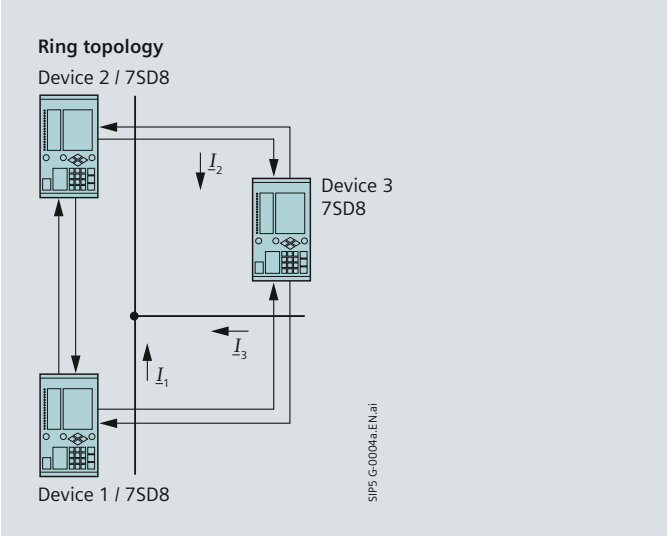


Fig. 30 Differential protection in ring topology

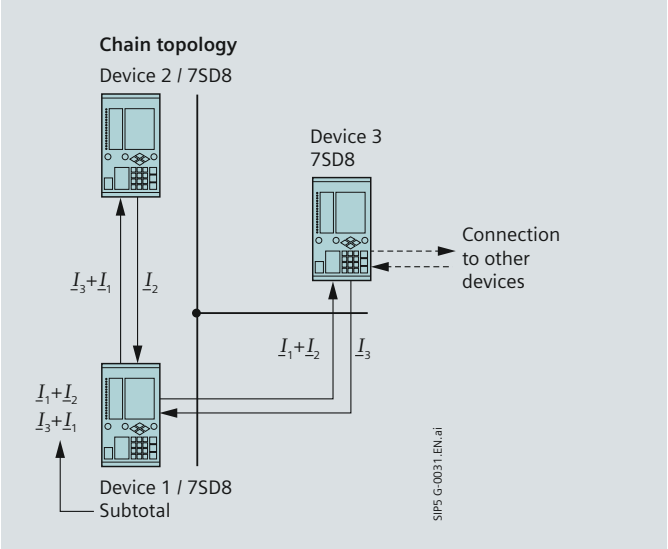


Fig. 31 Differential protection in chain topology

Phase-selective circuit-breaker intertripping and remote trip/ indications

- Normally the differential fault current is calculated for each line end nearly at the same time. This leads to fast and uniform tripping times. Under weak infeed conditions, especially when the differential protection function is combined with an overcurrent pickup a phase-selective breaker intertripping offers a tripping of all line ends. Therefore high-speed transfer-trip signals get transmitted to the other line ends. They can also be initiated by an external relay via binary inputs. Therefore they can be used to indicate, for example, a directional decision of the backup distance protection.
- Additional remote signals can be freely assigned to binary inputs and outputs and are circulating between the different devices (see Protection-data communication).

Communication topologies / modes of operation

Differential protection devices may work in a ring or chain line topology. The use of a test mode offers operating conditions and maintenance.

- The system tolerates the loss of one data connection in a ring topology. The ring topology is rerouted within 20 ms into a chain topology, while the differential protection function is still working.
- When a chain topology is given by the communication infrastructure, cost effective relays with only one protection interface are necessary at the chain ends.
- For important two-end lines a hot standby transmission is possible by a redundant communication connection to ensure high availability. When the main connection is interrupted, the communication switches over from the main path to a secondary path.
- For service or maintenance reasons individual differential protection devices within multi-end topologies can be logged out by a signal via binary input. Circuit-breaker positions and load currents get checked before a logoff is initiated. The remaining devices are able to operate in this reduced topology.
- The whole configuration can be set up into a test mode. All functions and indications are available except the breakers will not trip. The local relay can be tested without tripping or intertripping at the other relays.

Distance protection (ANSI 21, 21N)

SIPROTEC 5 provides 6-system distance protection featuring all well-proven algorithms of previously supplied SIPROTEC protection devices.

By parallel calculation and monitoring of all six impedance loops, a high degree of sensitivity and selectivity is achieved for all types of faults. All methods of neutral-point treatment (compensated, isolated, solid or low-resistive grounded) are reliably dealt with. 1-pole and 3-pole tripping is possible depending on the specific device type. The distance protection is suitable for cables and overhead lines with or without series capacitor compensation.

The device provides quadrilateral as well as MHO and circular zone characteristics. The characteristics can be used separately for phase and ground faults.

Resistance ground faults can, for instance, be covered with the quadrilateral characteristic and phase faults with the mho characteristic. The evaluation of healthy voltages and the use of a voltage memory make optimal direction determination possible.

Zone characteristic quadrilateral

The quadrilateral characteristic permits separate setting of the reactance *X* and the resistance *R*. The resistance section *R* can be set separately for faults with and without earth involvement. This characteristic has therefore an optimal performance for detecting high-resistive faults.

Applications with ground fault dependent reactance reach per zone can be covered as well by simply using additional distance zones. Each distance zone can be set separately to operate for ground faults only, for phase faults only or for all fault types.

The distance zones can be set forward, backward or non-directional.

Zone-characteristic MHO

With the MHO characteristic, the mho circle expansion guarantees safe and selective operation for all types of faults, even for faults close to the zone boundary. The circle expands to the source impedance but never more than the selected impedance reach. The example in the figure (Fig. 33) shows the characteristic for a forward fault.

Zone-characteristic circular (being prepared)

The circular characteristic is commonly applied in medium voltage cable networks with very small line angle. Furthermore, for proper zone grading it is sensible to initially also apply the device with circular tripping characteristic when it is used to replace relays with circular tripping characteristic. A later change to the more flexible quadrilateral characteristic can be considered. The circular tripping characteristic consists of two segments of a circle about the zero point of the *R*/*X*plane.

Appropriate number of distance zones

The number of distance zones can be freely adapted according to the application requirements. Each distance zone can be set to operate independently or as a dependent zone, e.g. as an overreach zone. Each distance zone has its own timer, separately dedicated to 1-phase and 3-phase short circuits. Thus, the new flexibility of the SIPROTEC 5 device family provides optimal adaptation to each application. The distance protection will always provide the exact number of required distance zones.

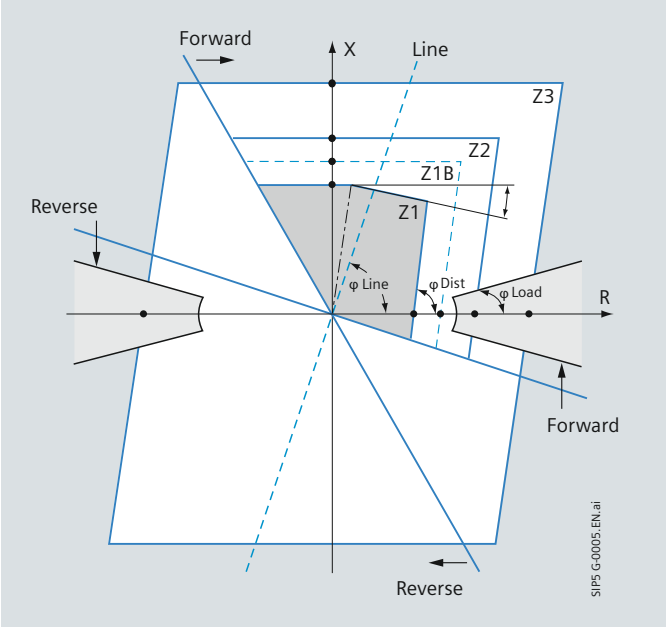


Fig. 32 Quadrilateral zone characteristic with the example of 4 zones

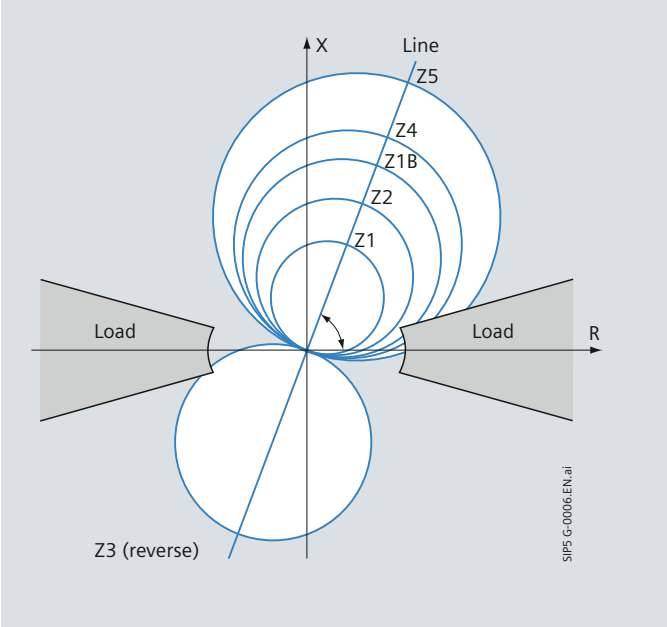


Fig. 33 MHO zone characteristic, with the example of 6 zones

Four pickup methods

The following pickup methods can be employed alternatively:

- Overcurrent pickup $I>>$ *
- Voltage-dependent overcurrent pickup V/I *
- Voltage-dependent and phase angle dependent overcurrent pickup $V/I/\varphi$ *
- Impedance pickup *Z*<

(Being prepared)*

Load zone

In order to guarantee reliable discrimination between load operation and short-circuit – especially on long, high loaded lines – the relay is equipped with a selectable load encroachment characteristic. Impedances within this load encroachment characteristic prevent the distance zones from unwanted tripping (cf. load cutout in figures 32 / 33).

Absolute phase-selectivity

The distance protection function incorporates a well-proven, highly sophisticated phase selection algorithm. The pickup of healthy loops is reliably eliminated to prevent the adverse influence of currents and voltages in the healthy loops. This phase selection algorithm achieves appropriate tripping decisions and correct distance measurement in a wide application range.

Arrangements for breaker-and-a-half schemes

When the cores of the two CT sets are connected in parallel (with suitable polarity), the resultant measured current will be the sum of the two currents flowing into the CTs. This sum-current corresponds to the current flowing into the feeder and is therefore used for the protection and other functions to represent the feeder current. This method is commonly used.

SIPROTEC 5 devices provide sufficient measuring inputs to connect two or several sets of CTs separately to the device. In this case the summation is carried out in software internally. The distance protection function detects possible saturation of only one of the CTs and can thus prevent unwanted pickup in case of an external error with high through-fault current. Through the separately measured currents, separate circuit-breaker failure protection functions can be activated for both switches.

Parallel-line compensation

The influence of wrong distance measurement due to parallel lines can be compensated by feeding the neutral-point current of the parallel line to the relay. Parallel line compensation can be used for distance protection as well as for fault location.

Load compensation

The distance protection function provides measures to compensate the load influence on the reach measurement.

Elimination of interference signals

Digital filters render the unit immune to signals contained in the measured values. In particular, the influence of DC components, capacitive voltage transformers and frequency changes is considerably reduced. A special method of measurement is employed in order to assure protection selectivity during saturation of the current transformers.

Measuring-voltage failure detection

Tripping of the distance protection is blocked automatically in the event of failure of the measuring voltage, thus preventing unwanted tripping. Distance protection is blocked if one of the voltage monitoring functions or the auxiliary contact of the voltage-transformer circuit-breaker operates and in this case the EMERGENCY protection can be activated (definite-time overcurrent protection).

Tele (pilot) protection for distance protection (ANSI 85/21)

A teleprotection function is available for fast clearance of faults up to 100% of the line length.

For conventional signal transmission the required send and receive signals can be freely assigned to binary inputs and outputs. The signals can certainly be transferred via the serial protection interface, a SIPROTEC 5-wide system feature. The transmission via GOOSE messages with IEC 61850 system interfaces is provided as well, if the available communication structures in the substations fulfill the intra-substation requirements acc. to IEC 61850-90-1. The following teleprotection schemes are provided for distance protection:

- Permissive underreach schemes PUTT
  - Pickup with overreach zone
  - Acceleration with pickup
  - Direct underreaching trip
- Permissive overreach schemes POTT
  - With overreach zone
  - Directional comparison pickup
- Unblocking
  - Each permissive scheme can be extended with an Unblocking logic
- Blocking
- Reverse interlocking
- Transmission link protection

The send and receive signals are available as general signals or as phase-selective signals. The phase-selective signals are particularly advantageous as they guarantee reliable 1-pole tripping, if 1-phase short circuits occur on different lines. The teleprotection schemes are suitable also for power lines with more than two line-ends, e.g. teed feeder. Up to six line-ends are possible.

Transient blocking (current reversal guard) is provided for all permissive and blocking schemes in order to suppress interference signals during tripping of parallel lines.

Overcurrent protection, phases (ANSI 50, 51)

The overcurrent protection phases function captures short-circuits at electric equipment and can be used as a reserve or as an emergency overcurrent protection in addition to the main protection. Depending on the device variation 1-/3-pole (7SA87/7SD87/7SL87) or only 3-pole tripping (7SA84/7SA86/7SD84/7SD86/7SL86) is possible.

Two definite time-overcurrent protection stages and a inverse time-overcurrent protection stage are preconfigured. A maximum of 4 definite time-overcurrent protection stages, as well as 1 inverse time-overcurrent protection stage and 1 stage with a user-defined characteristic curve can be operated simultaneously within this function.

Overcurrent protection, phases (ANSI 50, 51) (contin.)

For the inverse time-overcurrent protection stages all usual characteristic curves (see Fig. 35) according to IEC and ANSI/IEEE are available (see Technical Data in manual).

The protection function is structured such that the overcurrent protection stages can be activated selectively in emergency mode. This is the case, for example, when a distance protection in blocked by a measuring-voltage failure or a differential protection is blocked due to communication disturbance. Emergency mode can also be activated externally via binary input.

The stages of the overcurrent protection phases are, apart from the characteristic, structured identically:

- They can be blocked individually via binary input or by other functions (e.g. inrush current detection, automatic reclosing, cold-load pickup detection).
- Every stage can also be blocked only by trip command, so that there can still be pickup and recording (logs and fault records).
- For each stage the method of measurement can be chosen between measurement of the fundamental component and the RMS value.
- Dropout delays can be set individually.

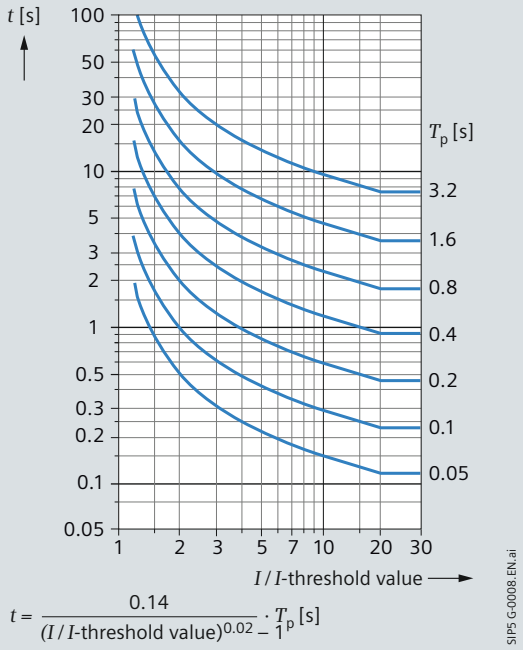


Fig. 34 xy-characteristic curves

Overcurrent protection ground (ANSI 50N, 51N)

The overcurrent protection ground function captures short-circuits at electrical equipment and can be used as a reserve or as an emergency overcurrent protection in addition to the main protection. The tripping is 3-pole. Two inverse time-overcurrent protection stages and a inverse time-overcurrent protection stage are preconfigured. A maximum of three definite time-overcurrent protection stages, as well as one inverse time-overcurrent protection stage and one stage with a user-defined characteristic curve can be operated simultaneously within this function.

For the inverse time-overcurrent protection stages all usual characteristic curves according to IEC and ANSI/IEEE are available.

The protection function is structured such that the overcurrent protection stages can be activated selectively in emergency mode. This is the case, for example, when a distance protection in blocked by a measured voltage failure or a differential protection is blocked due to communication disturbance. Emergency mode can also be activated externally via binary input.

The stages of the overcurrent protection ground are, apart from the characteristic, structured identically:

- They can be blocked individually via binary input or by other functions (e.g. inrush current detection, automatic reclosing, cold-load pickup detection).
- Each stage can also be blocked only by trip command, so that there can still be pickup and recording (logs and fault records).
- Parameters can determine whether the stage works with the measured value I_E or with the calculated value 3 I_0 from the 3-phase currents.
- For each stage the method of measurement can be chosen between measurement of the fundamental component and the RMS value.
- Dropout delays can be set individually.

Directional negative-sequence protection with definite-time delay (ANSI 46, 67)

The function directional negative-sequence protection with definite-time delay serves as the reserve short-circuit protection for asymmetrical faults. With the negative-sequence system, various monitoring and protection tasks can be realized:

- Detection of 1 or 2-phase short circuits in the network with a higher sensitivity than in classic overcurrent protection.
- Detection of phase conductor interruptions in the primary system and in the current transformer secondary circuits
- Location of short circuits or reversals in the connections to the current transformers
- Indication of asymmetrical states in the energy system
- Protection of electrical machines following asymmetrical loads that are caused by asymmetrical voltages or conductor interruptions (for example through a defective fuse).

The function comes factory-set with 1 stage. A maximum of 6 stages can be operated simultaneously. If the device is equipped with the inrush-current detection function, the tripping stages can be stabilized against tripping due to transformer inrush currents.

Circuit-breaker failure protection (ANSI 50BF)

The circuit-breaker failure protection incorporates a two-stage design and provides phase and ground backup protection if the main circuit breaker fails to clear a power-system incident. If the fault current is not interrupted after a time delay has expired, a retrip command or the busbar trip command will be generated. The correct circuit-breaker operation is monitored via current measurement and via breaker position contacts. The current detection logic is phase-segregated and can therefore also be used in 1-pole tripping schemes.

The circuit-breaker failure protection can be initiated by all integrated protection functions as well as by external devices via binary input signals or by serial communication with GOOSE message in IEC 61850 systems. To increase operational reliability, an external start can be applied with two binary inputs in parallel. For 1-pole and 3-pole starting separate delay times are available.

For applications with two current transformers per feeder, e.g. breaker-and-a-half, ring bus or double circuit-breaker applications, the SIPROTEC 5 device can be configured with two independent circuit-breaker failure protection functions.

Automatic reclosing (ANSI 79)

About 85% of the arc faults on overhead lines are extinguished automatically after being tripped by the protection. The overhead line can therefore be re-energized. Reclosure is performed by an automatic-reclosing function (AR). Each protection function can be configured to start or block the auto-reclosure function.

Basic features and operating modes

- Tripping controlled start with action time or without action time
- Pickup controlled start with action time or without action time
- 3-pole auto-reclosing for all types of faults; different dead times are available depending on the type of fault
- Multiple-shot auto-reclosure
- Cooperation with external devices via binary inputs and outputs or via serial communication with GOOSE message in IEC 61850 systems
- Control of the integrated AR function by an external protection
- Cooperation with the internal or an external synchrocheck
- Monitoring of the circuit-breaker auxiliary contact
- Dynamic setting change of overcurrent protection elements, depending on the AR status

Two auto-reclosure functions

For applications with two circuit breakers per feeder, e.g. breaker-and-a-half, ring bus or double circuit-breaker applications the devices can be configured to operate with two independent auto-reclosure functions.

1-pole auto-reclosure

In electrical power systems with grounded system neutral-point and if the circuit-breaker pole can be operated individually, a 1-pole auto-reclosure is usually initiated for 1-phase short circuits.

1-pole auto-reclosure functionality is available in SIPROTEC 5 devices with 1-pole tripping capability. The following operating modes are provided in addition to the above mentioned features:

- 1-pole auto-reclosure for 1-phase short circuits, no reclosing for multi-phase faults
- 1-pole auto-reclosure for 1-phase faults and for 2-phase faults without ground, no reclosing for multi-phase short circuit
- 1-pole auto-reclosure for 1-phase fault and 3-pole auto-reclosing for multi-phase faults
- 1-pole auto-reclosure for 1-phase faults and for 2-phase faults without ground and 3-pole auto-reclosure for other faults
- Appropriate evolving fault response
- 3-pole coupling (positive 3-pole tripping) in case of circuit-breaker pole discrepancy.

Voltage-dependent supplementary functions

The integration of auto-reclosure in the feeder protection allows evaluation of the line-side voltages. A number of voltage-dependent supplementary functions are thus available:

- DLC
  By means of a dead-line check, reclosure is effected only when the line is de-energized (prevention of asynchronous circuit-breaker closure), if no synchrocheck can be used.
- ADT
  The adaptive dead time is employed only if auto-reclosure at the opposite end was successful (reduction of stress on equipment).
- RDT
  Reduced dead time is employed in conjunction with auto-reclosure where no teleprotection is used: When faults within the overreach zone, but external to the protected line, are switched off for short-time interruption, the RDT function decides on the basis of measurement of the reverse polarity voltage from the opposite end, which has not tripped, whether or not to reduce the dead time.

Synchrocheck, synchronizing function (ANSI 25)

When two partial networks are closed with a control command or 3-pole auto-reclosure of the circuit breaker, it must be ensured that the networks are synchronous with each other. For this purpose, synchronization functionalities are provided.

For synchronous networks a synchrocheck is available. Asynchronous networks can be switched with a synchronization function. In synchronous networks there are minor differences with regard to phase angle and voltage modulus and so the circuit-breaker response time does not need to be taken into account. In asynchronous networks, however, the differences are larger and the range of the connection window is traversed at a faster rate. Therefore it is wise here to take the circuit-breaker response time into consideration.

The measured values for synchronization are voltage magnitude difference, phase angle difference and frequency difference. Depending on the available number of voltage transformer inputs, one or two synchronizing locations (circuit breakers) can be applied in one device.

Synchrocheck, synchronizing function (ANSI 25) (contin.)

Each function provides the option to use up to two parameter sets (stages) for synchrocheck applications and up to six parameter sets (stages) for the synchronization function per device. This is of special interest when several switches with different operating times are to be operated by one single device or if the operating conditions for one circuit breaker differ from network condition to network condition (see Fig. 35).

Directional ground-fault protection with phase selector for high-resistance ground faults (ANSI 51G, 67G, 50G)

In grounded systems, it may happen that the main protection sensitivity is not sufficient to detect high-resistance ground faults. The SIPROTEC 5 device therefore has protection functions for faults of this nature.

Multiple stages

The ground fault overcurrent protection can be used with 6 definite-time stages (DT) and one inverse-time stage (IDMTL). The following inverse-time characteristics are provided:

- Inverse acc. to IEC 60255-3
- ANSI/IEEE inverse
- Logarithmic inverse
- V0-inverse
- S0-inverse

Appropriate direction decision modes

The direction decision can be determined by the residual current I_0 and the zero sequence voltage V_0 or by the negative sequence components V_2 and I_2. Using negative-sequence components can be advantageous in cases where the zero sequence voltage tends to be very low due to unfavorable zero sequence impedances.

In addition or as an alternative to the directional determination with zero sequence voltage, the ground current of a grounded power transformer may also be used for polarization. Dual polarization applications can therefore be fulfilled. Alternatively, the direction can be determined by evaluation of zero sequence power. Each stage can be set in forward or reverse direction or both directions (non-directional).

High sensitivity and stability

The SIPROTEC 5 devices can be provided with a sensitive neutral (residual) current transformer input. This feature provides a measuring range for the ground current (fault current) from 5 mA to 100 A with a rated current of 1 A and from 5 mA to 500 A with a nominal current of 5 A. Thus the ground-fault overcurrent protection can be applied with extreme sensitivity.

The function is equipped with special digital filter algorithms, providing the elimination of higher harmonics. This feature is particularly important for low zero sequence fault currents which usually have a high content of 3rd and 5th harmonics.

Dynamic setting change

Dynamic setting change of pickup values and delay time settings can be activated depending on the status of an auto-reclosure function. An instantaneous switch-on to fault is applicable for each stage.

Phase selector

The ground-fault protection is suitable for 3-phase and, optionally, for 1-phase tripping by means of a sophisticated phase selector. It may be blocked during the dead time of 1-pole auto-reclose cycles or during pickup of a main protection function.

Teleprotection for directional ground-fault protection (ANSI 85/67N)

For fast clearance of faults up to 100% of the line length the directional ground-fault protection can be expanded with a teleprotection scheme. The following schemes are available:

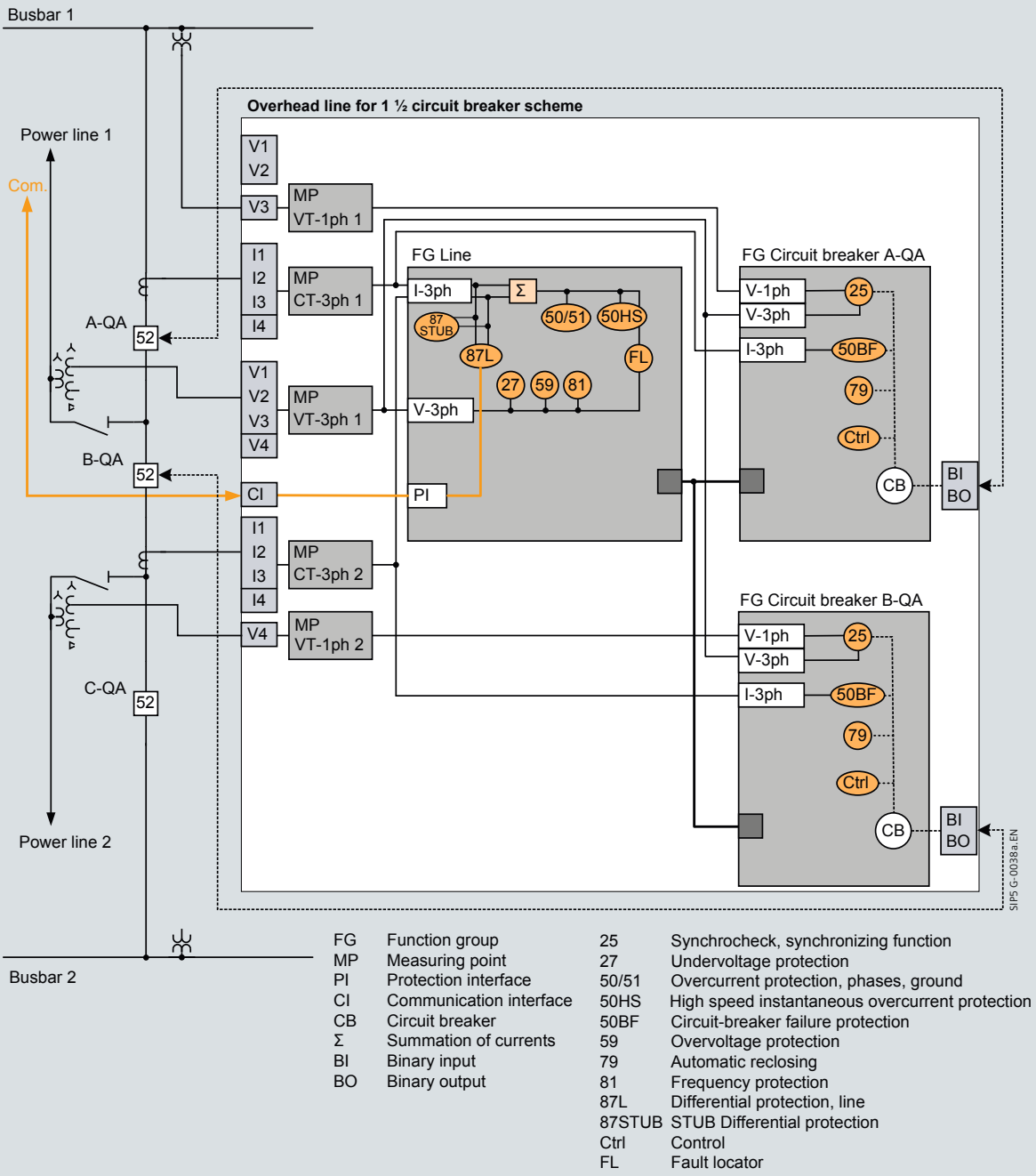
- Directional comparison
- Blocking
- Unblocking

The send and receive signals are available as general signals or as phase-selective signals in combination with the phase-selector of the directional ground-fault protection. For conventional signal transmission the send and receive signals can be freely assigned to binary inputs and outputs. The signals can certainly be transferred via the serial protection data interface, a SIPROTEC 5-wide system feature. The transmission via GOOSE messages with IEC 61850-system interfaces is provided as well, if the available communication structures in the substations fulfill the intra-substation requirements according to IEC 61850-90-1.

The “transient blocking” (current reversal guard) function can be enabled in order to suppress the interference signals during tripping of parallel lines. Communication of the teleprotection functions for distance protection and ground-fault protection can use the same signaling channel or separate and redundant channels.

Weak or no infeed: Echo and Tripping (ANSI 85/27)

To prevent delayed tripping of distance protection permissive schemes and ground-fault directional comparison scheme during weak or zero infeed situations, an echo function is provided. If no fault detector is picked up at the weak-infeed end of the line, the signal received here is returned as echo to allow accelerated tripping at the strong infeed end of the line. It is also possible to initiate phase-selective tripping at the weak-infeed end. A phase-selective 1-pole or 3-pole trip is issued if a send signal is received and if the measured voltage drops correspondingly. This feature is available for all permissive underreach and overreach schemes. As an option, the weak infeed logic can be equipped according to a French specification. (Being prepared).



FG	Function group	25	Synchrocheck, synchronizing function
MP	Measuring point	27	Undervoltage protection
PI	Protection interface	50/51	Overcurrent protection, phases, ground
CI	Communication interface	50HS	High speed instantaneous overcurrent protection
CB	Circuit breaker	50BF	Circuit-breaker failure protection
Σ	Summation of currents	59	Overvoltage protection
BI	Binary input	79	Automatic reclosing
BO	Binary output	81	Frequency protection
		87L	Differential protection, line
		87STUB	STUB Differential protection
		Ctrl	Control
		FL	Fault locator

Fig. 35 Two synchronization control functions (25) in one and the same device, here with a breaker-and-a-half scheme

Power-swing blocking (ANSI 68)

Dynamic transient incidents, for instance short-circuits, load fluctuations, auto-reclosures or switching operations can cause power swings in the transmission network. During power swings, large currents along with small voltages can cause unwanted tripping of distance protection devices. The power-swing blocking function avoids uncontrolled tripping of the distance protection.

Power swings can be detected under symmetrical load conditions as well as during 1-pole auto-reclose cycles (see Fig. 36).

No settings required

The function requires no settings. The optimal computation is always obtained by automatic adaptation. During a power-swing blocking situation all swing properties are constantly supervised. A subsequent network fault is reliably detected and results in phase-selective reset of the distance protection blocking by the power-swing detection.

Out-of-step protection (ANSI 78)

In electric power transmission systems electrical stability must be maintained at all times. If system conditions arise that threaten the stability measures must be taken to avoid an escalation. One such system is the out-of-step protection. The function can be applied as out-of-step protection or can be integrated into more complex systems for supervision and load control, i.e. system integrity protection systems (SIPS).

The out-of-step function constantly evaluates the impedance trajectory of the positive sequence impedance. The response characteristic is defined by impedance zones in the R/X plane. Accumulators are incremented depending on the point at which the impedance trajectory enters or exits the associated impedance zone. Tripping or signaling occurs when the set accumulator limits are reached. The out-of-step protection provides up to four independent impedance zones which can be adjusted and tilted according to the requirements of stability in the power network. (see Fig. 37).

High speed instantaneous overcurrent protection (ANSI 50HS)

When switching on a faulty line, immediate tripping is possible. In the case of high fault currents this overcurrent protection with instantaneous tripping effects a very rapid 3-pole tripping when switching on to faults.

The closure detection is determined from the manual closure signal or from measured values (current, voltage) or by means of the circuit-breaker auxiliary contacts.

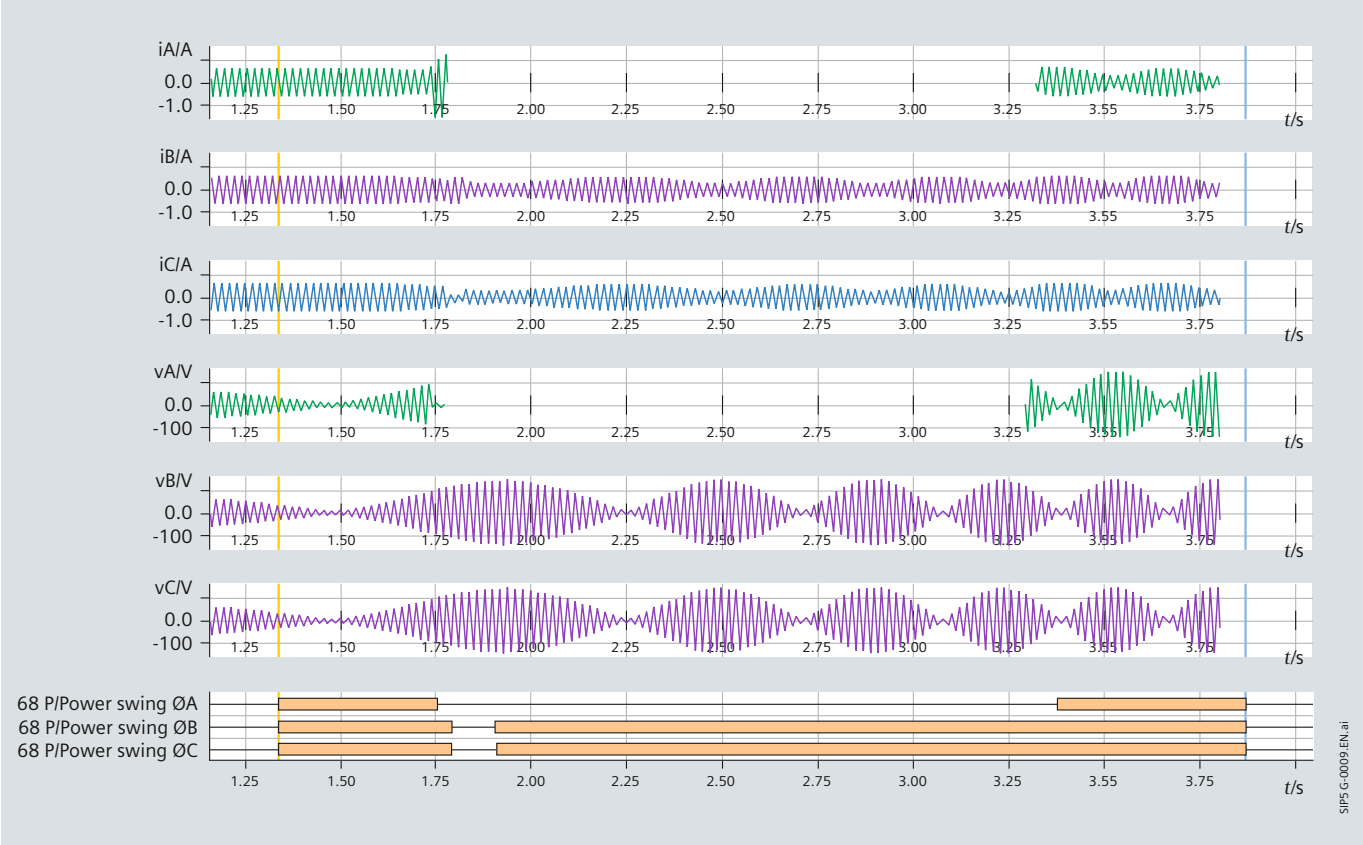


Fig. 36 Power-swing detection during 1-pole open condition

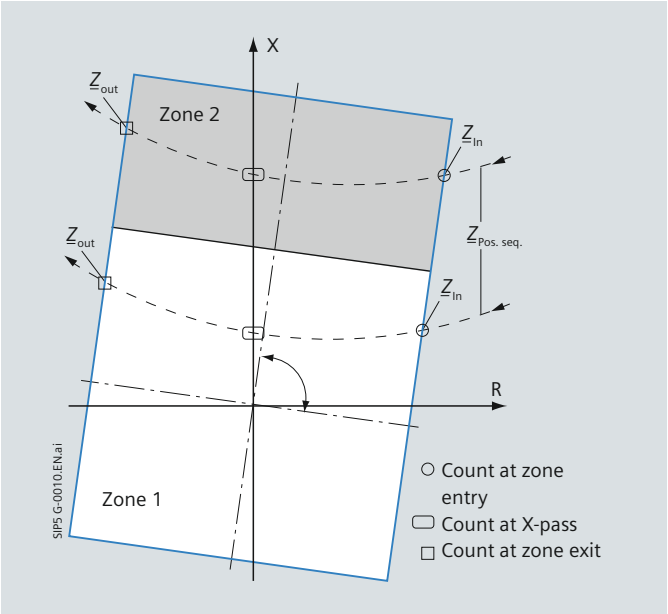


Fig. 37 Impedance zones for out-of-step protection

Instantaneous tripping at switch-on to fault (SOTF)

This function is available for applications in which overcurrent protection (50HS) is not sufficient or not used.

It enables instantaneous tripping even with low fault currents. The function has no measuring function of its own. It is linked on the input side with the pickup (measurement) of another protection function, e.g. the distance protection overreach zone Z1B or the stage of an overcurrent protection and then trips with switching to a short-circuit. Typically, such protection stages are configured that themselves trip with a delay.

External trip initiation

Any signal from an external or internal protection or supervision function can be coupled into the trip logic of the device by means of binary inputs or by serial communication. The trip command may be delayed. 1-pole tripping is available if device and circuit breaker are capable of 1-pole operation.

STUB differential protection (ANSI 87 STUB)

Stub differential protection is a full-fledged line differential protection, but without communication between the line ends. It is used with a teed feeder or a breaker-and-a-half scheme, when a feeder of the line section can no longer be selectively protected by opening the disconnector (example distance protection).

The activation of the Stub differential protection occurs through the feedback of the disconnector position. The SIPROTEC 5 line protection device must be equipped with two 3-phase current inputs in its hardware for this. The Stub differential protection corresponds structurally and with regard to the setting parameters to the line differential protection (ANSI 87L) in all regards, with the exception of protection data communication. It guarantees the selective protection of the remaining line section and rapid tripping times up to 10 ms.

Overvoltage protection functions (ANSI 59, 47, 59N, 64)

Overvoltages occur in long lines with little or no load. The overvoltage protection monitors the permissible voltage range, protects equipment from subsequent damage through overvoltages and serves to decouple systems (e.g. wind energy infeeds).

Various overvoltage measuring elements are available. By default, two stages are preconfigured. Up to three identical stages are possible. Tripping by overvoltage measuring elements can be effected either at the local circuit breaker or at the opposite end via transfer-trip signals. The following measuring elements are available:

Overvoltage protection with 3-phase voltage (ANSI 59)

- Optionally, measurement of phase-to-phase voltages or phase-to-ground voltages
- *Method of measurement:* optionally, measurement of the fundamental component or of the effective value (RMS value).

Overvoltage protection with positive-sequence voltage (ANSI 59)

- Capturing symmetrical, stationary overvoltages with positive-sequence voltage
- *Method of measurement:* calculation of positive-sequence voltage from the measured phase-to-ground voltages.

Overvoltage protection with positive-sequence voltage and compounding (ANSI 59)

- By means of capacitive line impedances, stationary overvoltages at the opposite end of the line can arise (Ferranti effect).
- *Method of measurement:* The positive-sequence system of the voltage is calculated at the other end of the line by means of the local, measured voltages and current using the equivalent circuit of the line.

Overvoltage protection with negative-sequence voltage (ANSI 47)

- Monitoring the power system and electric machines for voltage unbalance.
- *Method of measurement:* calculation of negative-sequence voltage from the measured phase-to-ground voltages.

Overvoltage protection with zero-sequence voltage/residual voltage function (ANSI 59N, 64):

- Detection of ground fault-affected phases in case of missing neutral-point grounding
- *Method of measurement:* Measurement of the residual voltage directly at the broken-delta winding or calculation from the measured phase-to-ground voltages.
- *Measuring methods:* Optionally, measurement of the fundamental component (standard or with especially strong attenuation of harmonics and transients) or of the RMS value.

Overvoltage protection with any voltage (ANSI 59)

- Capture of any 1-phase overvoltage for special applications
- *Measuring methods:* optionally, measurement of the fundamental component or of the effective value (True RMS).

Undervoltage protection (ANSI 27)

The undervoltage protection monitors the permissible voltage range or protects equipment from subsequent damage due to undervoltage. It can be used in the network for decoupling or load shedding tasks and can protect motors and generators from possible loss of stability.

Various undervoltage measuring elements are available. By default, two stages are preconfigured. Up to three identical stages are possible. Tripping by undervoltage measuring elements can be effected either at the local circuit breaker or at the opposite end via transfer-trip signal. All undervoltage measuring elements and their stages can be blocked by means of a current criterion. The following measuring elements are available:

Undervoltage protection with 3-phase voltage

- Optionally, measurement of phase-to-phase voltages or phase-to-ground voltages
- *Measuring methods:* optionally, measurement of the fundamental component or of the effective value (True RMS).
- A maximum of four stages possible.

Undervoltage protection with positive-sequence voltage

- 2-pole short circuits or ground faults lead to an unbalanced voltage collapse. This makes this function particularly suitable for the assessment of stability problems.
- *Method of measurement:* calculation of positive-sequence voltage from the measured phase-to-ground voltages.

Undervoltage protection with any voltage

- Capture of any 1-phase undervoltage for special applications
- *Measuring methods:* optionally, measurement of the fundamental component or of the effective value (True RMS).

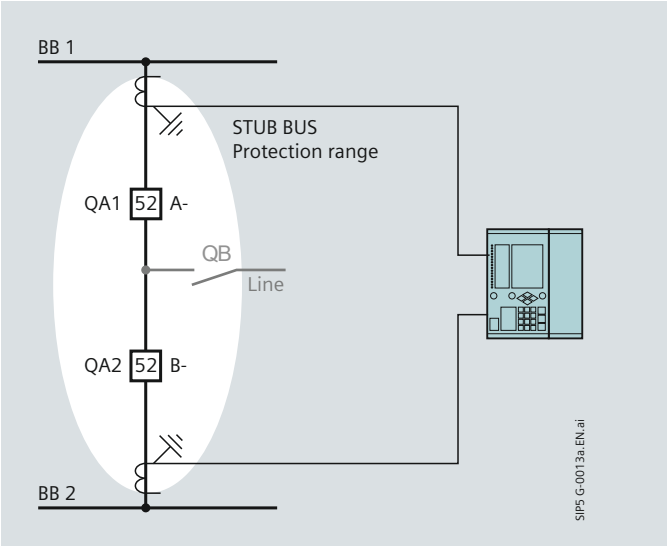


Fig. 38 Breaker-and-a-half scheme topology

Frequency protection (ANSI 81O, 81U)

Frequency deviations are caused by an unbalance between the active power generated and consumed. Causes are, for example, load shedding, network disconnections, increased need for active power, generator failures or faulty functioning of the power and frequency regulation.

The frequency protection detects frequency deviations in the network or in electric machines.

It monitors the frequency band and outputs failure indications In case of critical power frequency entire generation blocks can be isolated or networks can be decoupled. To ensure network stability, load shedding can be initiated.

Different frequency measuring elements with high accuracy and short pickup times are available.

Tripping by frequency measuring elements can be effected either at the local circuit breaker or at the opposite end by remote tripping. The following measuring elements are available:

Overfrequency protection (ANSI 81O)

Two preconfigured stages, can be increased up to three stages. All stages are of identical design.

Underfrequency protection (ANSI 81U)

Three preconfigured stages, can be increased up to five stages. All stages are of identical design.

Each frequency measuring element provides two different methods of measurement:

- *Angle difference method:* Angle change of the voltage phasor over a time interval
- *Filter method of measurement:* Evaluation of immediate voltage values with special filters

Power protection (ANSI 32, 37)

The power protection works 3-phase and detects exceedance or underrunning of the set effective power or reactive power thresholds (see Fig. 37). Pre-defined power limits are monitored and corresponding warning alerts are issued. The power direction can be determined via angle measurement of the active power. Thus, for example, feeding back in the network or at electric machines can be detected. Idling machines (motors, generators) are detected and can be shut down via a message.

The power protection can be integrated into any automation solution, for example, to monitor very specific power limits (further logical processing in CFC)

The power protection function comes with one factory-set stage each for the active and the reactive power. A maximum of four active power stages and four reactive power stages can be operated simultaneously in the function. The tripping stages are structured identically.

Thresholds for exceedance or underrunning of the power lines can be defined. The combination of the different stages via CFC result in various applications.

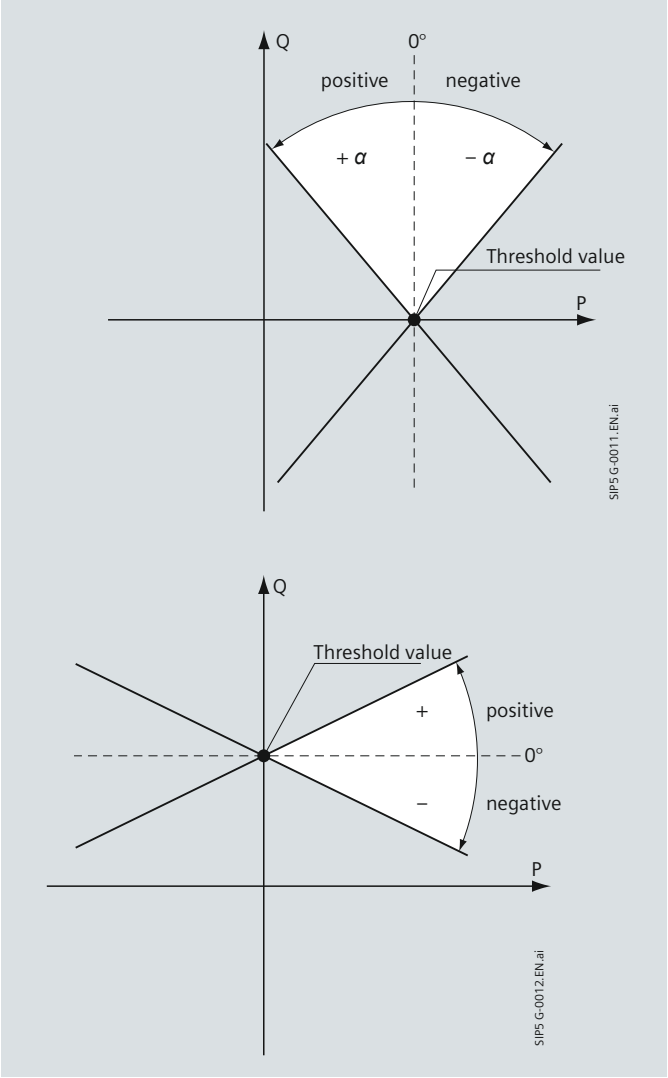


Fig. 39 Active power characteristic curve and reactive power characteristic curve

Application examples:

- Detection of negative active power. In this case reverse-power protection can be applied by using the CFC to link power protection outputs to the "Direct trip" function.
- Detection of capacitive reactive power. In the case of overvoltage being detected due to long lines under no-load conditions it is possible to select the lines where capacitive reactive power is measured.

Thermal overload protection (ANSI 49)

The thermal overload protection function protects equipment (overhead lines, cables, motors, generators and transformers) from thermal overstraining by monitoring the thermal conditions.

The thermal overload protection calculates the overtemperature from the measured phase current according to a thermal single body model.

Stages

A current and thermal alarm stage is provided for the thermal overload protection to initiate an alarm before tripping. The tripping time characteristics are exponential functions according to IEC 60255-8. The preload is considered in the tripping times for overloads.

Consideration of the ambient temperature (being prepared)

The currently measured ambient temperature can be taken into account in the calculation of the overtemperature. This results in a more accurate determination of this overtemperature.

If the ambient temperature is lower than the stipulated reference temperature, a larger thermal reserve results and the equipment can be put under greater strain. As the ambient temperature increases, the thermal reserve of the equipment is reduced.

Fault locator (ANSI FL)

Single ended fault locator

The integrated fault locator calculates the fault impedance and the distance-to-fault. The result is displayed in ohms, miles, kilometers or in percent of the line length. Parallel line and load-current compensation are also available.

Double ended fault locator (being prepared)

Due to load current there is an angular displacement between the voltages of both line ends. This angle and possible differences in the source impedance angle cause the angular displacement between both line end currents. As a result, the voltage drop across R_F (resistance of failure) is affected by this angle between the currents R_F. The single ended measurement cannot compensate for this.

As an option for a line with two ends, a fault locator function with measurement at both ends of the line is available. The full line model is considered. Thanks to this feature, measuring accuracy on long lines under high load conditions and high fault resistances is considerably increased.

Control

SIPROTEC 5 includes all bay level control and monitoring functions that are required for efficient operation of the switching substations. The application templates supplied provide the full functionality that you need for your application.

Protection and control functions access the same logical elements. In the application template for breaker-and-a-half scheme templates, this is illustrated for example by the circuit-breaker function group (e.g., FG CB A-QA). From the point of view of the switching device, protection and control are treated with equal priority.

The modern, scalable hardware can be optimized for the system conditions. You can simply put together the desired hardware quantity structure. For example, a single SIPROTEC 5 can be used to control and monitor an entire breaker-and-a-half scheme.

A new level of quality in control is achieved with the application of communication standard IEC 61850. For example, binary information from the field can be processed and data (e.g., for interlocking across multiple fields) can be transmitted between the devices. Cross communications via GOOSE enables efficient solutions, since here the hardwired circuits are replaced with data telegrams. All devices have up to 4 switching objects (switches, disconnectors, grounding switches) via the base control package. Optionally, additional switching objects and switching sequence block can be activated (switching sequence function chart (CFC)).

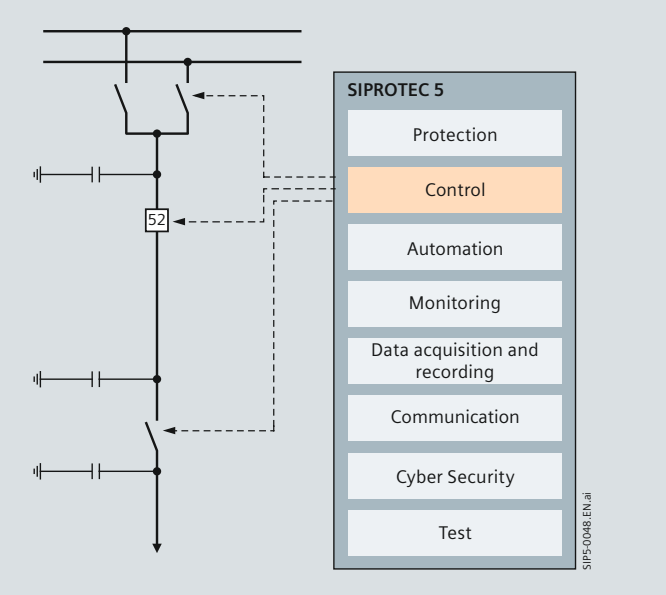


Fig. 40 Possible functional extension of SIPROTEC 5 devices

Automation

An integrated graphical automation function enables you to create logic diagrams clearly and simply. DIGSI 5 supports this with powerful logic modules based on the standard IEC 61131-3.

All devices have a powerful base automation package. This makes it easy to provide specific functions for automating a switching cell or switchgear and substation. Depending on the requirements of the application the scope of the CFC (Continuous Function Chart) can be expanded. The scope covered by the "basic function chart" is always available while the others packages are optional extras.

- Basic function chart (CFC)
- Arithmetic function chart (CFC)
- Switching sequence function chart (CFC).

With the basic function chart (CFC) package you can graphically link all internal digital information, such as internal protection signals or operating states directly to the logic modules and process them in real time. To evaluate and process measured values, e.g. monitoring of thresholds, the arithmetic function chart (CFC) package must be purchased. The switching sequence function chart (CFC) package is used for the realization of derived switching sequences, e.g., diversions due to a change in the grid status.

Example automation applications are:

- Interlocking checks
- Switching sequences (switching sequence function chart (CFC))
- Message derivations of switching actions
- Messages or alarms by linking available information
- Load shedding a feeder (arithmetic function chart (CFC) and switching sequence function chart (CFC))
- Management of decentralized energy feeds
- System transfer depending on the grid status
- Automatic grid separations in the event of grid stability problems.

Of course, SIPROTEC 5 provides a substation automation system such as SICAM PAS with all necessary information, thus ensuring consistent, integrated and efficient solutions for further automation.

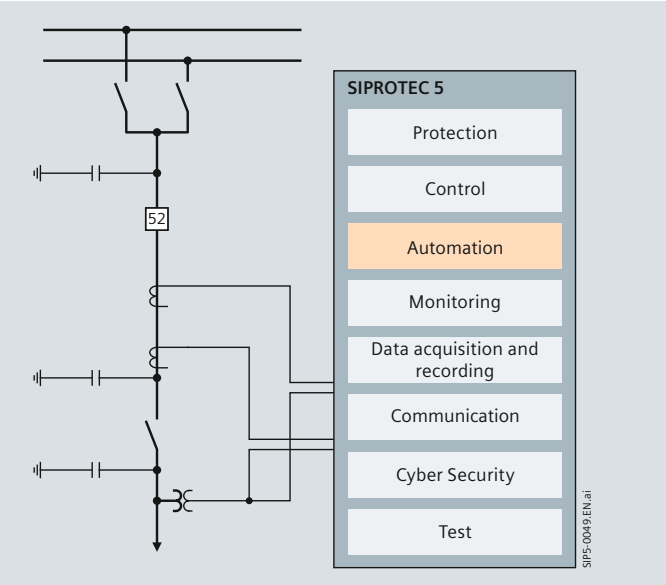


Fig. 41 Possible functional extension of SIPROTEC 5 devices

Monitoring

SIPROTEC 5 devices can take on a wide variety of monitoring tasks. These are divided into four groups:

- Self monitoring
- Monitoring grid stability
- Monitoring power quality
- Monitoring of equipment (condition monitoring).

Self monitoring

SIPROTEC 5 devices are equipped with many monitoring procedures. These procedures detect faults internal to the device as well as external faults in the secondary circuits and store them in buffers for recording and reporting. This stored information can then be used to help determine the cause of the self monitoring fault in order to take appropriate corrective actions.

Grid stability

Grid Monitoring combines all of the monitoring systems that are necessary to assure grid stability during normal grid operation. SIPROTEC 5 provides all necessary functionalities, e.g., fault recorders, continuous loggers, fault locators and phasor measurement units (PMUs) for grid monitoring.

The grid monitoring functionality of SIPROTEC 5 devices allows them to be programmed to monitor grid limit violations (e.g., Dynamic Stability Assessment via load angle control) and actively trigger the appropriate responses. This data in the grid control systems can also be used as input variables for online load flow calculation and enable significantly faster response if statuses in the grid change.

Equipment

The monitoring of equipment (Condition Monitoring) is an important tool in asset management and operational support from which both the environment and the company can benefit. Equipment that typically requires monitoring includes for example: circuit breakers, transformers and gas compartments in gas-insulated switchgear (GIS).

The measuring-transducer inputs (analog inputs) (0 mA to 20 mA) enable connection to various sensors and monitoring of non-electrical variables such as for example gas pressure, gas density and temperature. Thus, SIPROTEC 5 enables a wide range of monitoring tasks to be carried out. SIPROTEC 5 provides the process interfaces, buffers, loggers and automation functions necessary for monitoring the system:

- Process values are stored together with a time stamp in the operational log
- The circuit-breaker statistics provides essential data for condition based maintenance
- Process variables (e.g., pressure, SF_6 loss, speed, temperature etc.) are monitored to ensure they remain within the limits via measurement transducers connected to the sensors.

Data acquisition and recording

The recorded and logged field data is comprehensive. It represents the image and history of the field. It is also used by the functions in the SIPROTEC 5 device for monitoring, interbay and substation automation tasks. It therefore provides the basis for these functions now and in the future.

Measurement

A large number of measured values are derived from the input variables and present a current image of the process.

Depending on the device design, the following base measured values are available:

- Operational measured values
- Fundamental phasor and symmetrical components
- Protection-specific measured values, e.g., differential and restraint current for differential protection
- Mean values
- Minimum values and maximum values
- Energy measured values
- Statistical values
- Limiting values.

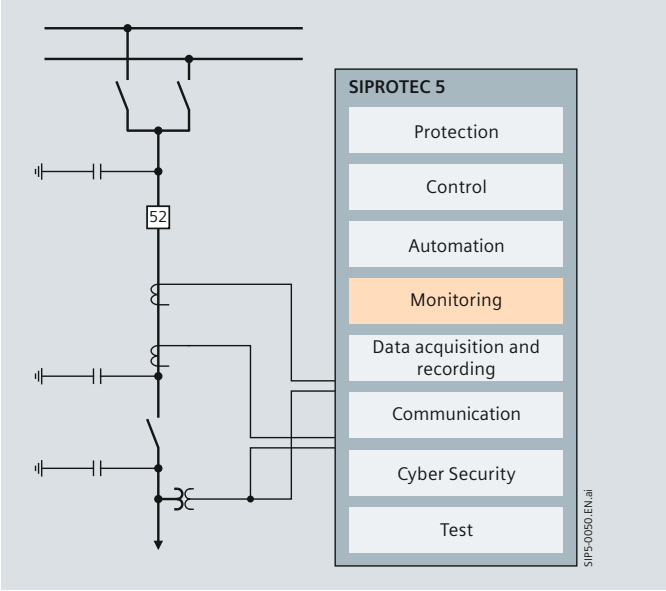


Fig. 42 Possible functional extension of SIPROTEC 5 devices

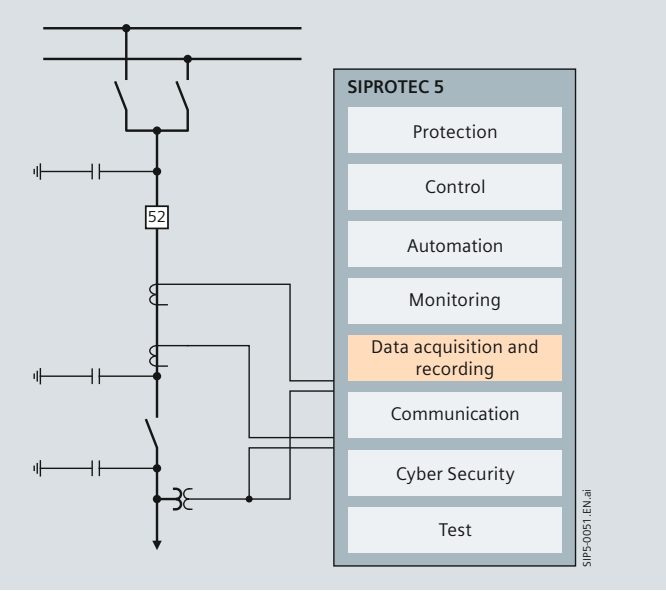


Fig. 43 Possible functional extension of SIPROTEC 5 devices

Data acquisition and recording (contin.)

Besides the base measurement values, phasor-measurement units (PMUs) can also be activated in the devices. Phasor measurement values support a range of applications for monitoring grid stability. For this purpose, SIPROTEC 5 devices record the necessary PMU data. These are high-precision, time-stamped phasors, power frequency and the change in the power frequency. They can be transmitted to central analysis systems via the high-performance communication system. Measured values are per-unit quantity both in primary and secondary values, and also in reference values. These values are also made available to other applications, e.g., transferred to the systems control or for automation tasks. Standard devices can be supplied with up to 24 analog inputs (for special applications, e.g. the fault recorder 7KE85 with up to 40 can be supplied).

The analog inputs of the SIPROTEC-5 devices can be selected with a corresponding accuracy class and dynamic range suitable for connection to both protection and measurement cores. The innovative current terminal technology enables the secondary rated current to be changed via setting. The current transformer input can also be changed on site if for example a measurement in stead of protection class CT input is required (exchange of CT terminal module). The following precisions are typical:

Processing via the protection-input transformer:

- $V, I \leq$ Cl. 0.5 (0.5 % accuracy)
- $P, Q \leq$ Cl. 1 (1 % accuracy)

Processing via the measuring-input transformer:

- $V, I \leq$ Cl. 0.2 (0.2 % accuracy)
- $P, Q \leq$ Cl. 0.5 (0.5 % accuracy)

Separate measuring transducers (analog inputs) are therefore unnecessary. The highly precise measured data enables extended energy management and makes commissioning much easier. SIPROTEC 5 thus provides the following measured values for analysis and further processing:

- The base measured values with high dynamic range and high accuracy (protection-class current transformer)
- The base measured values with very high accuracy (instrument transformer)
- Phasor measurement with highly precise time stamping for subsequent task such as grid stability monitoring.

Recorder

In SIPROTEC 5, various data logs and recorder provide recording large volumes of data. They feature a large number of analog and binary inputs, and a high sampling frequency. An extremely wide range of records can be converted. Either continuously or as determined by various trigger criteria.

Besides storing the data fail-safe on internal storage devices, SIPROTEC 5 devices can also transfer the data to central analysis systems. Consequently, you are able to monitor networks with regard to typical characteristics.

Fig. 44 Devices for evaluation of fault records

Fault recorder

The fault recording stores analog and binary traces during a fault event, e.g., in the event of phase or ground faults, and preserves the records, including high-precision time stamps for subsequent analysis. Calculated measurement values, e. g., power or frequency can also be incorporated into the fault recording function. Analysis takes place after the data is read out from the device by DIGSI using SIGRA. Recorded data is archived to prevent data loss in the event of supply voltage failure. Analog and binary tracks for recording are freely configurable, and pre-trigger and seal-in times can be programmed within a very wide range. SIPROTEC 5 fault recording provides long recording times with outstanding accuracy.

- Recording of up to 24 analog channels
- Sampling frequencies programmable between 1 kHz and 8 kHz
- High recording capacity for individual records of 20 s for 24 channels with 8 kHz sampling frequency
- Storage capability for up to 128 fault records
- The recording duration for all records is limited by the available storage capaity of the device, and depends on the number of configured channels and sampling frequency.
  Example
  - Line protection with 8 analog channels (4 I , 4 V),
  - Sampling frequency 1 kHz, 6 measured value channels and 20 binary channels: resulting recording capacity of the device about 890 s!
- Up to 100 freely configurable digital and 50 additional measured value tracks
- The 7KE85 fault and power quality recorder has yet more features:
  - Extended trigger criteria: Gradient trigger ($\Delta M/\Delta t$); binary trigger; network trigger ...
  - Higher-frequency sampling of 16 kHz for up to 40 analog channels
  - Longer recording duration due to internal mass storage media.

Event-log buffer

Event-log buffers mark important events with a time stamp (accurate to 1 ms) for subsequent analysis.

The long recording length is achieved with large event-log buffers and separate buffers for different event categories. The events to be logged are freely configurable and for improved manageability. Configuration of user-specific event-log buffers for cyclical or event-driven recording is also supported.

Convenient, thorough analysis

Event-log buffers of different categories enable easier, targeted analysis. Changes to parameters and configuration data are recorded.

Ease of maintenance

Hardware and software are constantly monitored and irregularities are detected immediately. In this way, extremely high levels of security, reliability and availability are achieved at the same time. Important information about essential maintenance activities (e.g., battery supervision), hardware defects detected by internal monitoring or compatibility problems are recorded separately in the diagnostic buffer. All entries include specific instructions for taking action. Table 12 "Overview of typical message buffers" provides an overview of typical logs.

Operational log	2000 Messages	Cyclical recording of operational messages (e.g. control processes)
Fault log	1000 Messages	Storage of data after a protection trigger or external triggering; no limit on the number of faults
User-specific log	200 Messages	Option of cyclical or event-drive recording of user-defined signals
Ground-fault log	200 Messages	Storage of messages in ground-fault situations
Logs of parameter setting history (cannot be erased)	200 Messages	Recording of all parameter changes and configuration downloads
Communication buffer	500 Messages	Recording of status of all configured communication connections, such as e.g. faults that arise, testing and diagnostic operation and communication loads
Security log (cannot be erased)	500 Messages	Recording of successful and unsuccessful access attempts to areas of the device with restricted access rights
Diagnostic buffer	500 Messages	Recording and display of concrete instructions for action in case of necessary maintenance (e.g. battery monitoring), detected hardware defects or compatibility problems.

Table 12 Overview of typical message buffers

Communication

SIPROTEC 5 devices are equipped with high-performance communication interfaces. These are integrated interfaces or interfaces that are extendable with plug-in modules to provide a high level of security and flexibility. There are various communication modules available. At the same time, the module is independent of the protocol used. This can be loaded according to the application. Particular importance was given to the realization of full communication redundancy:

- Multiple redundant communication interfaces
- Redundant, independent protocols with control center possible (e.g. IEC 60870-5-103 and IEC 61850 or double IEC 60870-5-103 or DNP3 and DNP IP)
- Full availability of the communication ring when the switching cell is enabled for servicing operations
- Redundant time synchronization (e.g. IRIG-B and SNTP).

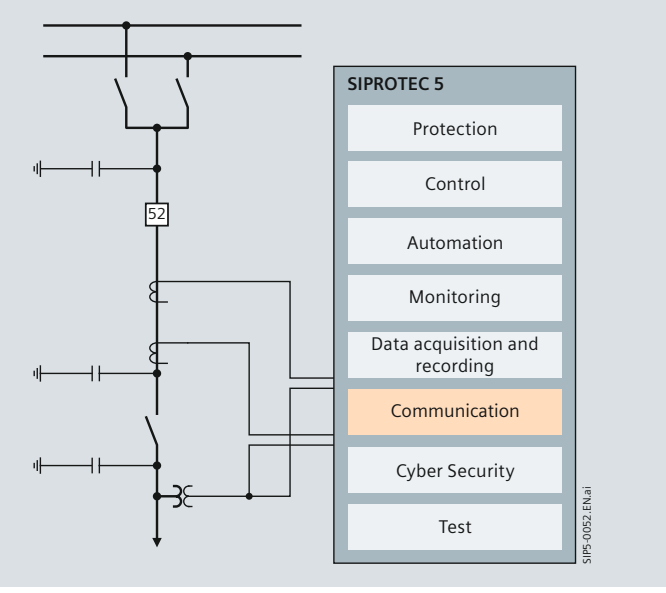


Fig. 45 Possible functional extension of SIPROTEC 5 devices

Cyber Security

A multilevel security concept for the device and DIGSI 5 provides the user with a high level of protection against communication attacks from the outside and conforms to the requirements of the BDEW Whitebook and NERC CIP.

Authentication

In general, secure authentication takes place between the device and DIGSI 5. This precludes another program from accessing the devices and reading or writing data there.

Establishment of connection after password testing

If the optional connection password has been activated for remote access, remote access via the Ethernet cannot take place until the password has been entered. Once the connection has been established, the user has only read access to the device.

Access control with confirmation code

Security prompts must be answered for security-critical actions, e.g., changing parameters, in order to obtain write access to the device. These prompts can be configured by the user, and may be different for different application areas.

Accesses to areas of the device with restricted access rights are logged. This makes it possible to track which groups had access to protected areas and when. Unsuccessful and unauthorized access attempts are also recorded and an alarm can be triggered by an independent telecontrol link.

In addition, security-critical operations are logged in the device and safeguarded against deletion. All files that can be loaded into the device via DIGSI 5 are signed. In this way, corruption from outside by viruses or trojans is reliably detected. Unused Ethernet services and the associated ports can be disabled in the device with DIGSI.

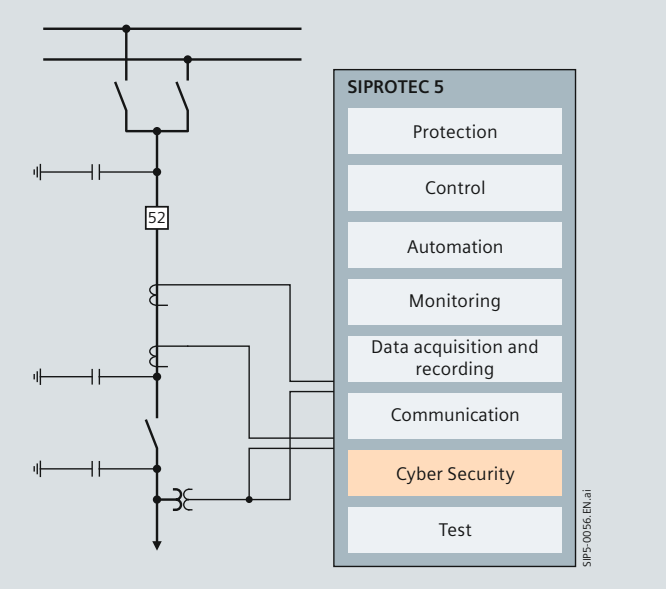


Fig. 46 Possible functional extension of SIPROTEC 5 devices

Test

To shorten testing and commissioning times, extensive test and diagnostic functions are available to the user in DIGSI 5. These are combined in the DIGSI 5 Test Suite.

The test spectrum includes, among other tests.:

- Hardware and wiring test
- Protection-function test
- Simulation of binary signals and analog sequences by integrated test equipment
- De-bugging of function charts
- Circuit-breaker test and AR (automatic reclosing) test function
- Communication testing
- Loop test for communication connections
- Protocol test.

The engineering, including the device test, can therefore be done with one tool.

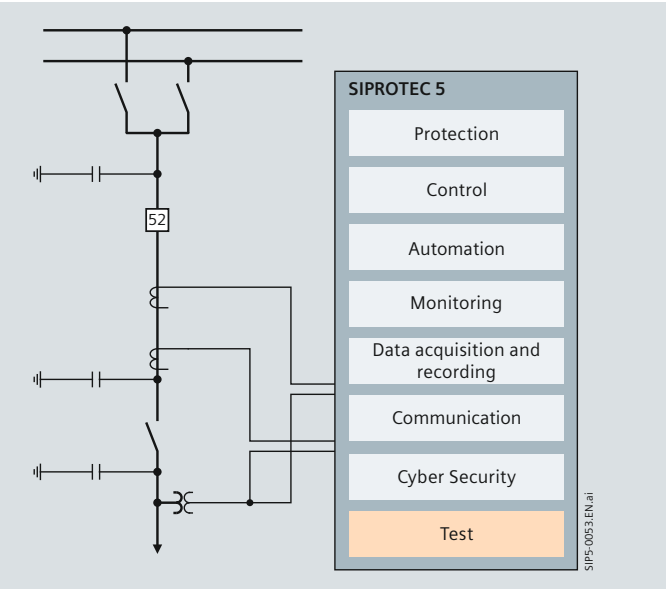


Fig. 47 Possible functional extension of SIPROTEC 5 devices

Overview of the standard variants

Standard variant for 7SA84, 7SD84

Type 1	1/3, 5 BI, 8 BO, 16 LED, 4 I, 4 V	
	Housing width 1/3 × 19", 5 binary inputs, 8 binary outputs (1 lifecontact, 2 standard, 5 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO214.	

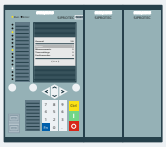
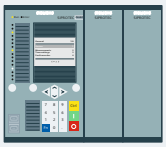
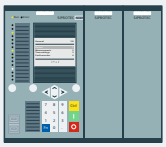
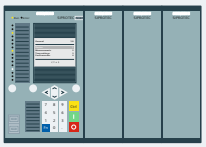
Standard variants for 7SA86, 7SD86, 7SL86, 7SA87, 7SD87, 7SL87, 7VK87

Type 1	1/3, 7BI, 14BO, 16 LED, 4 I, 4 V	
	Housing width 1/3 × 19", 7 binary inputs, 14 binary outputs (1 lifecontact, 5 standard, 8 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208.	
Type 2	1/3, 11 BI, 9 BO, 16 LED, 4 I, 4 V	
	Housing width 1/3 × 19", 11 binary inputs, 9 binary outputs (1 lifecontact, 2 standard, 6 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202.	
Type 3	1/2, 13 BI, 21 BO, 16 LED, 4 I, 4 V	
	Housing width 1/2 × 19", 13 binary inputs, 21 binary outputs (1 lifecontact, 12 standard, 8 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion module IO206.	
Type 4	1/2, 19 BI, 30 BO, 16 LED, 4 I, 4 V	
	Housing width 1/2 × 19", 19 binary inputs, 30 binary outputs (1 lifecontact, 21 standard, 8 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion module IO205.	
Type 5	1/2, 21 BI, 17 BO (4P), 16 LED, 4 I, 4 V	
	Housing width 1/2 × 19", 21 binary inputs, 17 binary outputs (1 lifecontact, 6 standard, 6 fast, 4 power), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202, expansion module IO204.	
Type 6	1/2, 15 BI, 18 BO (4HS), 16 LED, 4 I, 4 V	
	Housing width 1/2 × 19", 15 binary inputs, 18 binary outputs (1 lifecontact, 5 standard, 8 fast, 4 high-speed), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion module IO209.	
Type 7	1/2, 15 BI, 20 BO, 16 LED, 8 I, 8 V	
	Housing width 1/2 × 19", 15 binary inputs, 20 binary outputs (1 lifecontact, 5 standard, 14 fast), 16 LEDs, 8 current transformers, 8 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion module IO202.	

Attachment

Overview of the standard variants

Standard variants for 7SA86, 7SD86, 7SL86, 7SA87, 7SD87, 7SL87, 7VK87

Type 8	2/3, 31 BI, 46 BO, 16 LED, 4 I, 4 V	
	Housing width 2/3 × 19", 31 binary inputs, 46 binary outputs (1 lifecontact, 37 standard, 8 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion modules IO205, IO205.	
Type 9	2/3, 29 BI, 23 BO (4P), 16 LED, 4 I, 4 V	
	Housing width 2/3 × 19", 31 binary inputs, 25 binary outputs (1 lifecontact, 10 standard, 6 fast, 8 power), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202, expansion modules IO204, IO204.	
Type 10	2/3, 27 BI, 34 BO (4HS), 16 LED, 4 I, 4 V	
	Housing width 2/3 × 19", 27 binary inputs, 34 binary outputs (1 lifecontact, 21 standard, 8 fast, 4 high-speed), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion modules IO205, IO209.	
Type 11	2/3, 27 BI, 36 BO, 16 LED, 8 I, 8 V	
	Housing width 2/3 × 19", 27 binary inputs, 36 binary outputs (1 lifecontact, 21 standard, 14 fast), 16 LEDs, 8 current transformers, 8 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion modules IO202, IO205.	
Type 12	5/6, 27 BI, 33 BO (8HS), 16 LED, 8 I, 8 V	
	Housing width 5/6 × 19", 27 binary inputs, 33 binary outputs (1 lifecontact, 8 standard, 16 fast, 8 high-speed), 16 LEDs, 8 current transformers, 8 voltage transformers Contains the modules: Base module with PS201 and IO208, expansion modules IO208, IO209, IO209.	

Standard variants for 7SJ86

Type 1	1/3, 11 BI, 9 BO, 16 LED, 4 I, 4 V	
	Housing width 1/3 × 19", 11 binary inputs, 9 binary outputs (1 lifecontact, 2 standard, 6 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202.	
Type 2	1/2, 17 BI, 16 BO, 16 LED, 4 I, 4 V	
	Housing width 1/2 × 19", 17 binary inputs, 16 binary outputs (1 lifecontact, 9 standard, 6 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202, expansion modules IO206.	
Type 3	1/2, 23 BI, 25 BO, 16 LED, 4 I, 4 V	
	Housing width 1/3 × 19", 23 binary inputs, 25 binary outputs (1 lifecontact, 18 standard, 6 fast), 16 LEDs, 4 current transformers, 4 voltage transformers Contains the modules: Base module with PS201 and IO202, expansion modules IO205.	

The technical data for the line protection devices can be found in the line protection device manuals.
www.siemens.com/siprotec

Legal Notice

Indication of conformity

CE This product complies with the directive of the Council of the European Communities on harmonization of the laws of the Member States relating to electromagnetic compatibility (EMC Council Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low Voltage Directive 2006/95/EC).

This conformity has been proved by tests performed according to the Council Directive in accordance with the generic standards EN 61000-6-2 and EN 61000-6-4 (for EMC directive) and with the standard EN 60255-27 (for Low Voltage Directive) by Siemens AG.

The device is designed and manufactured for application in an industrial environment. The product conforms with the international standards of IEC 60255 and the German standard VDE 0435.

Disclaimer of liability

This document has been subjected to rigorous technical review before being published. It is revised at regular intervals, and any modifications and amendments are included in the subsequent issues. The content of this document has been compiled for information purposes only. Although Siemens AG has made best efforts to keep the document as precise and up-to-date as possible, Siemens AG shall not assume any liability for defects and damage which result through use of the information contained herein.

This content does not form part of a contract or of business relations; nor does it change these. All obligations of Siemens AG are stated in the relevant contractual agreements. Siemens AG reserves the right to revise this document from time to time.

Document version: 02

Release status: 02.2012

Version of the product described: Edition 2

Registered trademarks

SIPROTEC, DIGSI, SIGUARD, SIMEAS and SICAM are registered trademarks of Siemens AG. Any unauthorized use is illegal. All other designations in this document can be trademarks whose use by third parties for their own purposes can infringe the rights of the owner.

Herausgeber und Copyright © 2012:
Siemens AG
Infrastructure & Cities Sector
Smart Grid Division
Energy Automation
Humboldtstr. 59
90459 Nuremberg, Germany

For more information, please contact our
Customer Support Center.
Phone: +49 180 524 84 37
Fax: +49 180 524 24 71
(Charges depending on provider)
E-Mail: support.ic@siemens.com
www.siemens.com/siprotec

Order No. E50001-K4605-A021-A2-7600
Printed in Germany
Dispo 06200, c4bs 7442
KG 02.12 0.75 64 En
7500 / 39910 WÜ
Printed on elementary chlorine-free bleached paper.