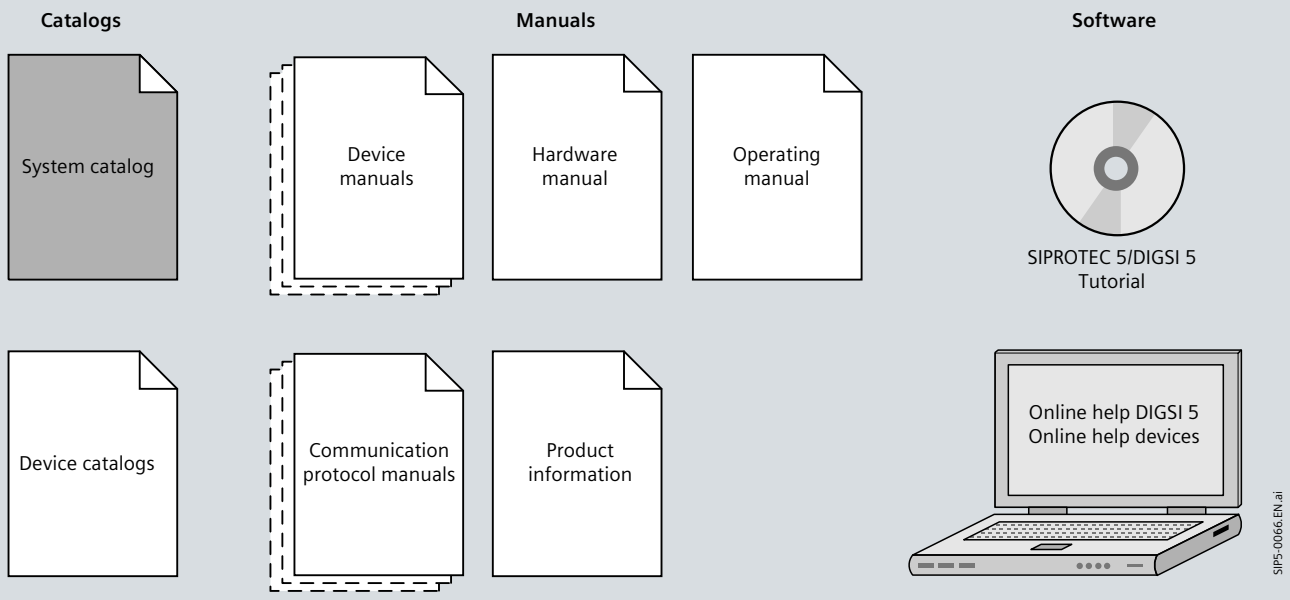
SIPROTEC 5 – System Overview
Protection, Automation and Monitoring

Energy Automation

Catalog SIP 5.01 · V1.0

Answers for energy.

SIEMENS



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 with higher-level control centers.

Product information

The product information includes general information about device installation, technical data, limit values for input and output modules, and conditions when preparing for operation. This document is provided 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 of SIPROTEC 5 and DIGSI 5.

Contents

SIPROTEC 5 – System Overview Protection, Automation and Monitoring

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ISO 9001
ISO 14001
DNV
Certified Company

OHSAS 18001
DNV
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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
Energy Sector
Power Distribution Division
Energy Automation Products

Introduction

Protection of electrical power generation, transmission and distribution systems has always been, and still is, a critical task in ensuring a reliable power supply for consumers. A protection device can detect a fault in the network and isolate the affected section within a few milliseconds. This leaves the "healthy" sections free to continue carrying electricity. A network event is handled by the protective devices and communicated to the local and central control system, where a system operator can take action as needed.

How did protection technology become energy automation?

Protection, automation, monitoring: these are the fundamental requirements for a complete field device, which have always applied for all generations of the technology. Today's users expect modern field devices to be: multifunctional, reliable, safe and designed to communicate. SIPROTEC devices designed with these modern energy automation functions can assist in optimal and economical operational management of the system and at the same time provide the tools and technology to help meet stringent supply reliability requirements.

The increasing integration of many functions into a single multifunctional device, internet working of these devices, the merging of process and communication networks, and the ultimate evolution of all these elements into smart grids are resulting in effective yet complex structures. From these new or expanded requirements are emerging: an optimally supported engineering process, IT security, service and testability or simple, safe usability of devices and tools.

The implementation of high-precision phasors (synchrophasors) in SIPROTEC 5 devices enables monitoring of system stability so that blackouts can be averted.

Secure system solution for the entire lifecycle

Power system operators strive to operate their systems as efficiently, reliably and safely as possible. This includes operation of existing systems as well as the integration of newer technologies into the systems. These demands cannot be met satisfactorily by isolated optimization of individual system components, such as an isolated upgrading of the functions of a protection device. Today's power system requirements for performance, reliability and safety demand high-performance components that can be added into the existing system while ensuring optimized support and integration of the existing work processes. In this context, SIPROTEC 5 devices support easy system integration while providing the functionality to ensure you have a solution for your system that is efficient, cost-effective, and above all safe throughout its entire life cycle of the system.

Fig. 1.1 Application in the high-voltage power system

Fig. 1.2 SIPROTEC 5 hardware module

Introduction

The SIPROTEC brand

For several decades now, SIPROTEC has enjoyed a solid reputation as the respected brand name of a high-performance, full-range system family of digital protection and field devices on the energy market. SIPROTEC protection devices from Siemens fully cover the application range from medium to high voltage. With SIPROTEC, you can achieve full, uncompromised protection and control of your systems in a safe and reliable manner.

History and innovations

For over a century, Siemens has driven innovations and set trends in protection technology, delivering products that help you design sophisticated networks reliably, efficiently and with consideration for the environment, and operate them profitably. Siemens has been a pioneer in the development of digital protection technology, and has made significant contributions to its development (Fig. 1.4). The first application of digital protection technology was put into operation in Würzburg (Germany) in 1977.

The most important innovative advance in the 1990s was the end-to-end integration of protection and control functions for all SIPROTEC devices. Following the adoption of IEC 61850 in 2004, Siemens was the first manufacturer in the world to deliver an operational system based on this communication standard. The system is located in Switzerland. In 2006, the company was honored with the "Technology Leadership Award" by Frost & Sullivan (USA) for its leading role in the implementation of IEC 61850.

How can you benefit from this experience?

- Fully operational, better tuned, complete application
- Optimized cooperation among components in the system
- Highest quality hardware and software
- Outstanding user friendliness of devices and tools
- Highly reliable data exchange between the applications
- Excellent continuity between product and system
- Reduced complexity due to simple operation.

Expertise and experience

Siemens Energy Sector is an experienced and reliable partner in delivering highly effective energy solutions with focus on maximizing customer benefits. Siemens supports its customers with efficient technology all along the energy conversion chain – from oil and gas production to power generation and electricity transmission and distribution.

As our customer you can benefit from Siemens expertise and experience:

- Siemens has the knowledge of your industry and can understand your specific business environment
- Siemens has a location near you – with over 160 sites in more than 90 countries
- Siemens has the expertise and products along the entire energy conversion chain
- Siemens delivers innovative, standardized products and solutions to ensure rapid, highly economical execution
- Siemens has the highly trained staff to tackle any technical problem – including customized solutions to highly specialized requirements
- Siemens products and solutions aim for the highest possible quality and reliability, with proven results.

Fig. 1.3 Integration in a high-voltage switchgear

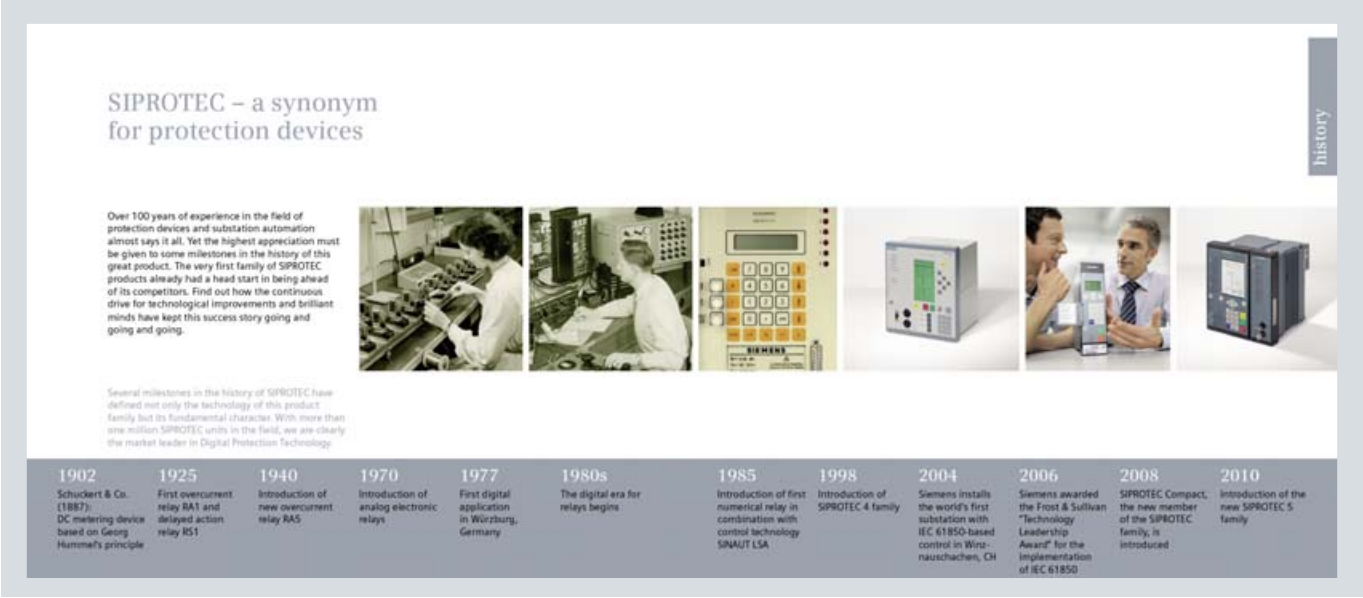


Fig. 1.4 Historical development of SIPROTEC

Our products, systems and solutions for energy automation enable networks to be developed, modernized, extended or completely reconstructed to meet the requirements of the future.

Siemens solutions concepts and implementation are based on a powerful, full-range product portfolio.

Our SIPROTEC protection intelligent devices have gained wide industry acceptance, many approvals from users, and also have been certified by various independent test institutions and universities (KEMA, EPRI, LOYD, UR Laboratories).

For you as the customer, taking advantage of the Siemens expertise and experience can ensure the safety and protection of your investment in a reliable and proven solution.

Levels of energy automation

The development of power generation with wind, photo-voltaic and biomass power stations is bringing about a fundamental change in the structure of the grid. For example, injection points from regenerative energy producers can be found at all voltage levels. The intelligent automation of these networks will remain a challenge for the coming years.

Due to the modular construction of hardware and software, flexible, high-performance communication capability and scalability, SIPROTEC 5 devices represent a key technology for smart automation. They provide all the infor-mation that is needed for fast, smart control.

Siemens offers end-to-end, optimal solutions for all levels of energy automation – from power systems control to the bay level (Fig. 1.5). The Siemens ENEAS (Efficient Network and Energy Automation Systems) system solutions cover the entire spectrum of energy automation.

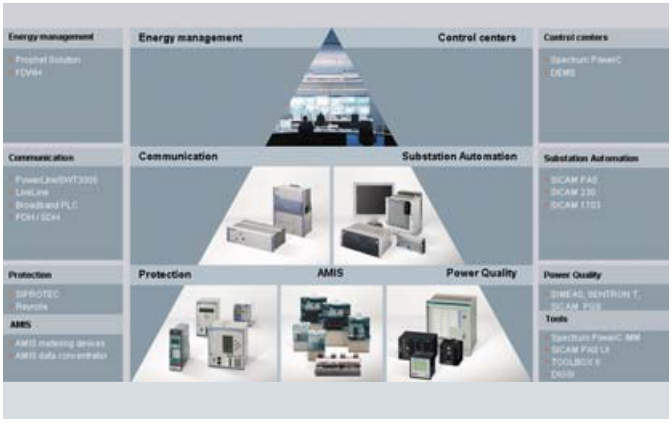


Fig. 1.5 Products and systems for energy automation

High-performance station automation is much more than simply combining a number of different devices. Siemens ENEAS Generic Solutions take into account the various system and application functions of transformer stations and sub-stations – and the integration of the system in a total communi-cation network. The SICAM family of substation controllers provide all the control, measuring and automation functions a switchgear needs (e.g., tap changer in transformers). They work with decentralized intelligence. Communication between the branch-side devices and the central unit is transmitted via interference-proof fiber-optic connections. Bay level SIPROTEC devices are compact and can be installed directly in medium- and high-voltage switchgear.

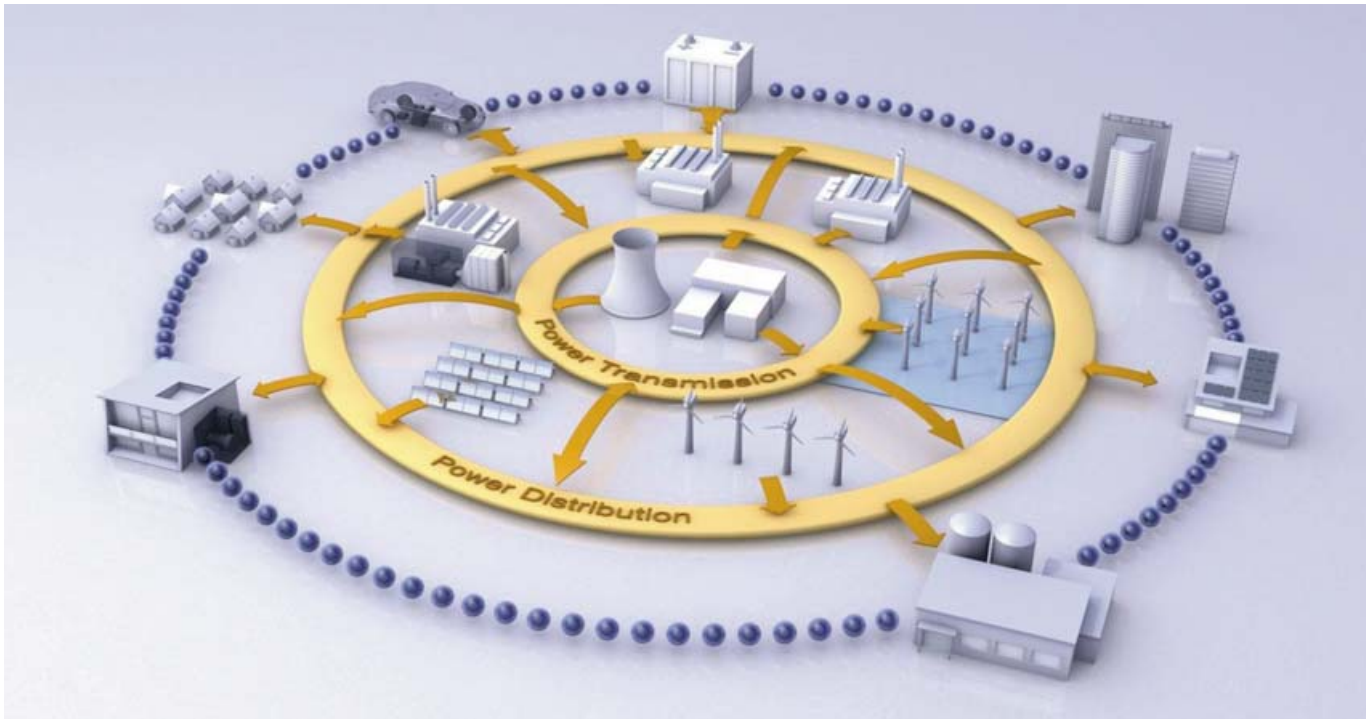


Fig. 1.6 New structures in the smart power grid

Innovation highlights

With SIPROTEC 5, Siemens is writing yet another chapter in the successful history of protection technology, representing the 5th digital generation and over 100 years of experience in protection. SIPROTEC 5 represents the next logical step in this development. With SIPROTEC 5, we have combined a functionality that has been proven and refined over years with a high-performance and flexible new platform, extended with trendsetting innovations for present and future demands.

Holistic workflow

The tools for end-to-end engineering from system design to operation will make your work easier throughout the entire process.

The highlight of SIPROTEC 5 is the greater-than-ever emphasis on daily ease of operation. SIPROTEC 5 provides support along all the steps in the engineering workflow, allowing for system view management and configuration down to the details of individual devices, saving time and cost without compromising quality (Fig. 2.2).

Holistic workflow in SIPROTEC 5 means:

- Integrated, consistent system and device engineering – from the single-line diagram of the unit all the way to device parameterization
- Simple, intuitive graphical linking of primary and secondary equipment
- Easily adaptable library of application templates for the most frequently used applications
- Manufacturer-independent tool for easy system engineering
- Libraries for your own configurations and system parts
- Multiuser concept for parallel engineering
- Open interfaces for seamless integration into your process environment
- A user interface developed and tested jointly with many users that pays dividends in daily use
- Integrated tools for testing during engineering, commissioning, and for simulating operational scenarios, e.g., grid disruptions or switching operations.

For you, Holistic workflow in SIPROTEC 5 means:

An end-to-end tool from system design to operation – even allowing crossing of functional and departmental boundaries – saves time, assures data security and transparency throughout the entire lifecycle of your system.

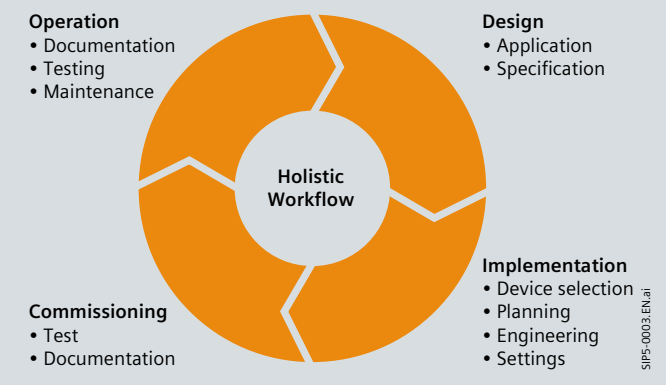


Fig. 2.2 End-to-end tools – from design to operation

Fig. 2.1 SIPROTEC 5 – innovation highlights

Perfectly tailored fit

Individually configurable devices provide you with cost-effective solutions that match your needs precisely throughout the entire lifecycle.

SIPROTEC 5 sets new standards in cost savings and availability with its innovative modular and flexible hardware, software and communication. SIPROTEC 5 provides a perfectly tailored fit for your switchgear and applications unparalleled by any other system.

Perfectly tailored fit with SIPROTEC 5 means:

- Modular system design in hardware, software and communication ensures the perfect fit for your needs
- Functional integration of a wide range of applications, such as protection, control, measurement, power quality or fault recording
- The same expansion and communication modules for all devices in the family
- Innovative terminal technology ensures easy assembly and interchangeability with the highest possible degree of safety
- Identical functions and consistent interfaces throughout the entire system family mean less training requirement and increased safety, e.g., an identical automatic reclosing (AR) for line protection devices 7SD8, 7SA8, 7SL8
- Functions can be individually customized by editing for your specific requirements
- Innovations are made available to all devices at the same time and can easily be retrofitted as needed via libraries.

For you, perfectly tailored fit with SIPROTEC 5 means:

Individually configurable devices save you money in the initial investment, spare parts storage, maintenance, extending and adapting your system.

Designed to communicate

The trendsetting system architecture places communication firmly under your control. Powerful, flexible, and above all reliable communication is the most important prerequisite for distributed and decentralized systems such as smart grids. In the system architecture of SIPROTEC 5 we have placed immense importance on communication, and we have gone to exceptional lengths to ensure that you are ideally equipped for the communication demands of today and the future.

Designed to communicate with SIPROTEC 5 means:

- Adaptation to the topology of your communication structure using settings (ring, star, network, ...)
- Scalable redundancy in hardware and software (protocols) to match your requirements
- Multiple communication channels with various higher-level systems
- Pluggable, upgradable communication modules
- Hardware modules decoupled from communication protocols
- 2 independent protocols on one module
- Extensive routines for testing connections, functions and operating workflows.

For you, designed to communicate in SIPROTEC 5 means:

Communication as an integral component of the system architecture provides you with the flexibility and safeguards you need to design and implement highly operable and reliable networked systems.

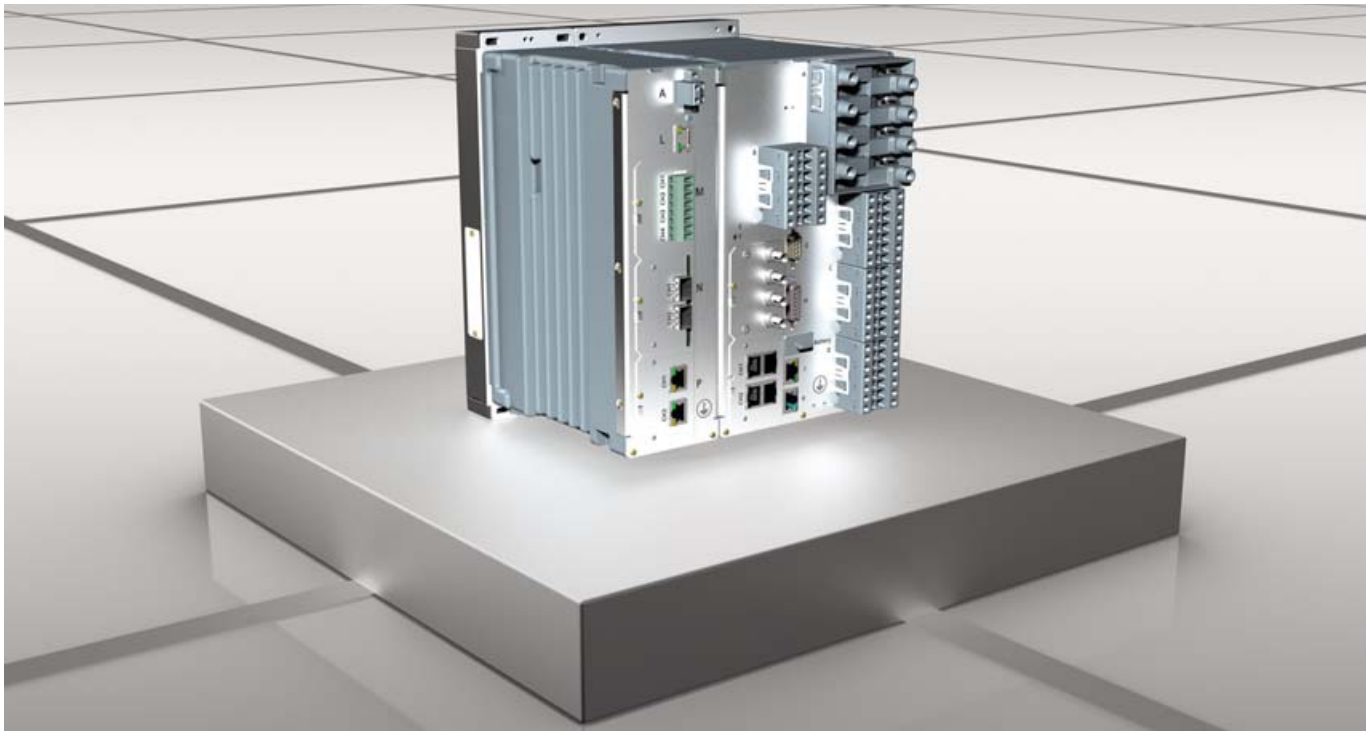


Fig. 2.3 SIPROTEC 5 device with extensive communication interfaces

Innovation highlights

Safety and security inside

Multilayer safety mechanisms in all links of the system safety chain provide you with the highest possible level of safety and availability.

Safety for personnel and equipment, and also ultimate availability, are all the top priorities. As the plant landscape systems become more open and complex, the conventional security mechanisms are no longer adequate. For this reason, a security concept has been integrated in the SIPROTEC 5 device architecture that is designed to address these multidimensional aspects in a holistic approach.

Safety and security inside with SIPROTEC 5 means:

- Proven functions for protecting systems and personnel, continuously developed over five generations
- Long-lasting, rugged hardware (housings, assemblies, plugs) and sophisticated layout of the entire electronics for highest resilience against voltage, EMC, climate and mechanical stress
- Sophisticated self-monitoring routines identify and report device malfunctions immediately and reliably
- Conformance with the stringent Cyber Security requirements according to the user guidelines and standards such as the BDEW Whitepaper and NERC CIP
- Encryption along the entire communication segment between DIGSI 5 and the device, conforming to the recommendations of IEC 62351
- Automatic recording of access attempts and security-critical operations on the devices and systems.

For you, safety and security inside with SIPROTEC 5 means:

With the multilayer safety mechanisms integrated in SIPROTEC 5, your equipment and systems will have the highest possible degree of security and reliability, conforming to the most recent requirements of international standards and technologies.

Smart automation for transmission grids

The extraordinary range of integrated functionalities for all the demands of your smart grid.

Climate change and dwindling fossil fuels are forcing a total re-evaluation of the energy supply industry, from generation to distribution and consumption. This is having fundamental effects on the structure and operation of the power grids.

Smart automation is a major real-time component designed to preserve the stability of these grids and at the same time conserve energy and reduce costs.

With SIPROTEC 5, you have the optimum smart automation platform for your smart grids.

Smart automation for transmission grids with SIPROTEC 5 means:

- Open, scalable architecture for IT integration and new functions
- The latest standards in the area of communication and Cyber Security
- “Smart functions”, e.g., for network operation, analysis of faults or power quality (power systems monitoring, power control unit, fault location)
- Integrated automation with optimized logic modules based on the IEC 61131-3 standard
- Highly precise acquisition and processing of process values and transmission to other components in the smart grid
- Protection, automation and monitoring in the smart grid.

For you, smart automation for transmission grids with SIPROTEC 5 means:

This is the first device that has been designed specifically to meet the requirements of the modern grid and offers the automation platform and future compatibility for smart grid projects.

The common features of all five innovation highlights described are IEC 61850 Edition 2 and its thoroughly designed, user-oriented implementation in SIPROTEC 5.

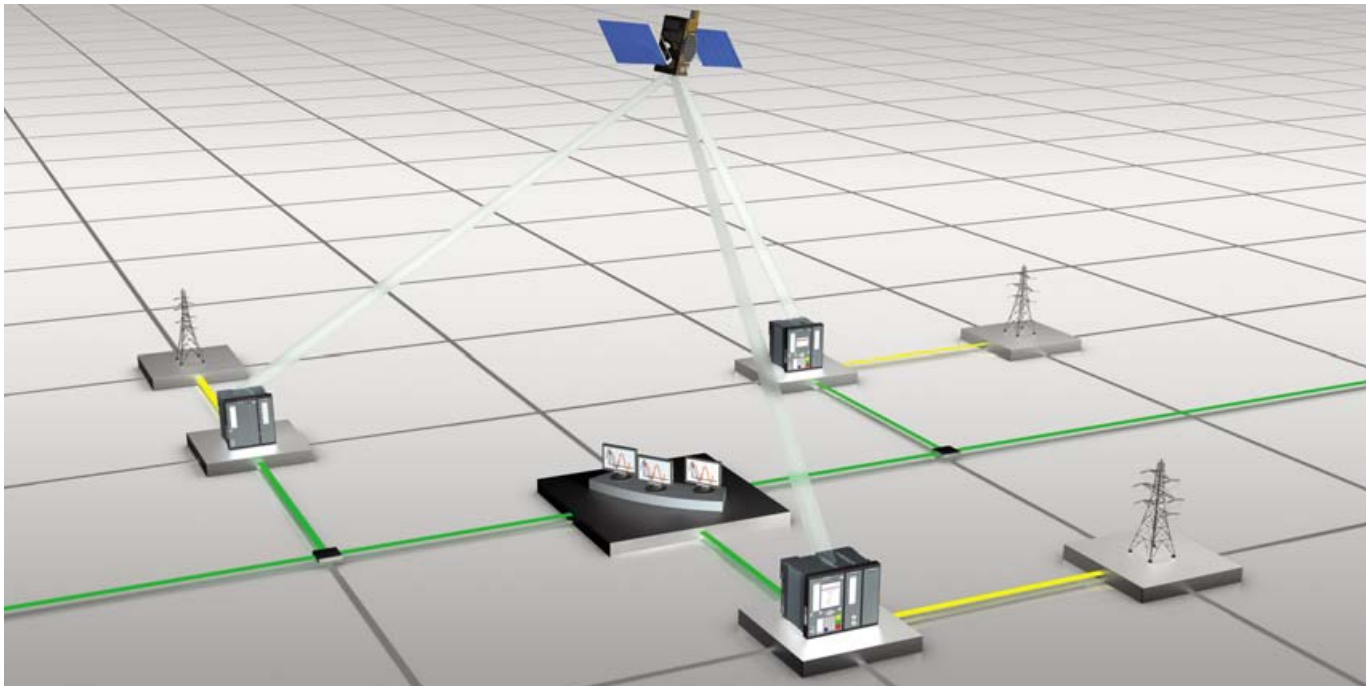


Fig. 2.4 SIPROTEC 5 as a system component of the smart grid

IEC 61850 – Simply usable

Siemens, the pioneer of IEC 61850 makes the full potential of this global standard simply usable for you.

The IEC 61850 standard is more than just a substation automation protocol. It comprehensively defines data types, functions and communication in station networks. In Edition 2, the influence of the standard is extended to more sectors and applications of the energy supply industry.

Siemens was actively involved in the process of standardization from Edition 1 to Edition 2, and with the largest number of completed installations in the world, our experience as a manufacturer in the field is unsurpassed. Jointly with key customers, we designed its implementation in SIPROTEC 5, paying close attention to interoperability, flexibility and compatibility between Editions 1 and 2.

Besides IEC 61850, SIPROTEC 5 also supports other standards such as IEC 60870-5-103 or DNP3/DNP3 IP.

"IEC 61850 – Simply usable" with SIPROTEC 5 means:

- Siemens is the pioneer and leading proponent of IEC 61850
- Full compatibility with Edition 1
- Open interfaces in accordance with IEC 61850 guarantee manufacturer-independent system configuration and interoperation
- Highly usable presentation of the complex IEC 61850 data model
- Integrated, consistent system and device engineering – from the single-line diagram of the unit all the way to device parameterization
- Assurance of mapping consistency between IEC 61850 and the device functions
- Flexible object modeling – freedom in addressing objects and flexible communication services assure the highest possible degree of interoperability and effective exchange and expansion concepts
- Optimization of handling based on many projects and close cooperation with customers from all application areas.

For you, IEC 61850 – simply usable with SIPROTEC 5 means:

The implementation of IEC 61850 Edition 2 unleashes the full potential of this standard by optimally supporting your operational needs and simplifying handling.

Meet the standard
IEC 61850

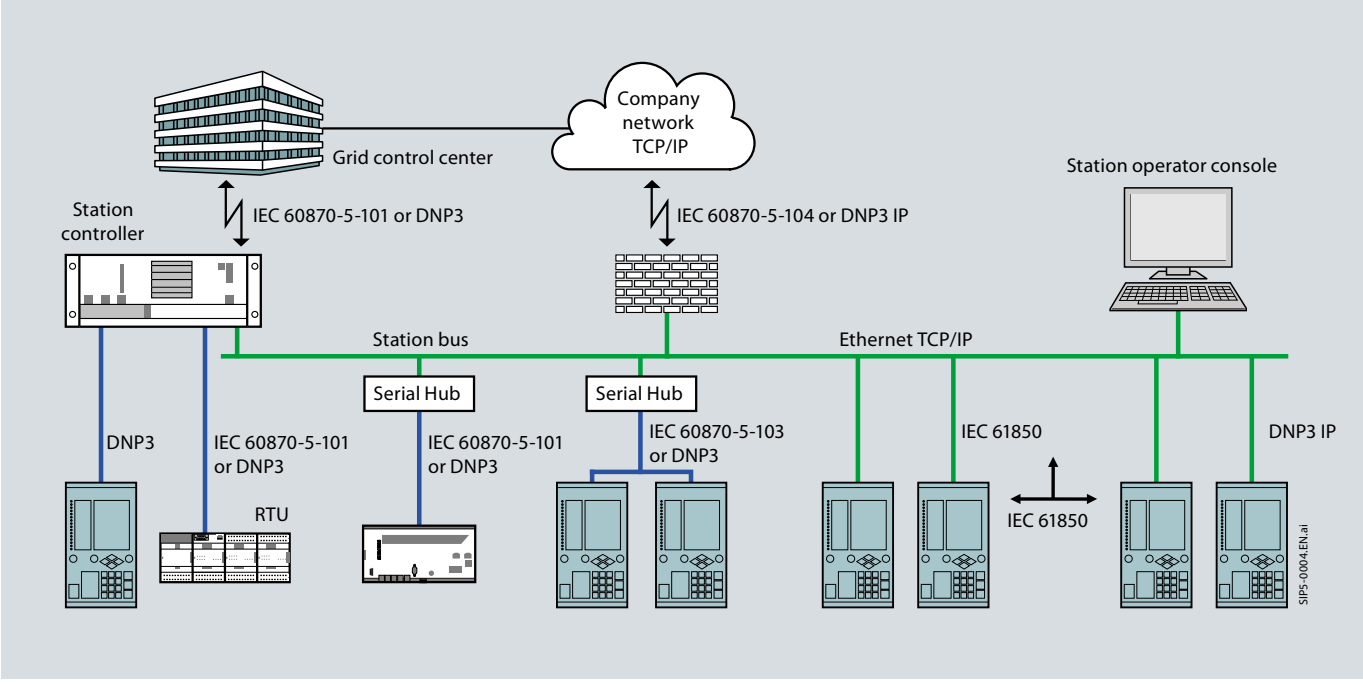


Fig. 2.5 Substation automation and power control systems

Device types

Device types

Now that you have been introduced to the innovation highlights of the SIPROTEC 5 devices, the following text will describe the devices that are used in the transmission system. They are easily identified with the aid of a five-digit abbreviation code.

The first digit (6 or 7) stands for the digital equipment. The two letters describe the functionality, and the last two digits identify typical properties. For further details, please refer to the catalog section of the respective device description.

Device types	Protection function
	Line protection
7SA84, 7SA86, 7SA87	Distance protection with PMU and control
7SD84, 7SD86, 7SD87	Line differential protection with PMU and control
7SL86, 7SL87	Combined line differential and distance protection with PMU and control
7VK87	Circuit breaker management device with PMU and control
	Overcurrent protection
7SJ85*)	Overcurrent protection with PMU, control and power quality
	Transformer protection
7UT85*) (two-winding transformer) 7UT86*) (three-winding transformer) 7UT87*) (up to 5 windings)	Transformer protection with PMU*), control monitoring
	Busbar protection
7SS85*)	Compact busbar protection
	Bay controllers
6MD85*), 6MD86*)	Bay controllers for control/interlocking tasks with PMU and monitoring
7KE85*)	**Fault recorders and power quality recorders**

*) Being prepared

Table 3.1 Available device types in the SIPROTEC 5 system

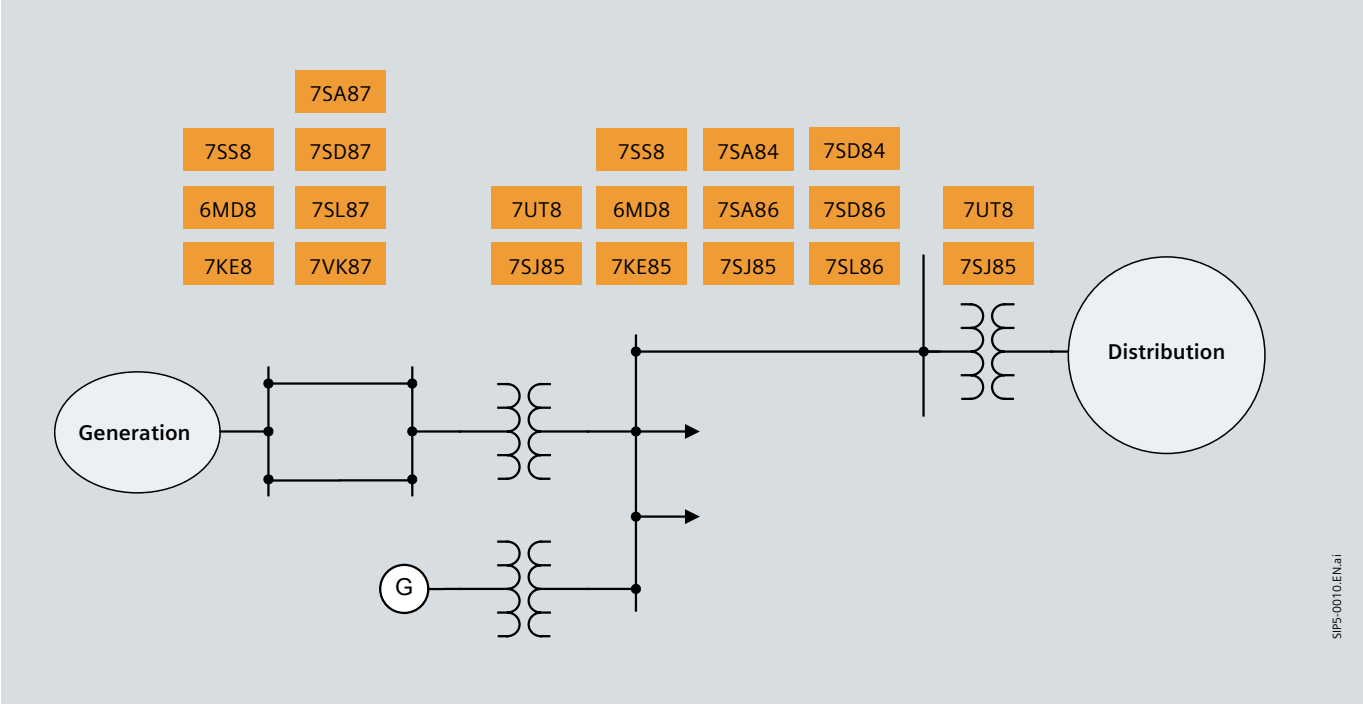


Fig. 3.1 Application areas of SIPROTEC 5 devices in the power transmission system

Fig. 3.1 provides an overview of the application of SIPROTEC 5 devices in the grid. This is a simplified illustration. Particularly with the advent of regenerative suppliers, energy is being injected into the grid at all voltage levels.

The protection objects are the busbars, the overhead lines or cables, and the transformers. The corresponding protection devices have been assigned to these objects.

Due to the modular construction of their hardware and software, and their functional integration, SIPROTEC 5 devices are well suited for all tasks in the electricity transmission and distribution grid.

The SIPROTEC 5 devices can be used for the following applications:

- **Protection**
- **Control and automation**
- **Monitoring**
- **Data acquisition and recording**
- **Communication and Cyber Security**
- **Test**

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. 3.2 shows the possible functional expansion of a SIPROTEC 5 device.

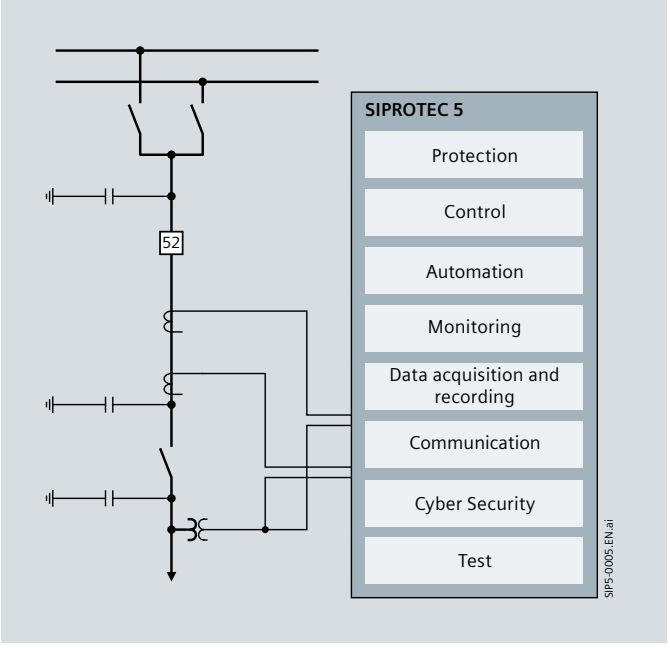


Fig. 3.2 Possible functional expansion of SIPROTEC 5 devices

Perfectly tailored fit – Protection

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 the specific functional scope for typical applications.

Fig. 3.3 shows an example of a system configuration with breaker-and-a-half scheme. Note that the functions in the application template are combined in functional groups (FG). The functional groups (FG) correspond to the primary components (protection object: line; switching device: circuit breaker), thereby simplifying the direct reference to the actual system. For example, if your switchgear includes 2 circuit breakers, this is also represented by 2 "circuit breaker" functional groups – a schematic map of your actual system.

Optimizing the application template for your specific application

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

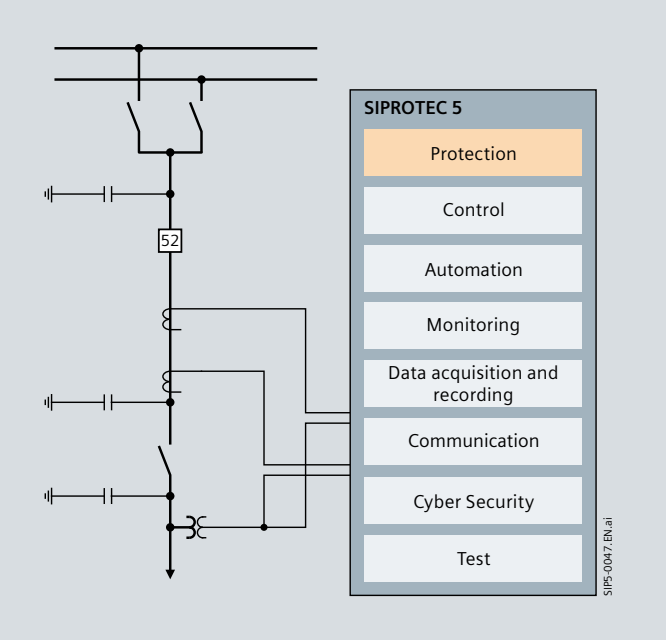


Fig. 3.4 Possible functional expansion of SIPROTEC 5 devices

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.

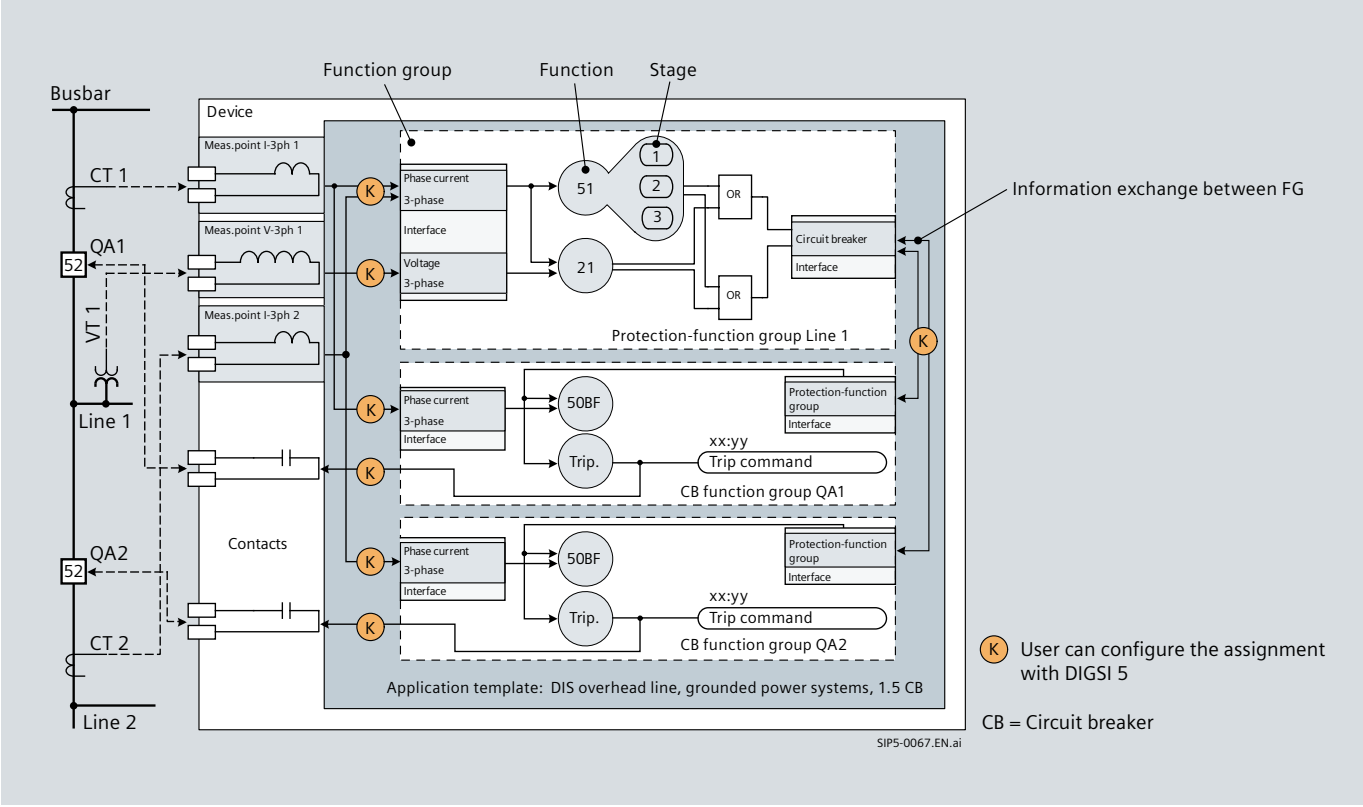


Fig. 3.3 System configuration with application template for breaker-and-a-half scheme

SIPROTEC 5 in breaker-and-a-half schemes

In switchgear configurations using breaker-and-a-half schemes, the SIPROTEC 5 devices process the measurement values directly from the current transformers and links them internally according to their protection function (e.g. summation for distance protection, separate processing for differential protection). Tripping events are carried out consistently with respect to the specific circuit breakers. Fig. 3.5 shows the typical structure.

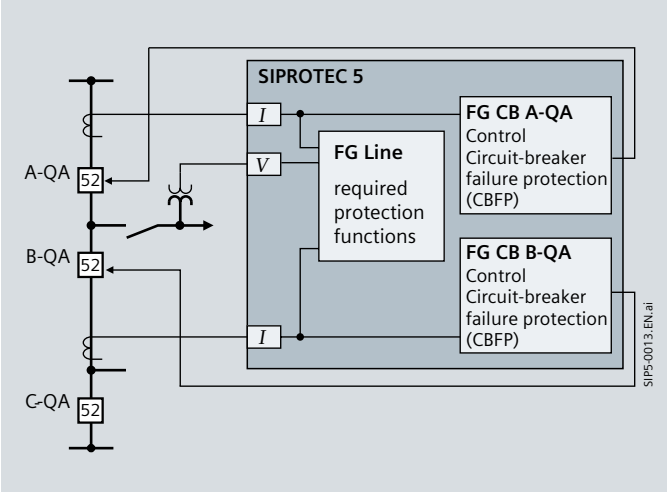


Fig. 3.5 Activation in breaker-and-a-half scheme

Redundant line protection

Protection applications for high-voltage transmission lines are based on the principles of distance protection and differential protection. Redundant protection schemes are required to ensure protection reliability and security. In order to prevent any possibility of systematic faults due to protective device fault detection and trip failures, differing protection principles are preferred. Fig. 3.6 shows one example of a possible application.

A 7SL87 (combination line differential and distance protection) is used as the main 1 protection. Data is exchanged between the devices via an SDH (Synchronous Digital Hierarchy) communication network. Main 2 protection is a 7SA87 distance protection in which the communication interfaces are also used. Tele-protection / pilot protection (e.g. permissive overreach POTT) is optionally implemented per protocol via the protection data interface. In addition to the main protection functions, other protective functions such as voltage or frequency protection and phasor measurement can be activated in both protection devices according to the requirements.

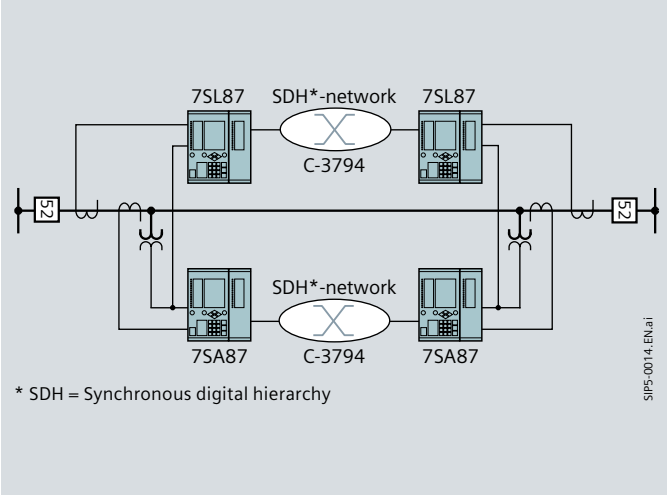


Fig. 3.6 Protection of a power transmission line, redundant protection configuration

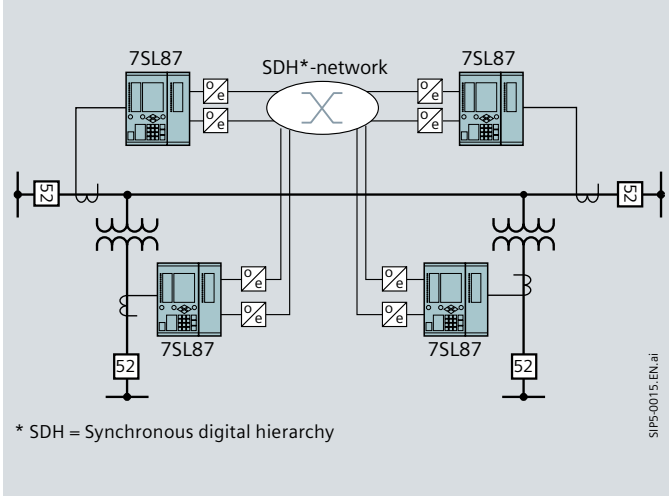


Fig. 3.7 Differential protection in high-voltage lines with branch line

Multiple terminal line protection

The line differential protection is perfectly tailored to protecting line configurations with multiple terminals (Fig. 3.7). Up to 6 devices can exchange data via different communication media. At the same time, a transformer can be included in the zone of protection.

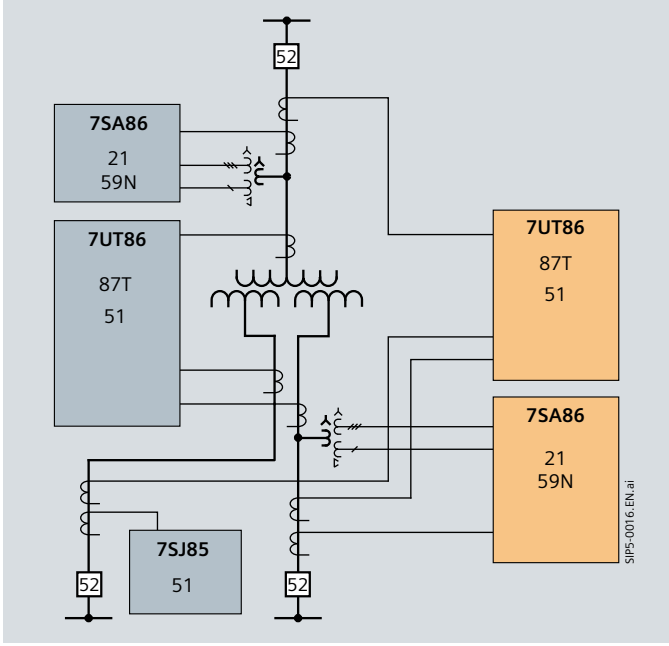


Fig. 3.8 Transformer protection with backup protection

Perfectly tailored fit – Protection

Transformer protection

The transformer protection 7UT8 can manage a wide variety of system configurations (two-winding transformer, three-winding transformer, multiple-terminal line applications, transformers with tap changer, autotransformers and phase shifting transformers as well as reactors, motors and generators). The main protection functions are phase and ground current differential protection. Overload protection monitors the thermal loading of the protected equipment. Functions can also be activated that monitor the lifecycle of the transformer on the basis of its load (current flow and measured temperature). Combining this transformer lifecycle monitoring and the additional condition monitoring capabilities of SIPROTEC 5 with its protection and control functions can therefore provide complete monitoring and protection of transformers using a single 7UT8 device (see page 19 for SIPROTEC 5 equipment condition monitoring capabilities).

Depending on the concept, the differential protection can be redundant or a distance or overcurrent protection may be used as the backup protection. Fig. 3.8 (page 15) shows an example of one possible protection scheme for a three-winding transformer using redundant differential and overcurrent protection on the transformer.

Instrument and protection-class current transformer

The flexibility of the SIPROTEC 5 family enables even greater functional integration and parallel processing of an extremely wide range of functions. The modular hardware enables an application-specific device configuration. If you also want to use the phasor measurement function, i.e., the highly precise acquisition of current and voltage phasors and the variables derived from them such as power and frequency, this function can be assigned to the measuring input. Another additional application is monitoring power quality characteristics.

Fig. 3.9 shows the connection to a protection-class and instrument current transformer for a feeder. The necessary protection functions are assigned to the protection-class current transformer and the measurement functions are assigned to the instrument transformer according to the application.

The highly precise measured values and status information provided by the SIPROTEC 5 devices can be transmitted over the high-performance communication system to automation systems such as a substation and power systems control or central analysis systems (e.g., SIGUARD PDP). In particular, the control and monitoring of “smart grids” require information from power generators (conventional or renewable energies) and from consumers (line branches). This essential information may be measured values, switching statuses, or messages from protection and monitoring functions. In addition to performing local protection, control and monitoring tasks, the SIPROTEC 5 devices are an excellent data source. The flexible communication among the devices enables them to be combined in various communication topologies. In this context, the widely used Ethernet-based communications standard IEC 61850 offers many advantages.

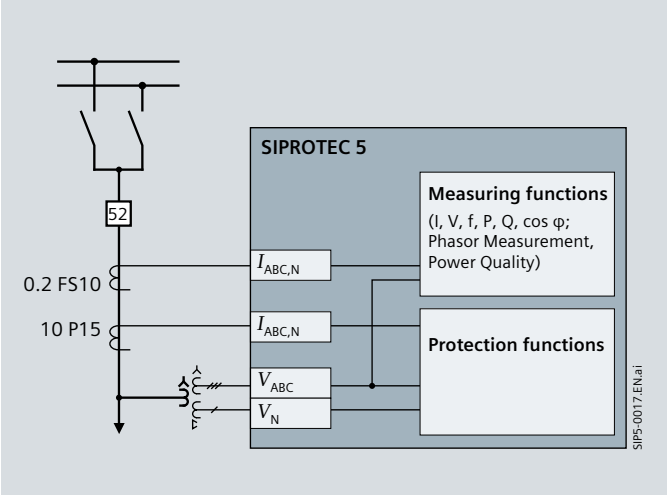


Fig. 3.9 Connection of field devices to instrument and protection-class current transformers

Control

SIPROTEC 5 includes all bay level control and monitoring functions that are required for efficient operation of the switchgear. The application templates supplied provide the full functionality that you need for your application. Protection and control functions access the same logical elements. In Fig. 3.3 – page 14 (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)).

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) function chart can be expanded. The scope covered by the "basic function chart" is always available while the other 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.

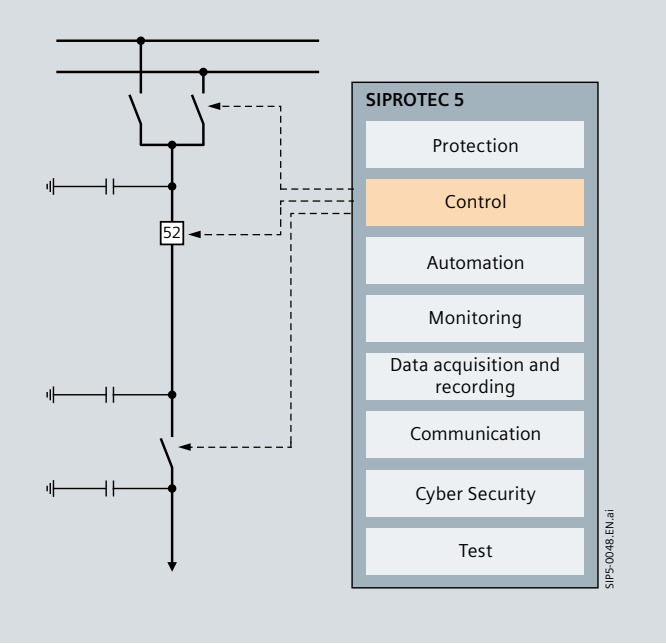


Fig. 3.10 Possible functional expansion of SIPROTEC 5 devices

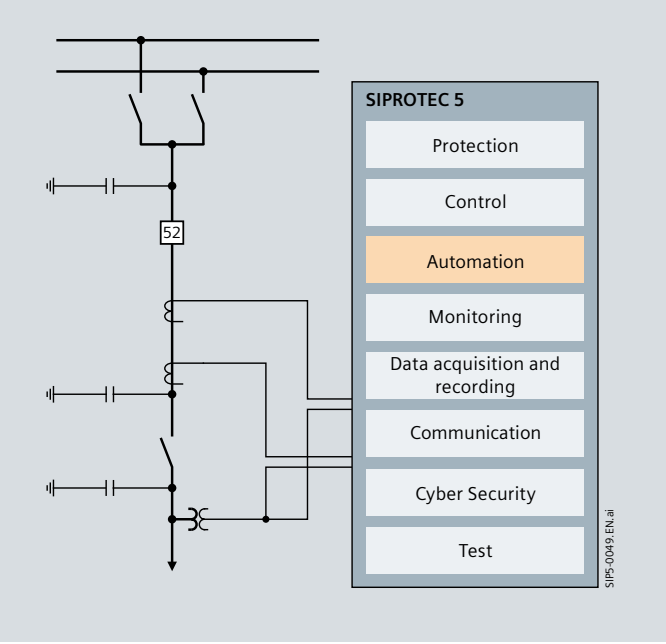


Fig. 3.11 Possible functional expansion of SIPROTEC 5 devices

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.

Perfectly tailored fit – Monitoring

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 self-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 recorders, fault locators and phasor measurement units (PMUs) for grid monitoring. The SIGUARD PDP Wide Area Monitoring System is available for analyzing and displaying the synchrophasor measurement units (see Fig. 3.12).

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.

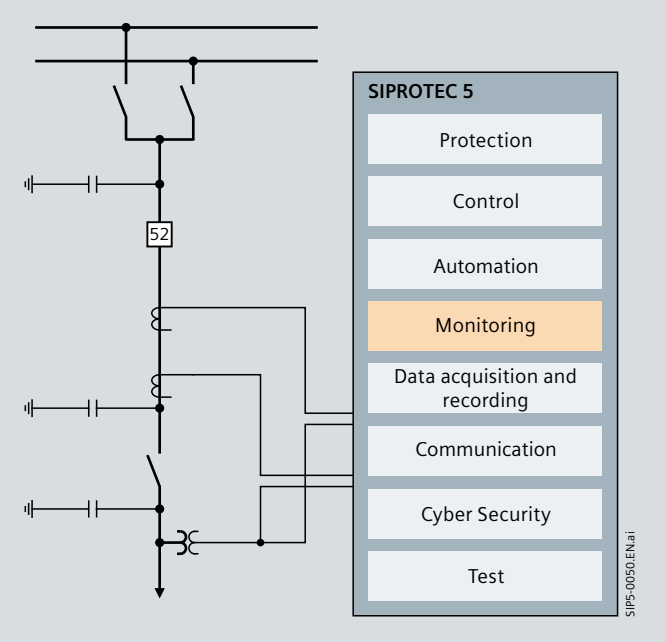


Fig. 3.13 Possible functional expansion of SIPROTEC 5 devices

Power quality

Besides availability, the end consumers demand that the electrical energy they receive is also of high quality.

The increasing use of power electronic components can have detrimental effects on power quality. Poor power quality can cause interruptions, production outages, and high follow-up costs. Accordingly, it is essential to capture and evaluate the grid variables reliably according to generally valid quality

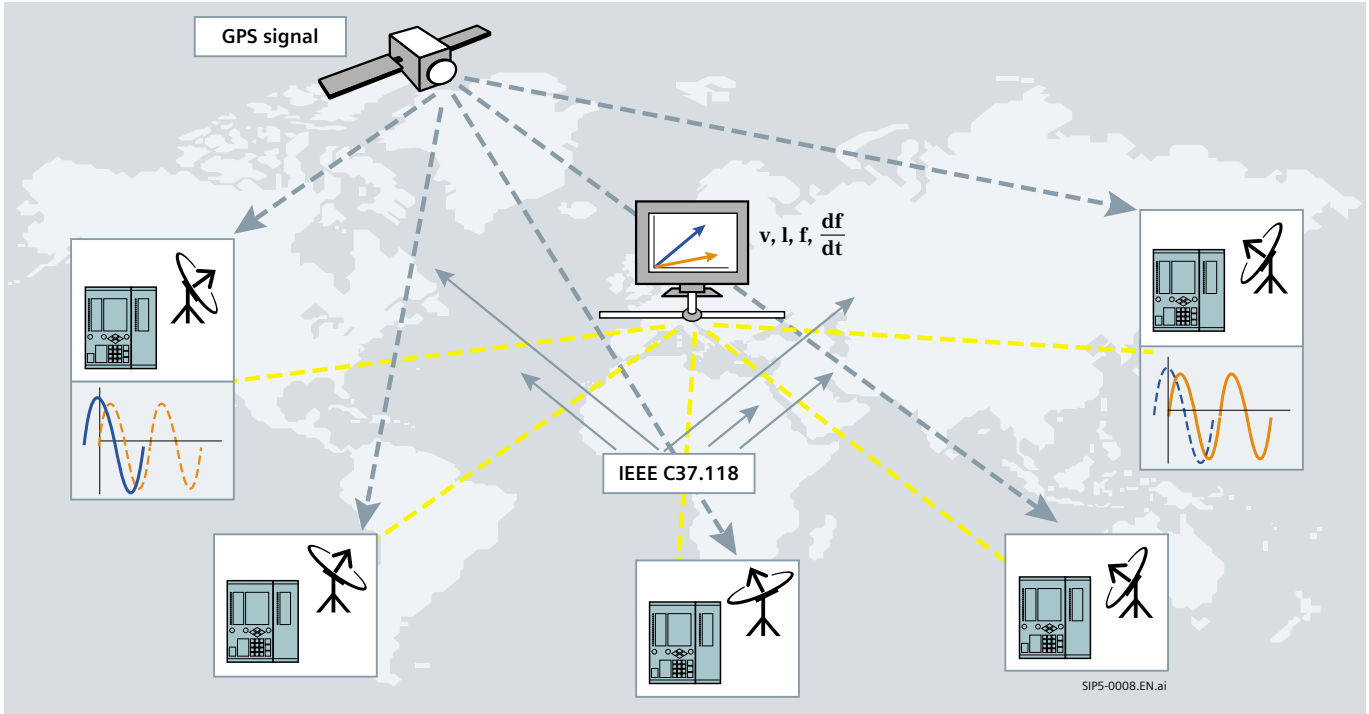


Fig. 3.12 Wide Area Monitoring with PMU

Monitoring (continued)

criteria as defined in the standard EN 50160. For this, SIPROTEC 5 provides corresponding power quality recorders. These can be used to detect weak points early so that appropriate corrective measures can be taken.

The large volume of data is archived centrally and analyzed neatly with a SICAM PQS system.

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 (Fig. 3.14).

SIPROTEC 5 provides the process interfaces, buffers, recorders 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 provide 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.

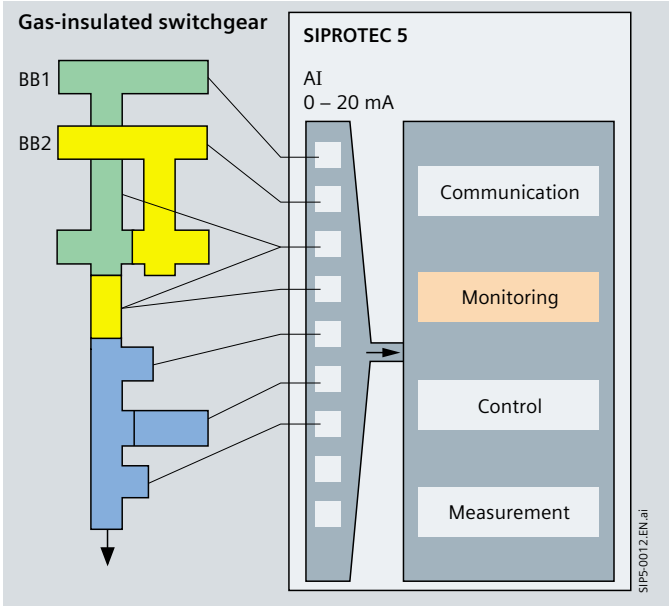


Fig. 3.14 Gas monitoring with SIPROTEC 5 device

Perfectly tailored fit – Data acquisition and recording

Data acquisition and recording

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

Measurement

A large number of measured values is derived from the input variables and presents 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.

Besides the base measured values, phasor-measured units (PMUs) can also be activated in the devices. Phasor measured 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).

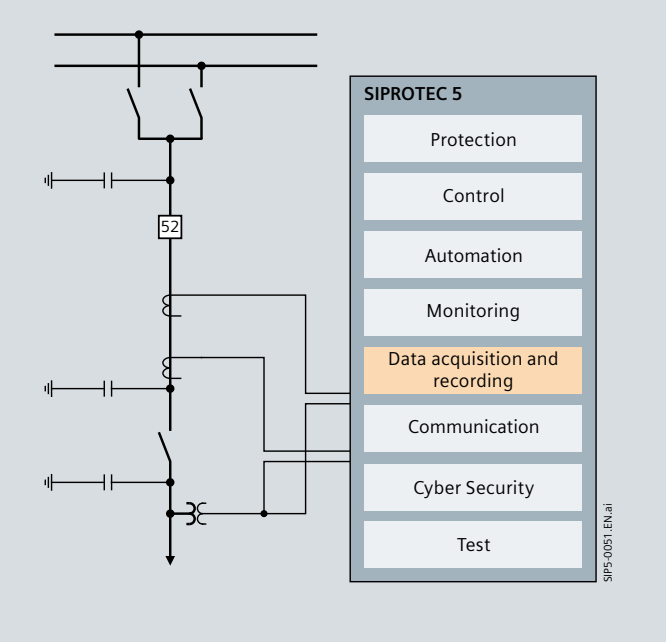


Fig. 3.15 Possible functional expansion of SIPROTEC 5 devices

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 instead of protection class CT input is required (exchange of CT terminal module). The following precisions are typical:

Processing via the protection-input transformer:

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

Processing via the measuring-input transformer:

- $I \leq$ 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.

Data acquisition and recording (continued)

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.

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 measured 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 capacity 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 binary and 50 additional measured value tracks
- The 7KE85 fault and power quality recorder has yet more features:
  - Extended trigger criteria: Gradient trigger (ΔM/Δt); 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.

Fig. 3.16 Analysis of fault recorder data using PQ analyzer

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.

Perfectly tailored fit – Data acquisition and recording

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 3.2 "Overview of typical message logs" provides an overview of typical logs.

Buffer	Scope of messages	Description
Operational log	2000 messages	Cyclical recording of operating messages (e.g., control procedures)
Fault log	1000 messages	Storage of data after a protective trip or external triggering; no limit to the number of faults
User specific log	200 messages	Optionally cyclical or event-controlled recording of user-defined signals
Sensitive ground-fault log	200 messages	Storage of messages in the event of a single ground fault in system with resonant grounded or isolated star point
Parameterization history log (cannot be deleted)	200 messages	Recording of all parameter changes and configuration downloads
Communication log	500 messages	Recording of the status of all configured communication connections such as malfunctions, test and diagnostic mode and communication loads
Security log (cannot be deleted)	500 messages	Recording of successful and unsuccessful attempts to access restricted areas of the device
Diagnostic log	500 messages	Recording and display of specific action instructions for essential maintenance activities (e.g., battery supervision), detected hardware defects or compatibility problems

Table 3.2 Overview of typical logs

Functionality of the fault recorder and power quality recorder

Besides the SIPROTEC 5 protection and control devices, which create fault records and perform power quality monitoring functions, the SIPROTEC 5 7KE85 device has a considerably expanded functionality in terms of fault recording and monitoring power quality characteristics. For example, instantaneous values (fault recorder) can be recorded with a sampling frequency of up to 16 kHz. Calculated values (rms values) are recorded in the slow scan recorder. Continuous recording (averages) can be performed with the continuous recorder. Recording of binary information is a further option. If the device is connected to an Ethernet network, the transmitted GOOSE messages are recorded.

Power quality characteristics are recorded and analyzed in accordance with the EN 50160 standard. Recordings can be initiated by various trigger criteria. All data are captured on a mass storage medium inside the device by means of a smart compression procedure. Final data archiving takes place on PC-based data concentrators. The strengths of the SIPROTEC 5 are revealed in the communication: A variety of interfaces and protocols can be used.

Another optional use of the 7KE85 fault and power quality recorder is for recording phasor measurement data. Fig. 3.17 shows the application of the 7KE85 in a subnetwork. The arrangement of the busbars is intended to indicate that the data from multiple branches can be recorded. The fault records, the power quality values and the voltage and current phasors (PMU data) are archived in the data concentrator. Analysis is performed by powerful tools. The SICAM PQS analyzes power quality values and fault records. SIGUARD is deliberately optimized for analyzing PMU data.

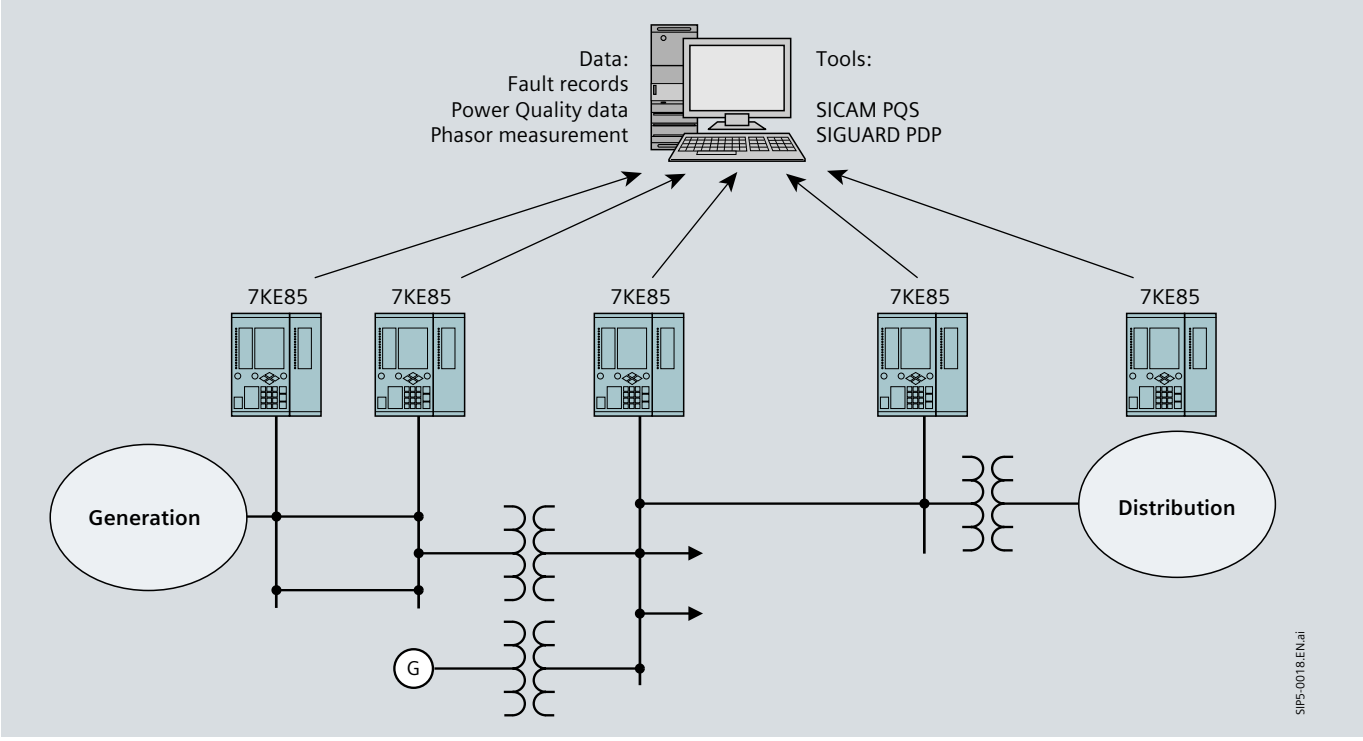


Fig. 3.17 Local data acquisition, central archiving and analysis

Perfectly tailored fit – Communication and Cyber Security

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).

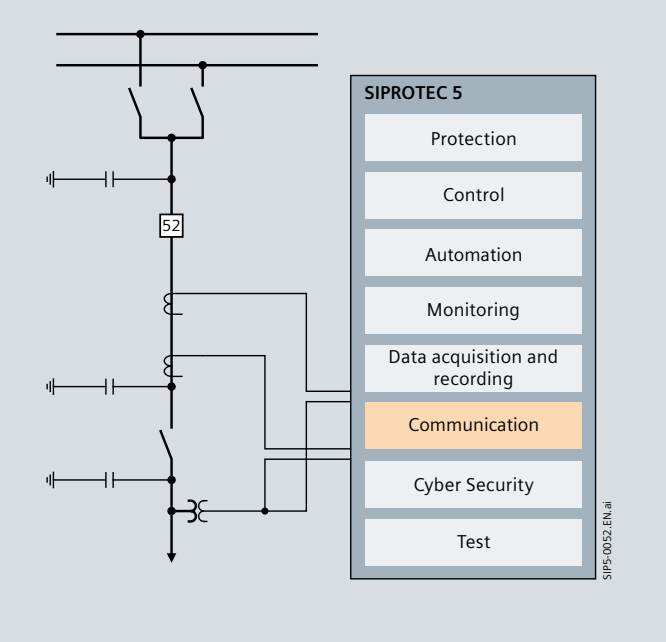


Fig. 3.18 Possible functional expansion of SIPROTEC 5 devices

Cyber Security

A multi-level 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 recorded. 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.

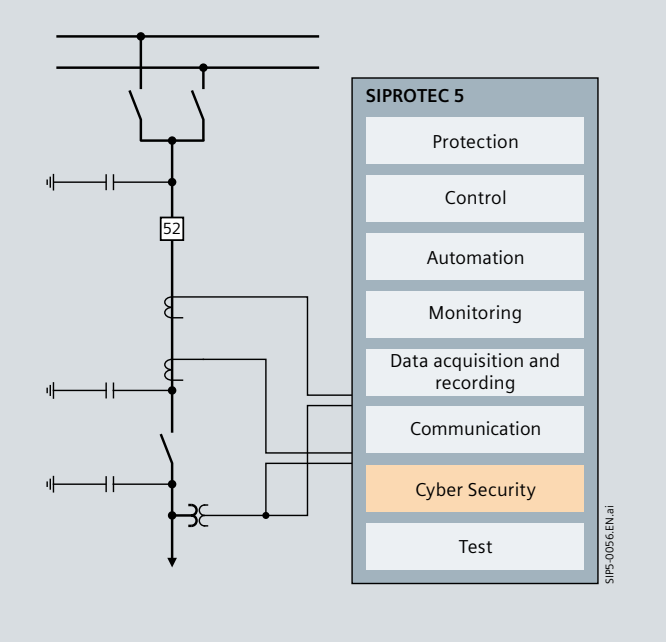


Fig. 3.19 Possible functional expansion of SIPROTEC 5 devices

In addition, security-critical operations are recorded 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.

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
- Function and protection-function test
- Simulation of digital 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.

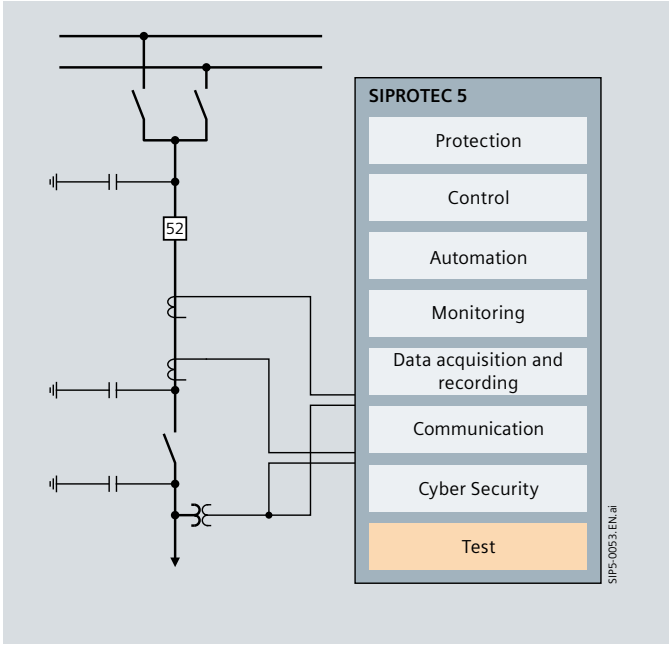


Fig. 3.20 Possible functional expansion of SIPROTEC 5 devices

The modular, flexible structure of the hardware and software ensures perfectly customized solutions for all your requirements in the network. With SIPROTEC 5, you have flexibility throughout the entire product lifecycle, and your investment is thus protected.

Perfectly tailored fit – Hardware building blocks

The SIPROTEC 5 hardware building blocks offer a freely configurable device. You have the choice:

Either you use a pre-configured device with a quantity structure already tailored to your application, or you build a device yourself from the extensive SIPROTEC 5 hardware building blocks to exactly fit your application.

The flexible hardware building blocks offer you:

- **Base modules and expansion modules, each with different I/O modules**
- **Various on-site operation panels**
- **A large number of modules for communication, measured value conversion and memory extension**

Flexible and modular

With SIPROTEC 5, Siemens has also taken a new path with the design. Proven elements have been improved and innovative ideas have been added. When looking at the new devices, the modular structure is evident. In this way, the scope of the process data can be adapted flexibly to the requirements in the switchgear assembly. You can choose: Either you use a pre-configured device with a quantity structure already tailored to your application, or you build a device yourself from the extensive SIPROTEC 5 hardware building blocks to exactly fit your application. Pre-configured devices can be extended as needed.

You can also combine different base and expansion modules, add communication modules and select an installation variant that fits the space you have available.

With this modular principle you can realize any quantity structures you desire. In this way, hardware that is tailored to the application can be selected. Fig. 4.1 shows a modular device consisting of a base module and 4 expansion modules.

SIPROTEC 5: The advantage of modular building blocks

The SIPROTEC 5 hardware module building blocks provides the cumulative experience of Siemens in digital protection devices and bay controllers. In addition, specific innovations were realized that make the application easier for you, e.g. recorder and PQ functionalities.

The SIPROTEC 5 hardware building blocks offer:

Durability and robustness

- Tailored hardware extension
- Robust housings
- Excellent EMC shielding in compliance with the most recent standards and IEC 61000-4
- Extended temperature range –25 °C to +70 °C/–13 °F to +158 °F.

Modular principle

- Freely configurable and extendable devices
- Large process data range (up to 24 current and voltage transformers for protection applications and up to 40 for central busbar protection as well as more than 200 inputs and outputs for recording applications possible)
- Operation panel that is freely selectable for all device types (e.g. large or small display, with or without key switches, detached operation panel)
- Identical wiring of flush-mounting and surface-mounting housings.

Fig. 4.1 SIPROTEC 5 device built in modules

User-friendly operation panel

- Eight freely assignable function keys for frequently required operator control actions
- Separate control keys for switching commands
- Context-sensitive keys with labeling in the display
- Complete numeric keypad for simple entry of setting values and easy navigation in the menu
- Up to 80 LEDs for signaling, 16 of which are in two colors.

Application-friendly design

- No opening of device necessary for installation and servicing
  - Easy battery replacement on the back of the device
  - Simple exchange of communication modules with plug-in technology
  - Electronically settable (no jumpers) threshold for binary inputs
  - Rated current (1 A/5 A) of current transformer inputs configurable electronically (no jumpers)
- Removable terminal blocks
  - Pre-wiring of terminals is possible
  - Simple replacement of current transformers, e.g. with sensitive ground current transformers if neutral grounding method is changed.
  - Increased safety, since open current transformer circuits are no longer possible (safety CT plug).

Hardware building blocks with a system

SIPROTEC 5 offers a modular, freely configurable device design. This maximum flexibility is guaranteed by the SIPROTEC 5 modular system. This contains coordinated components which you can combine to configure your individual device:

- Base modules and expansion modules, each with different I/O board
- Various front operation panels, e.g. with large display
- A large number of modules for communication, measured value conversion and memory extension.

With reference to SIPROTEC 5, the term device always designates all the basic, extension and plug-in modules as well the matching front panels combined together.

A base module together with a front operation panel is already a standalone device in itself. In order to obtain additional functionality, and above all more connections for process integration, you can supplement a base module with expansion modules. Fig. 4.1 shows you a single-line sample configuration with a base module and 4 expansion modules.

Base and expansion modules

A SIPROTEC 5 device can consist of exactly one base module, and in the case of a two-tier device, optionally up to 9 expansion modules and a power-supply module. Base and expansion modules are distinguished firstly by their width. A base module takes up a third of the width of a 19-inch frame, while an expansion module takes up a sixth. The larger width of the base module creates sufficient space at the rear for connection to the process (terminals) as well as plug-in modules. The expansion module can provide either additional process connections or additional communication connections.

Fig. 4.2 shows the rear side of a device consisting of a base module in which the power supply, the CPU module and an I/O board are permanently installed, as well as 4 expansion modules for extending the I/O quantity structure, and communication modules. Each expansion module contains an I/O board. The components are connected by bus connector plugs and mechanical interlockings.

Fig. 4.2 Rear view of base module with 4 expansion modules

Such a device can be ordered pre-configured from the factory. In this context you can choose between the standard variants predefined by Siemens and the devices you have combined yourself. Every SIPROTEC 5 device can also be converted or extended according to your wishes. The modular concept absolutely ensures that the final device meets all standards, particularly with regard to EMC and environmental requirements.

On-site operation panels

The on-site operation panel is a separate component within the SIPROTEC 5 modular system. This allows you to combine a base or expansion module with a suitable front operation panel, according to your requirements. The modular system offers 3 different on-site operation panels for selection, both for base modules and for expansion modules.

The following variants are available for base modules (Fig. 4.3):

- With a large display, keypad and 16 multi-colored LEDs
- With a small display, keypad and 16 multi-colored LEDs
- 16 multi-colored LEDs.

Fig. 4.3 Operation panels with (from left) large and small display, and operation panel without display

Perfectly tailored fit – Operation

On-site operation panels (continued)

The following variants are available for expansion modules (Fig. 4.4):

- Without operating or control elements
- With 16 LEDs (single-colored)
- With 16 LEDs (single-colored) and key switch.

The SIPROTEC 5 module is flexible with regard to selection of the operation panel. You can order any device type with a large, graphical display or with a smaller, economical standard display. For applications without device operation an operation panel without display is also available. The operation panel with a small display is the ideal solution for pure protection devices. The display offers seven lines for measured values or menu texts. All operation and control keys are available to the user, i.e. he can also control switching devices.

Elements of the on-site operation panels

The operator elements are illustrated with the example of the on-site operation panel with a large display.

The central element is the generously sized display for text and graphics. With its high resolution, it creates ample space for symbols in graphical representations (Fig. 4.5).

Below the display there is a 12 key keypad. In combination with 4 navigation keys and 2 option keys you have everything you need to navigate conveniently and quickly through all information that is shown in the display. 2 LEDs on the upper border of the operation panel inform you about the current device operating state.

16 additional LEDs, to the left of the keypad, ensure quick, targeted process feedback. The USB interface enables fast data transfer. It is easily accessible from the front and well protected with a plastic cover.

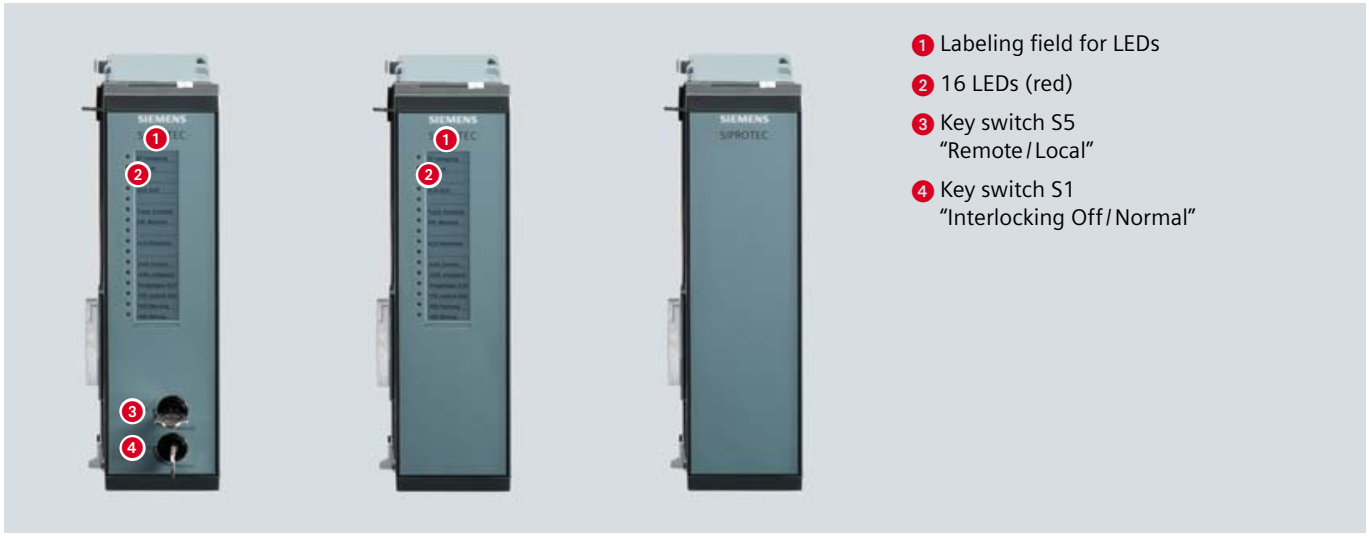


Fig. 4.4 Designs of the expansion modules

The operation panel with large display also enables representation of the control display (Fig. 4.5) and thus offers more room for measured values and the display of event lists. This operation panel is therefore the first choice for bay controllers or combined protection and control devices.

As a third option, an economical variant is available without keypad and display. This variant is appropriate for devices that are seldom or never used by the operational crew.

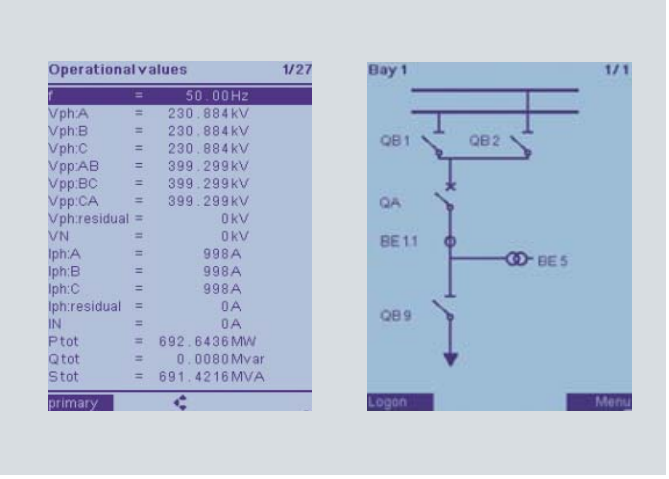


Fig. 4.5 Display of measured values in the large display

Elements of the on-site operation panels (continued)

The keys O and I (red and green) for the direct control of equipment, a reset key for the LEDs, and the control key for switching to the control display (mimic diagram), complete the operation panel (Fig. 4.6).

Options

You can order any SIPROTEC 5 device, regardless of its individual configuration, in 3 different installation variants:

- As flush-mounting device
- As surface-mounting device with integrated on-site operation panel
- As surface-mounting device with the on-site operation panel detached.

The construction of the flush-mounting devices will be recognizable from the previous sections. We would like to briefly introduce you to the two other variants here.

Surface-mounting device with integrated on-site operation panel

For wall-installation the SIPROTEC 5 devices can be ordered in the surface-mounting housing (Fig. 4.7). Thanks to a new concept, these devices have terminal connection diagrams that are identical to the corresponding flush-mounting devices. This is achieved by installing the devices using the principle "with the face to the wall" and then attaching the operation panels to the terminal side. With the brackets that are used, sufficient space remains for the wiring, which can be routed away upwards and downwards.

Surface-mounting device with the on-site operation panel detached

If the operation panel is to be installed detached from the device, it can be installed as a separate part and connected to the device with a 2.5 m long connecting cable. In this way, the SIPROTEC 5 device can be situated, for example, in the low-voltage fixture and the operation panel can be installed precisely at the correct working height in the cabinet door. In this case, the device is fastened like a surface-mounting device on the cabinet wall. An opening must be provided in the door for the operation panel.

Fig. 4.7 Device in surface-mounting housing

1. Large graphical display
2. Labeling field for LEDs
3. 16 LEDs (green or red, settable parameters)
4. 16 LEDs (red)
5. LED reset
6. USB interfaces
7. Labeling field for function keys
8. Numerical keys and function keys
9. Control/command keys
10. Context-sensitive keys
11. Cursor keys
12. Key switch S5 "Remote / Local"
13. Key switch S1 "Interlocking Off / Normal"

Fig. 4.6 SIPROTEC 5 operation panel

Perfectly tailored fit – SIPROTEC 5 terminals

The SIPROTEC 5 terminals

Innovative terminals offering many advantages were developed for the SIPROTEC 5 family (Fig. 4.2 – page 27).

All terminals are individually removable (Fig. 4.9). This enables pre-wiring of the systems, as well as simple device replacement without costly re-wiring.

Current terminals (safety CT plug):

The 8-pole current terminal with 4 integrated current transformers is available in 3 designs:

- 4 protection-class current transformers
- 3 protection-class current transformers + 1 sensitive protection-class current transformer
- 4 instrument transformers.

The terminal design enables the following advantages for the connection of currents:

- Exchange of the current transformer type also possible retroactively on-site (e.g. protection-class current transformer for instrument transformer, sensitive for normal ground current transformers in cases of network conversions)
- Additional safety during tests or device replacement, since the secondary current transformer circuits always remain closed.

Voltage terminal:

The voltage transformers and the binary input and output signals are connected via the 14-pole voltage terminal. The cable entry to the terminal enables clear access to the terminal connection. Bridges precisely matching the current and voltage terminals are available for bridging contacts with common potential (see spare parts/accessories, page 75 and Fig. 4.8).

Fig. 4.8 Voltage and current terminal block with bridges

Fig. 4.9 Removed current terminal block

Selection of the input/output boards

Which and how many process connections a base or expansion board has depends on the choice of a particular input/output board. The modular building block concept includes different input/output boards.

The IO202 input/output board is used e. g. as a base measuring module. By equipping several modules with this module, you can achieve up to 40 measuring channels per SIPROTEC 5 device.

In the module there are connections for:

- 4 voltage transformers
- 4 current transformers, optionally protection-class current transformer, sensitive protection-class current transformer or instrument transformers
- 8 binary inputs (BI)
- 6 binary outputs (BO), designed as 4 fast speed (Typ F) normally-open contacts and 2 fast speed change-over contacts.

The connections are distributed on (Fig. 4.10):

- 1 x 8-pole current terminal block
- 3 x 14-pole voltage terminal blocks

Select the modules suitable for your purposes so that you can build the SIPROTEC 5 device that precisely matches your application. You will find an overview of the modules that are available and their quantity structures in Table 4.1 Module quantity structures.

Module CB202

Module CB202 represents a special case. CB202 (CB = Communication Board) provides 3 positions for plug-in modules. These can be used to plug in up to 2 communication modules or up to 3 measurement transducer modules. Combinations are also possible, e.g. 2 communication modules and one measurement transducer module.

Designation	U input	I input	BI (isolated)	BI (connected to common potential)	BO normally-open contacts	BO normally-open contacts Type F	BO normally-open contacts Type HS	BO change-over contacts	BO change-over contacts Type F
PS201				3	1			2 *	
IO201		4	8			4			2
IO202	4	4	8			4			2
IO203		8	4			4			
IO205			12		16				
IO206			6		7				
IO207			16		8				
IO208	4	4	4		3	6			2
IO209			8				4		
IO214	4	4	2			4			1

Differentiation of relay types:
Type F – fast relay with monitoring (pickup time < 5 ms)
Type HS – high-speed relay (contact with solid-state bypass) with monitoring (pickup time < 0.2 ms) – * of which 1 life contact

Table 4.1 Quantity structures of the modules

The power supply is integrated, so that the CB202 can be powered independently of the main device. Communication with the main device is assured via an RJ45 connector and the bus connection on the front of the module.

The CB202 is always integrated in an expansion module (Fig. 4.11).

Fig. 4.10 Rear view of an expansion module IO202

Fig. 4.11 Expansion module based on the example of the CB202

Perfectly tailored fit – Modules

The application options for the modules (base module, expansion module) are listed in Table 4.3 "Fields of application and properties of modules". You can see whether the module includes a power supply and how many slots for plug-in modules it has.

Measuring ranges of the current transformer modules

The measuring range (full modulation) of the current transformers can be set to different values electronically – depending on the field of application. In all cases, you can choose between protection-class and instrument transformers. The possible measuring ranges according to rated current are shown in the following Table 4.4 "Measurement ranges according to rated current".

A large dynamic range is necessary for network protection applications, so that short-circuit currents can be recorded without distortion. A value of 100 × I_{rated} has proven optimal. For 5 A transformer rated current, this corresponds to a setting of 500 A, and consequently of 100 A for 1 A transformers. For applications in generator protection, while it is true that there are very large primary currents, a dynamic range of 20 × I_{rated} is still quite sufficient. Thus a measuring range of 100 A is obtained for a setting I_{rated} = 5 A and a measurement range of 20 A for I_{rated} = 1 A.

A smaller dynamic range means that greater accuracy is achieved in the rated current range. Consequently, the dynamic range for instrument transformers and sensitive protection-class current transformer input for ground fault currents is extremely limited. In this case, limited means that the input current is chopped on the analog side. Of course, the inputs in this case are protected against overdriving.

Module	Description
PS201	The power supply module PS201 is always permanently installed in the base module. Apart from providing the power supply for the device it makes room for 2 plug-in modules
IO201	This is the base module for protection applications that require no voltage measurement. It is available in the base module or in a separate expansion module
IO202	This is the base module for all devices that require current and voltage measurement. It is available in the base module or in a separate expansion module
IO203	This is the module for devices that require numerous current inputs. It is available in the base module or in a separate expansion module
IO205	For protection applications with binary inputs and binary outputs
IO206	For protection applications with binary inputs and binary outputs
IO207	Geared toward bay controllers due to the predominant number of binary inputs (feedback from switchgear)
IO208	This is the base module for all devices that require current and voltage measurement. It is available in the base module or in a separate expansion module. In contrast to the IO202, it is equipped with more relay outputs. It is a typical module for protective applications
IO209	This module is used when extremely fast tripping times (4 normally-open contacts, 0.2 ms pickup time) are required, such as, e.g. power system for very high voltages
IO 214	This is the base module for all devices that require current and voltage measurement. It is available in the base module or in a separate expansion module. In contrast to the IO202 it has a reduced quantity structure of binary inputs and outputs
CB202	Module with 3 additional slots for modules
The connection diagrams of the individual modules are included in the appendix.	

Table 4.2 Module overview

Module	Available in the base module	Available in the expansion module	Contains power supply	Number of slots for plug-in modules
PS201	X	–	X	2
CB202	–	X	X	3
IO201	X	X	–	–
IO202	X	X	–	–
IO203	X	X	–	–
IO205	–	X	–	–
IO206	–	X	–	–
IO207	–	X	–	–
IO208	X	X	–	–
IO209	–	X	–	–
IO 214	X	X	–	–

Table 4.3 Fields of application and properties of the modules

	Rated current I_{rated}	Measuring range
Protection-class current transformers	5 A	500 A
	5 A	100 A
	1 A	100 A
	1 A	20 A
Instrument transformers	5 A	40 A
	1 A	8 A
	1 A	1.6 A
Sensitive ground-current input	5 A	8 A
	1 A	1.6 A

Table 4.4 Measuring ranges according to rated current

Plug-in modules

Plug-in modules are available for communication or analog inputs. The communication modules are described in the "Communication" section.

The analog input module has four 20 mA inputs. It can be plugged into one of the slots in the PS201 or CB202. Multiple measured value modules can be used with each device (one in each available slot), but as a rule one slot is needed for a communication module. The connections are created via an 8-pole screwed terminal block (Fig. 4.12).

The technical data for the measuring-transducer module is provided in Section "Summary of technical data".

Standard variants

To make it easier to select the correct devices, Siemens offers you pre-configured devices, which are called standard variants. These combinations of a base module and one or more expansion modules are intended for specific applications. In this way, you can order exactly the right device with a single order number. And standard variants can also be modified easily and quickly with additional expansion modules. Thus, it is just as easy to add modules as it is to replace certain modules with others. The available standard variants are listed in the SIPROTEC 5 order configurator.

Fig. 4.13 shows one possible standard variant for the 7SL87. This variant describes a 1/2 x 19" wide device having the following quantity structure:

- 15 binary inputs
- 20 binary outputs
- 8 analog current inputs
- 8 voltage inputs.

The modules used in the device can be seen on the results page of the SIPROTEC 5 configurator (see Chapter 5, Fig. 5.3 for more details).

In our example, the following modules are used in positions 1 to 3 (Fig. 4.14, page 34):

- Position 1: IO208
- Position 2: PS201
- Position 3: IO202.

The individual terminations are defined by the mounting location of the module and the terminal designations of the module (see chapter Connection diagrams, page 71).

As an example the connection points of the first 4 current inputs, that are on the IO208 at position 1, are designated as follows:

- I1: 1A1 and 1A2
- I2: 1A3 and 1A4
- I3: 1A5 and 1A6
- I4: 1A7 and 1A8.

Fig. 4.12 Measuring-transducer input module ANAI-CA-4EL

Fig. 4.13 Standard variant for 7SL87

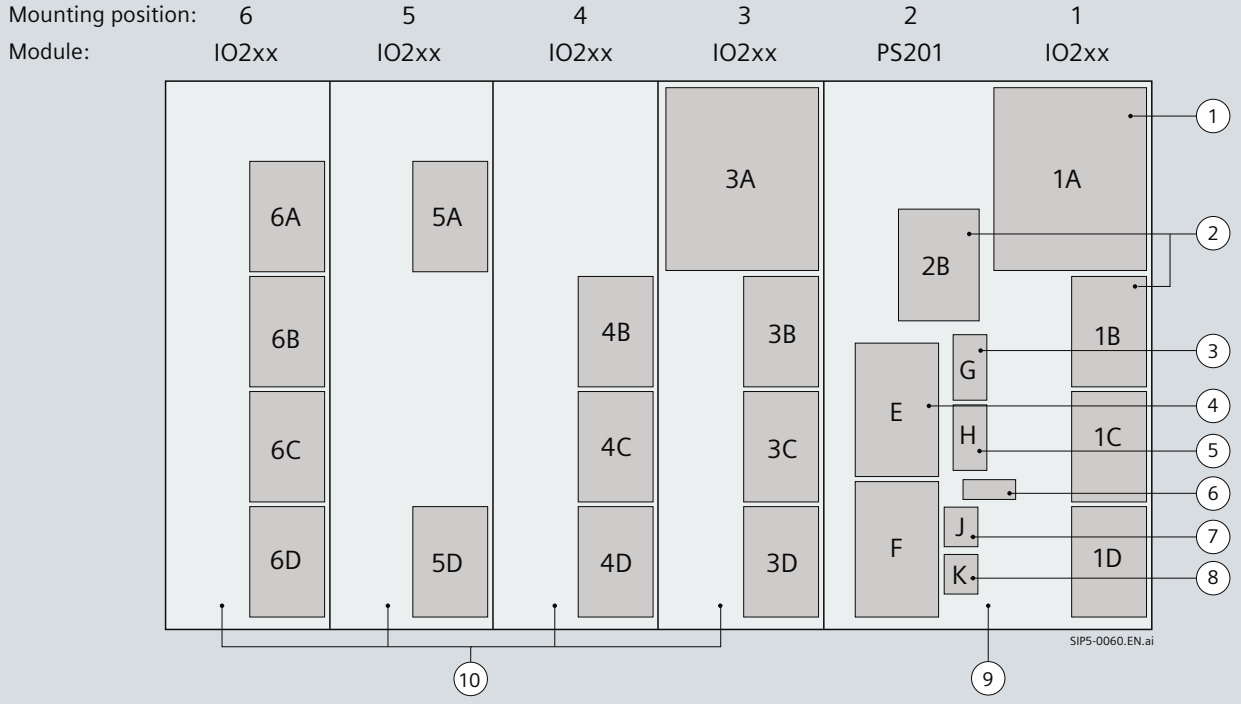
Perfectly tailored fit – Standard variants

Standard variants (continued)

The additional 4 current inputs are at the 3rd mounting position on the module IO202, and are designated as follows:

- I1: 3A1 and 3A2
- I2: 3A3 and 3A4
- I3: 3A5 and 3A6
- I4: 3A7 and 3A8.

Regardless of whether you choose a standard variant or configure your devices freely – you always receive a thoroughly tested, complete device.



(1) Current terminal A
(2) Voltage terminal A, B, C, D
(3) Terminal for time synchronization G
(4) Plug-in module E, F
(5) Terminal for detached on-site operation panel H
(6) Battery compartment
(7) Terminal for integrated Ethernet interface J
(8) Terminal for COM link K
(9) Base module 1/3 of 19 in
(10) Expansion module 1/6 of 19 in

Fig. 4.14 Example of connection designations of a device – rear view

Advantages of the flexible hardware module:

- **With the flexible hardware module, you conveniently configure the optimal hardware scope for your application**
- **For many applications, the appropriate device specification (standard variant) is already pre-defined**
- **The hardware design is appropriate for your switching cell**
- **The innovative SIPROTEC 5 terminal with integrated current transformers offers increased safety in systems testing and flexibility when exchanging the transformer type**

Project engineering with SIPROTEC 5 places your workflow in the center. It supports you from the beginning with the single-line diagram of the primary system on to ordering, engineering and parameter setting all the way through to testing and commissioning. For you, this means: fewer errors, higher quality and higher efficiency.

For you, holistic workflow means optimal, integrated support for all project phases:

- **Project specification**
- **System engineering**
- **Device engineering**
- **Commissioning**
- **Operation and service**

Product selection via the order configurator

The order configurator assists you in the selection of SIPROTEC 5 products. The order configurator is a Web application that can be used with any browser. The SIPROTEC 5 configurator can be used to configure complete devices or individual components, such as communication modules or extension modules.

At the end of the configuration process, the product code and a detailed presentation of the configuration result are provided. It clearly describes the product and also serves as the order number.

All functions from the library

The SIPROTEC 5 devices always have a base functionality available depending on device type. You can extend these flexibly with any desired functions from the library.

Additional functions are paid with your credit balance, which is reflected in function points. The function points calculator assists you in finding the correct function points value for your application. This guarantees that the selected device has the required functionality.

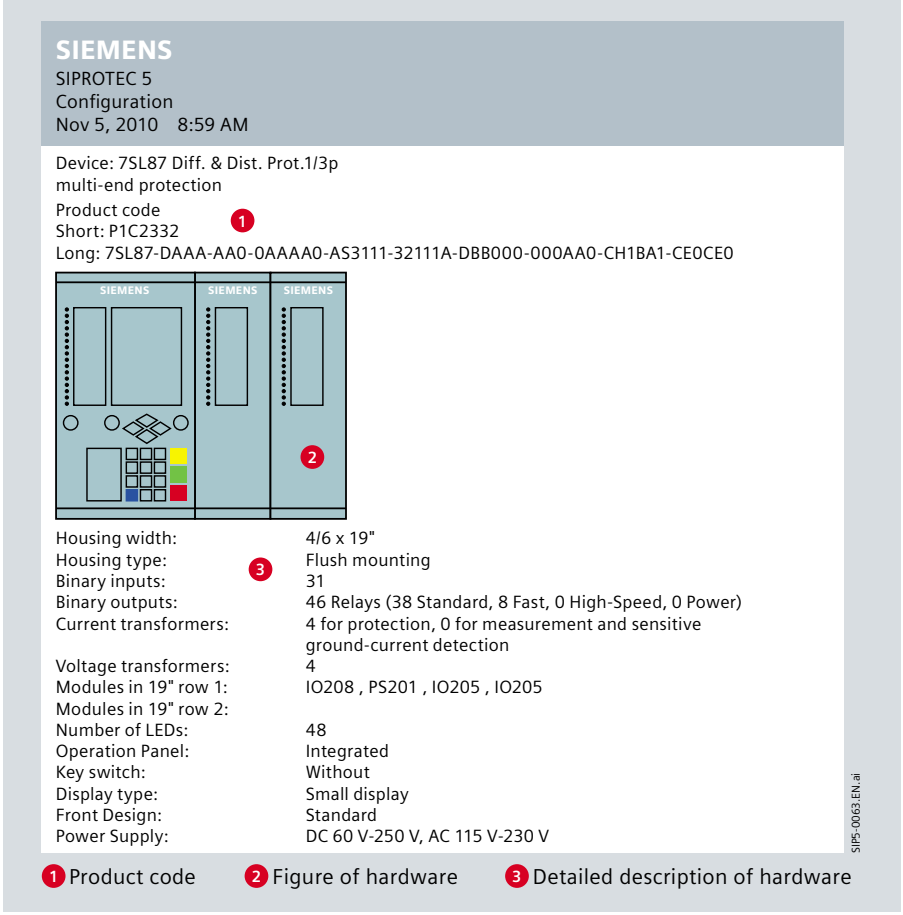


Fig. 5.1 Result representation of the configuration, hardware details

Holistic workflow – Order configurator

In the SIPROTEC 5 system, the main function is determined by selection of the device type, while the scope of additional functionality is determined by a single property, the function points value. This means that the functionality does not have to be fixed in detail during product selection. In the later engineering phase, any optional additional function can be selected from the device-specific function library. You must simply ensure that your balance of function points ordered for the device is not exceeded. Extra function points can simply be reordered at any time.

Clearly presented result representation

The successful configuration of a device is represented on a clearly organized result page. You can also save the result as a .pdf file (Fig. 5.2). The specified product code can then be adopted directly into the information system or the ordering system or DIGSI 5 (www.siemens.com/energy/siprotec5).

SIEMENS
SIPROTEC 5
Configuration
Nov 5, 2010 8:59 AM

Functional scope 7SL87 Diff. & Dist. Prot.1/3p:

ANSI	Function	Abbr.	Always included	Add selected Qty.	x	Value	=	Result Points	Qty.
	Protection functions for 3-pole tripping	3-pole	✔						✔
	Protection functions for 1-pole tripping	1-pole	✔						✔
	Hardware-Inputs/Outputs expandable	I/O	✔						✔
21, 21N	Distance protection	Z<							✔
87L	Line differential protection for 2 line ends		✔						✔
87L	Line differential protection for 3 to 6 line ends		✔						✔
25	Synchronism check, synchronizing function			2	x	60	=	120	2x
27	Undervoltage protection, 3-phase	V<			x	6	=		
27	Undervolt. protection, positive sequence	V1<		2	x	6	=	12	2x
27	Undervoltage protection, universal, Vx	Vx<			x	6	=		
32, 37	Power protection Watt/Var	P<>, Q<>			x	10	=		
46	Negative sequence overcurrent protection with direction	I2>, U2/I2			x	15	=		
49	Thermal overload protection				x	10	=		
50	Instantaneous high current switch-ontofault protection	I>>>	✔						✔
50BF	Breaker failure protection			2	x	25	=	50	2x
50/51	Phase overcurrent protection	I>	✔						✔
50N/51N	Ground overcurrent protection	3I0>	✔						✔
59	Overvoltage protection, 3-phase	V>			x	6	=		
59	Overvoltage protection, positive sequence	V1>		2	x	6	=	12	2x
59	Overvoltage protection, compounding	V1comp>			x	6	=		
59	Overvoltage protection, negative sequence	V2>			x	6	=		
59N	Overvoltage protection, zero sequence	V0>			x	6	=		
59	Overvoltage protection, universal, Vx	Vx>			x	6	=		
67	Overcurrent protection, directional				x	40	=		
67N	Directional ground fault protection for grounded networks				x	30	=		

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Fig. 5.2 Result representation of the configuration, functional scope

DIGSI 5 without detours

The product code calculated with the SIPROTEC 5 configurator can be adopted directly into the engineering program DIGSI 5. In this way you create your selected devices directly in DIGSI 5. Since all device characteristics are uniquely specified via the product code, engineering work with DIGSI 5 starts on a consistent basis, without the need for a time-consuming re-entry of the device characteristics.

From planning to engineering up to testing – DIGSI 5

The all-in-one engineering tool DIGSI 5 assists you in your workflow from planning to operation of your systems with SIPROTEC 5 devices. With DIGSI 5 you have full control over the engineering. The functional scope of the tool covers all tasks – from device configuration and device setting to commissioning and evaluation of fault data. This is how a modern, efficient engineering process looks in short form:

In the rough planning, the system layout is documented using CAD. These CAD data are imported into the single line editor as the basis for the detailed planning. Depending on the application, the required functionality (protection functions, control and automation scope as well as auxiliary functions) is defined and a device is selected. In the next step, the device is assigned an application template tailored to the application. Function adaptations are possible at any time after the selection of the application template. The high-performance copying functions with consistency tests enable rapid project engineering. Then the system configuration (routings, implementation of corresponding logic into function charts (CFC)) and the parameterization must also be performed.

The new program structure of DIGSI 5 is designed to optimally support the required work steps during a project. The application-oriented engineering approach guarantees that you are always aware of the workflow. DIGSI 5 makes you more productive – from design to engineering and even with installation, commissioning and operation.

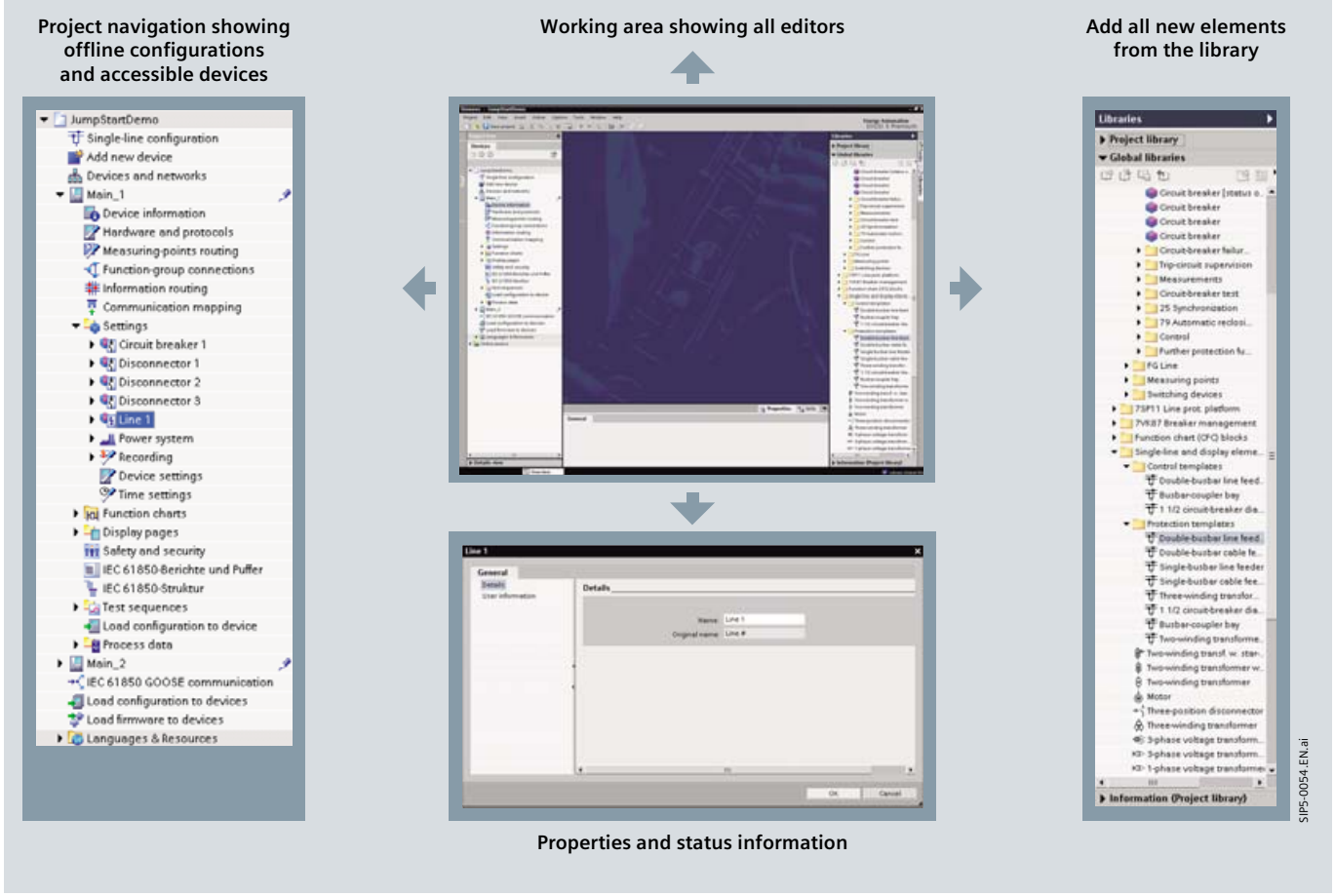

Fig. 5.3 Structure of the DIGSI 5 user interface

Holistic workflow – DIGSI 5

The project view leads through the entire workflow

In DIGSI 5 processing and maintenance of all components of IEDs and of all associated data is carried out in a project-oriented fashion. This means that the topology, devices, parameter values, communication settings, process data and much more are stored in one project.

All device data are a click away. By simply opening the device in the project tree and the entire contents is made available. When you begin with a device, you can process your tasks simply and intuitively. The user interface of DIGSI 5 is divided into several areas (Fig. 5.3, page 37). In the project tree on the left everything is displayed that belongs to your project, for example devices and global settings. With a double-click on an entry, an editor opens up in the main area of the window. This can be, for example an editor for changing protection parameters, for configuring communication mappings or for creating function charts (CFC).
In the lower area of the screen view, you can quickly and conveniently access the properties of all elements (e.g. with circuit breakers or signals). This area also contains lists with warnings and errors. The libraries are particularly important in DIGSI 5. They are located on the right and contain everything that is used in the editors. Here you select the required scope and insert it into your project. When configuring the hardware, you can select different hardware components, e.g. a communication module. On the other hand, if you are working with function charts (CFC), you select the corresponding logical building blocks and choose the required functionality while configuring the protection scope. For this you move the elements to the position of the editor where you need them.

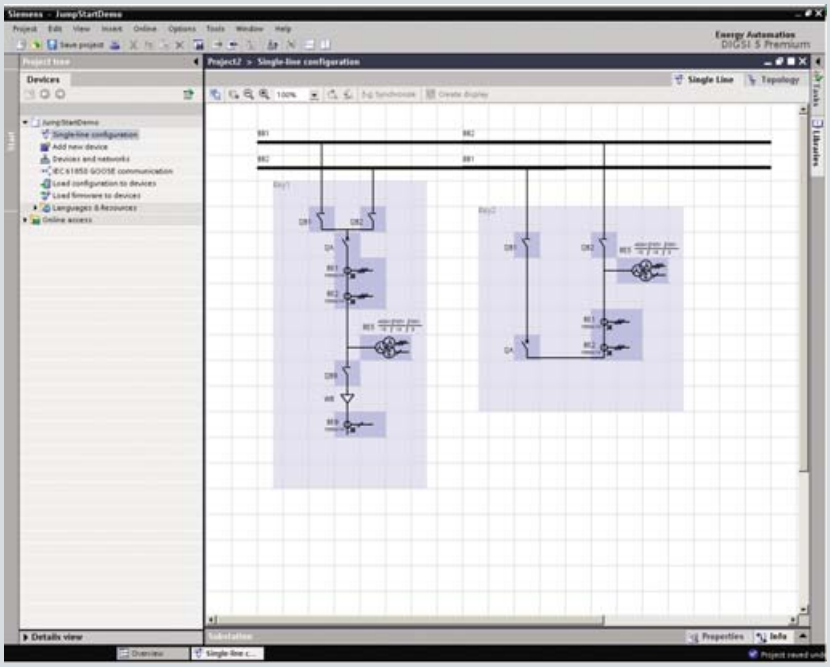

Fig. 5.4 Graphical definition of the topology of a substation in single line

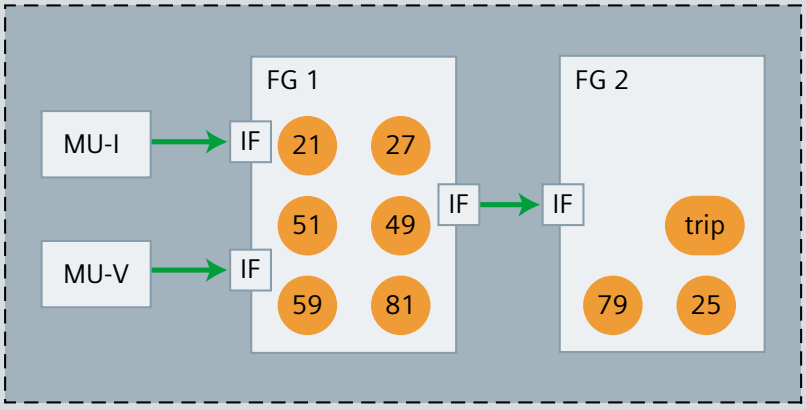

Fig. 5.5 Principle of an application template

Visual definition of the primary topology in single lines

The single line diagram describes the primary topology of your system (Fig. 5.4). For this, simply select the correct single line template from the library. But you can also import a diagram already present in your CAD. Further processing, e.g. extension, is possible without difficulty. DIGSI 5 contains a library with elements that are familiar to you from the ANSI and ISO standards.

From the application to the solution: Application templates and their modification

After the topology has been defined, the next step is to add the required device. You simply adopt the ordering code from the configurator in DIGSI 5 and your device specification is already known. In the following step, you select the application template appropriate for your application and adapt it according to your requirements (Fig. 5.5).

Remove functions that are not needed and add the desired functions. The library offers you an extensive selection that you can use for this. The consistency of the device configuration is continually checked.

Finally, you can graphically connect the application template with the primary elements of the single line diagram (voltage and current transformers as well as circuit breakers) (Fig. 5.6, page 39). Thus a topological reference is created. Setting values of the transformers (primary and secondary rated values, as well as the neutral point formation with current transformers) can then be adopted from the single line diagram.

Design of user defined control displays

With the display editor you can create or change the factory-preset displays, known as control displays. The editor assists you in a typical workflow. You simply decide which fields of your already created single line diagram are to be used for the display pages – and that is all there is to it. Naturally, the displays can also be completely newly created or imported.

For this, drag a signal from the library to a dynamic element in the display and the connection is created.

Besides the use of symbols in accordance with the IEC and ANSI standards, you can create your own static or dynamic symbols in a symbol editor.

Routing and assignment

The routing matrix is one of the most important functionalities of DIGSI 5. It is conveniently divided between 2 editors: "Information routing" and "communication assignment". Both views are designed such that you can quickly complete your task.
With pre- or self-defined filters you reduce the displayed information to a minimum. As in Excel, you can select which information is to be displayed for each column (Fig. 5.7).

In the matrix, all signals are sorted according to function and function groups. Sources and destinations are displayed as columns. The scope reaches from the compressed form of representation to a detailed representation of information in which you can view and change each piece of information (routing to binary inputs and outputs, LEDs, buffers etc.) in different columns. In this way, all information can be configured very simply.

For communication assignment all necessary settings are already populated for the selected protocol. You can adapt these simply and quickly to your needs.

With a large selection of filters and the option to open and close rows and columns you will find it easy to display only the information that you need.

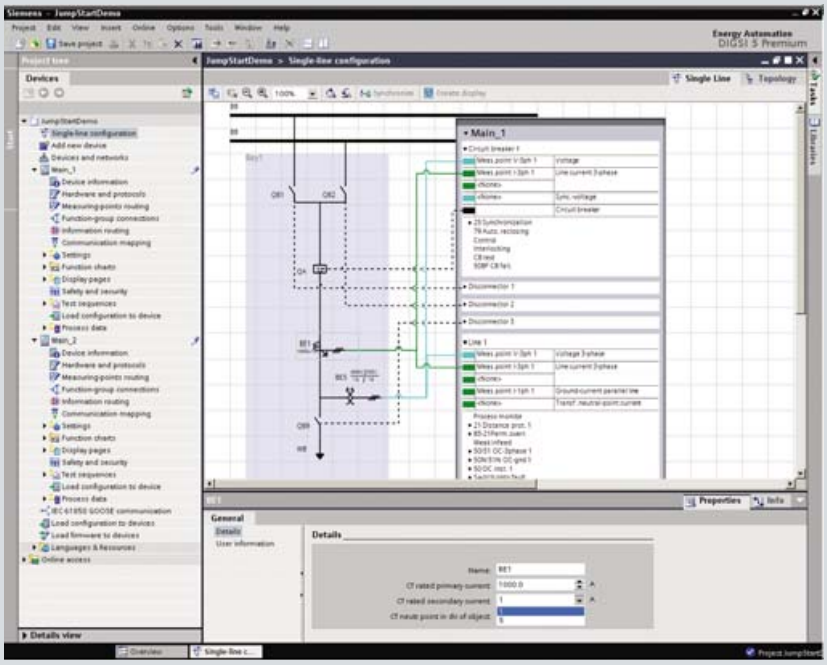

Fig. 5.6 Graphical linkage of primary and secondary equipment

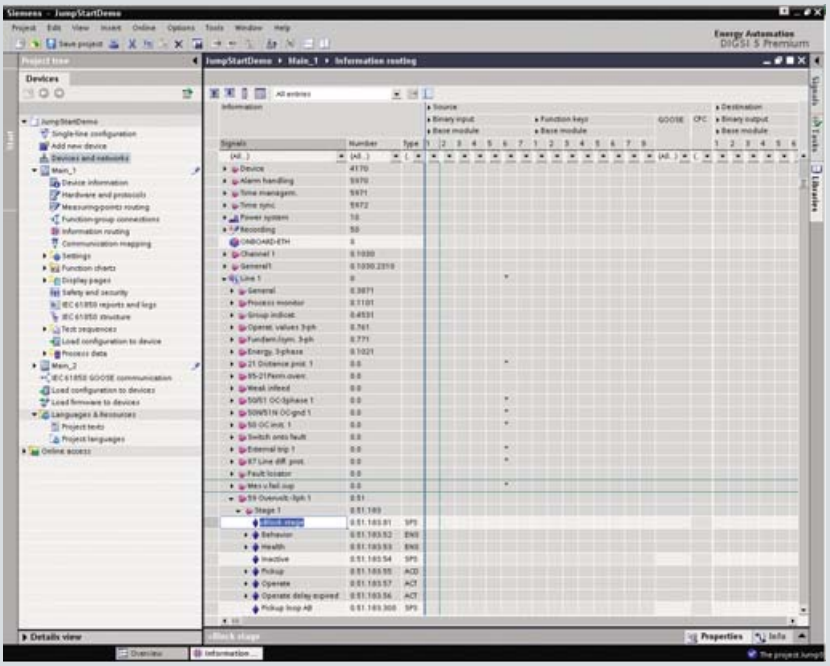

Fig. 5.7 The entire flexibility of the information routing editor

Saving time is a priority with DIGSI 5. All table-based data displays furnish the functionality to fill adjacent cells with a single mouse-click – in the same way you know from Excel.

Additionally, you can copy everything in DIGSI 5 in order to avoid having to enter settings, functions and devices etc. twice.

Holistic workflow – DIGSI 5

Better protection of the system against invalid operation

In SIPROTEC 5 devices, a PLC (Programmable Logic Controller) is integrated, in which e.g. standard interlockings can be executed. If you want to change or adapt these, use the function chart (CFC) editor that is included as a component in DIGSI 5 Standard and Premium. Thanks to the fully graphical user interface, even users without programming knowledge can fully utilize the functional scope and thus flexibly adapt the functionality of the device (Fig. 5.8). For this, an entire library is available to you with building blocks that are compatible with IEC 61131-3. This library contains simple logical operators, such as AND, but also complex functions such as timers relays, command chains for switching sequences, and much more.

The use of the editor is more efficient than ever before. You thus need fewer building blocks in order to achieve your objectives. This decisively improves the readability of the function chart (CFC). New display modes also increase clarity. The new modes offer you a compressed view of the building blocks and connection points, so that you can see all the information you need without having to scroll through it.

Even the use of signals in a function chart (CFC) is designed to be simpler. Drag a signal via drag & drop from the signal library to the input or output port of a building block – and you are finished.

If you need a signal from another device, you can fetch it from the library with drag & drop. If the signal is to be sent to a device via GOOSE communication, the GOOSE configuration is performed automatically.

Naturally, your function charts can also be transferred from DIGSI 4. Thus you can continue to use logic plans that have already been created. Created logic plans can be tested even without devices (offline) with DIGSI 5. This ensures the necessary quality for commissioning and gives you a time advantage.

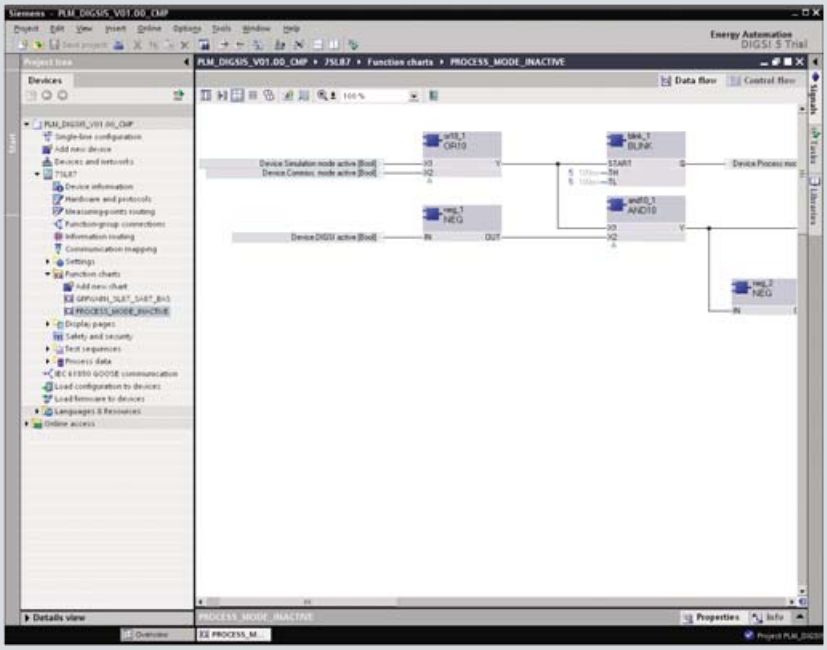

Fig. 5.8 Simple creation of automation with the CFC editor

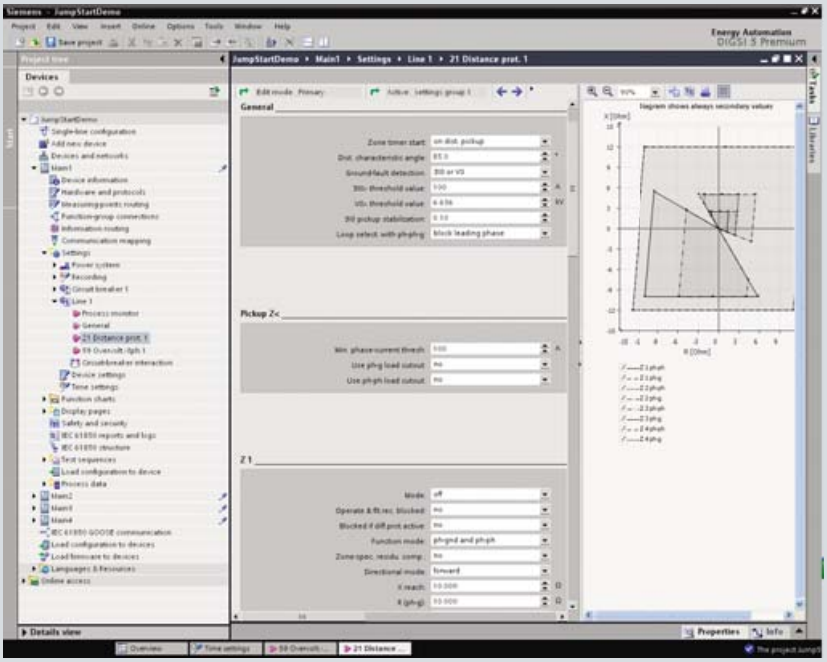

Fig. 5.9 Setting parameters was never simpler

Setting the parameters of the device

All parameter settings are represented in the same way. This occurs in the parameter editor, which displays all parameters of a function. Here you have the choice between different views of the settings. On the one hand there is a primary view, in which you can directly enter the primary setting values.

In this way, the conversion using conversion factor ratios, which can lead to setting errors, can be avoided. The same applies for the “per unit” view, where setting parameters refer to object rated values. If you decide on the secondary view, the setting parameters must be converted to secondary values.

For setting special protection characteristics, the graphical representation of the characteristics is advantageous. In the parameter editor all characteristic variants of the function are represented. Through this you can immediately graphically check the effects of changes in the settings. Setting values of different parameter groups can quickly and easily be compared in a common window, differences can be detected and compensated for (Fig. 5.9).

Cooperating in teams

Improve your engineering performance by cooperating in teams. While one crew works on the settings of the routing, others can define the protection parameters or set the parameters of the system interface. The individual areas can be updated at any time with new entries of colleagues. For example, when the protection parameter crew has updated its data this data can be adopted into the project.

Comprehensive testing support during commissioning and operation

The testing and diagnostic functions assist you in the commissioning phase. You can thus quickly and simply test the wiring or observe the effect that a message carried over the system interface has in the superordinate station. The error messages that are recorded in the case of a fault of the protection object in the relay are listed in DIGSI 5 and can be displayed, saved and printed for documentation purposes.

The new testing options are an innovation (also see test). Multi-level test sequences can be defined (even for phasor) via a sequencer functionality. These are loaded into the device with DIGSI 5 and simulate the physical inputs there. These are then executed in the device via the integrated test sequencer, which simulates the analog process values. In this way, you can define and execute complex checks for testing your project engineering and logic already at an early stage.

With the test and diagnostic functions, extensive test equipment is no longer necessary or their tests are reduced to a minimum. Processes that were developed for testing special protection principles, e.g. for line differential protection, can be found in the respective device manual.

The function chart (CFC) editor also offers new analysis functions. DIGSI 5 thus enables offline debugging of logic plans as well as tracing of measured values – both in the representation of the logic plan and in the representation of lists (Fig. 5.10, Fig. 5.11). Accordingly, overall testing effort is reduced during commissioning. The results of the function chart (CFC) analysis can also be represented after completion of the test sequence, e.g. with the assistance of SIGRA. Thus even complex runtime relations can be analyzed simply.

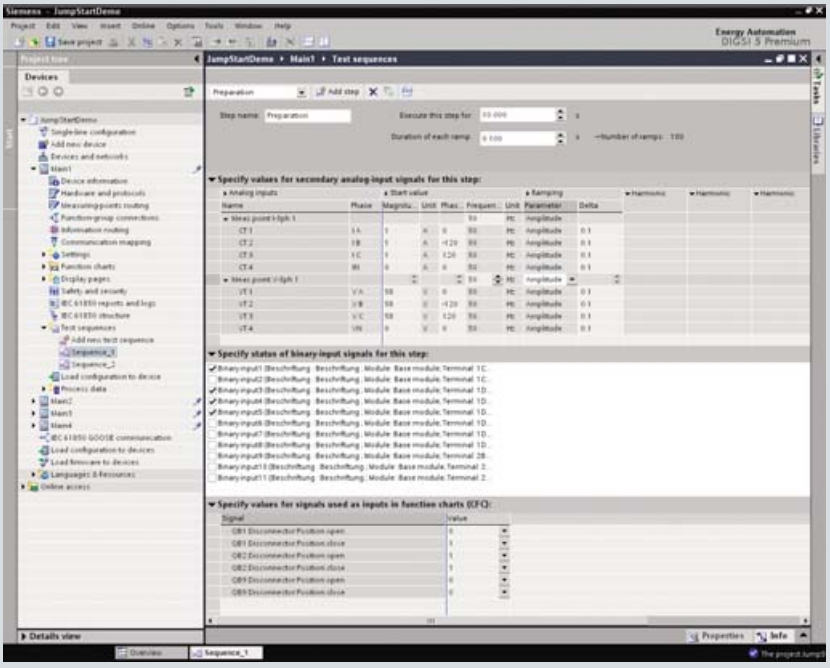

Fig. 5.10 Definition of test sequences for comprehensive tests of device configurations

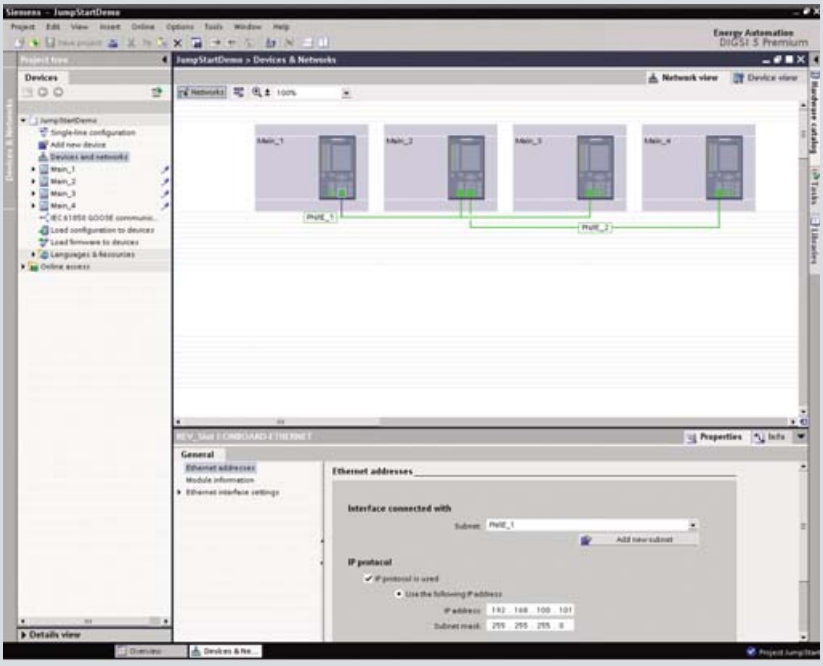

Fig. 5.11 Graphical configuration of network connections between devices

Holistic workflow – DIGSI 5

Direct online access of all accessible devices

DIGSI 5 also assists you in your workflow if your devices engineered offline are connected with the devices in your plant in your system. In DIGSI 5, all devices accessible via communication interfaces are displayed immediately next to your offline devices. The preferred communication in networks is Ethernet. Naturally, you can individually access devices via a USB interface. In order to work with a physical device, connect the online device and offline configuration via drag & drop and you are done.

Besides transferring the device configuration to individual devices, you can also automatically transfer all device configurations to your devices.

Thanks to its high-performance communication, DIGSI 5 can access remote devices of the remote station via a protection interface connection. Thus, commissioning and functional testing of the devices are simplified. This innovation is especially convenient when working with our line protection devices (7SD8, 7SL8).

Besides online access, in addition to reading fault records and message buffers, you can also display measured values and messages. You can save snapshots of measured values and messages in archives for subsequent analysis or for documenting tests of temporary operating states or commissioning.

Openness through import and export

DIGSI 5 offers a broad spectrum of exchange formats. These include the standard formats of IEC 61850 (SCD, ICD, CID, SSD) as well as the uniform data exchange format TEAX of Siemens Energy Automation Tools. This XML-based format is the foundation for all import-export scenarios and ensures efficient workflows in the engineering process. Since data must only be entered once, engineering effort is reduced and you profit from consistent data quality at all levels of automation.

Besides efficient data exchange for the levels of energy automation, the XML data format also supports the simple exchange of data with other applications.

Via the import interface, you can read data from other applications into DIGSI 5. This thus enables external project engineering of the devices. Similarly, you can export the settings data to other applications for further processing. It is thus easy to exchange data with other power distribution applications, e.g. network calculations, protection data administration/evaluation as well as data for the protection function test.

With Siemens ENEAS Generic Solutions, Siemens is taking the next step forwards and offers a modular system with defined templates, consisting of precise definitions and ready-made project engineering and documentation solutions for configurations, SIPROTEC field devices, SICAM station units, operating management, for functions and communication. The result is that all project phases from planning to commissioning, as well as all upgrades, extensions and maintenance, are more efficient.

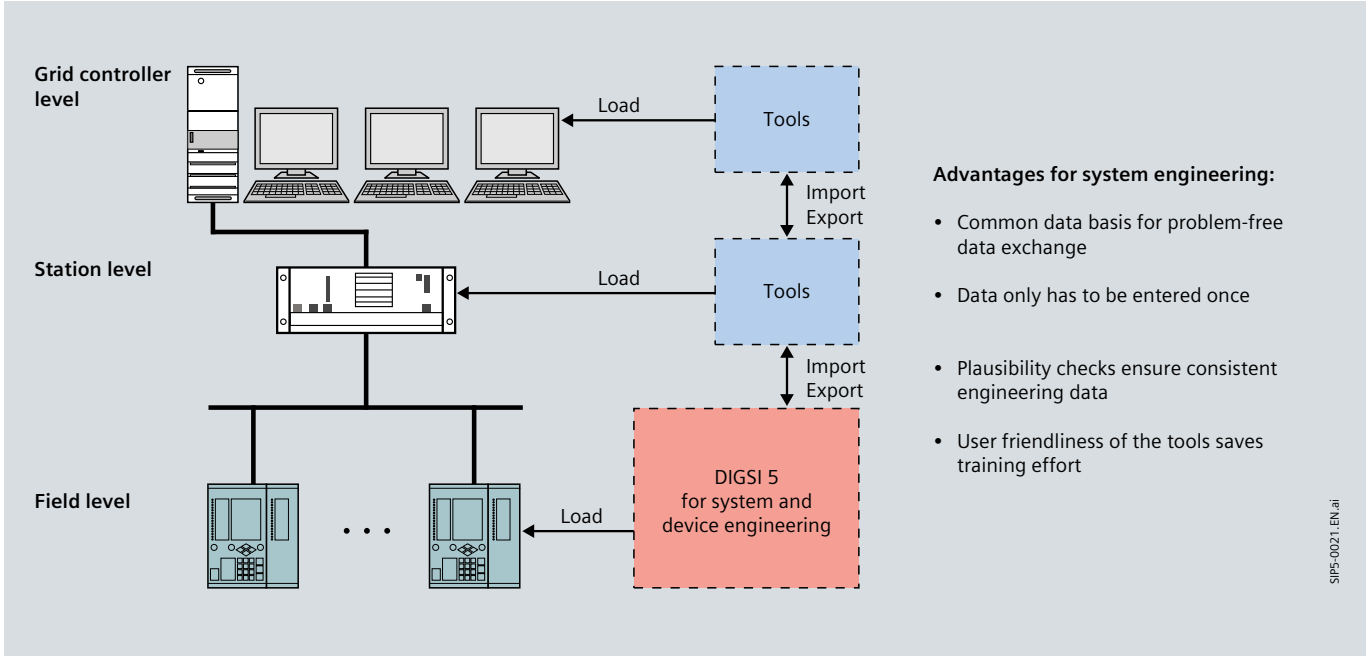

Fig. 5.12 Open exchange formats allow reuse of data on all levels

Effective fault analysis with SIGRA

After a protection trip following a network fault, it is important that the disturbance is quickly and completely analyzed. With the fault records saved in the SIPROTEC 5 devices you can investigate and resolve even complicated faults. The high-performance tool SIGRA assist you in your evaluation. Besides the usual time-signal representation of the recorded measured variables, it is also designed to display vector diagrams, locus diagrams and bar charts in order to represent harmonics and data tables. From the measured values recorded in the fault records, SIGRA calculates further values, e.g.: missing variables in the 3-phase system, impedances, symmetrical components, etc. Defect tracing can be evaluated simply and conveniently using 2 measuring cursors.

You are also able to evaluate several fault records in parallel with SIGRA. For example, the records from the ends of a line differential protection: you can synchronize these on a common time basis, then process as usual and save as a new record (representation in one diagram). Thus, the defect trend can be well documented.

SIGRA also has an offline fault locator. In this context, the fault record from the line ends are evaluated. Through the precise determination of the fault location you save time, which you can then use to investigate the fault on-site.

SIGRA can be used for all fault records present in the COMTRADE file format. The software product is available as an optional package in addition to DIGSI 5 Standard, as a standalone variant, and is a component of DIGSI 5 Premium.

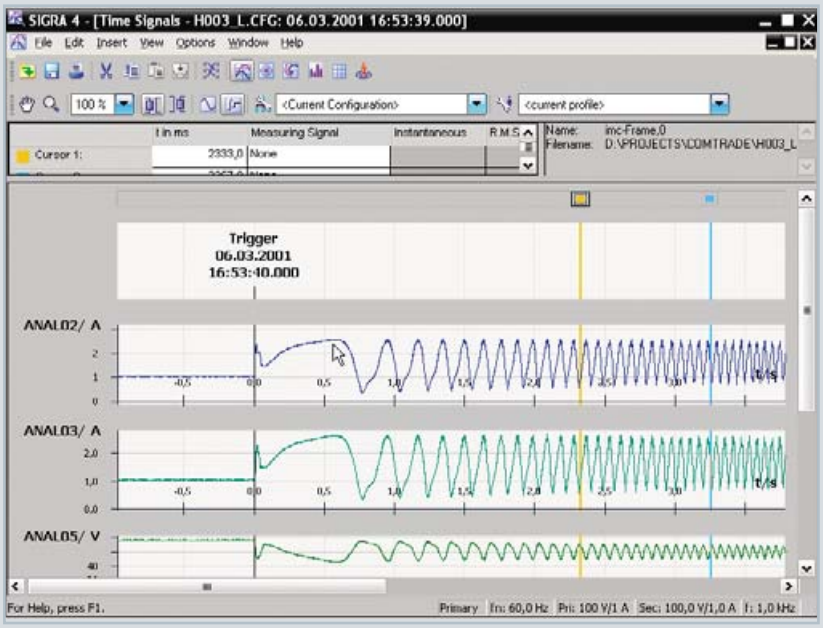

Fig. 5.13 SIGRA time signals

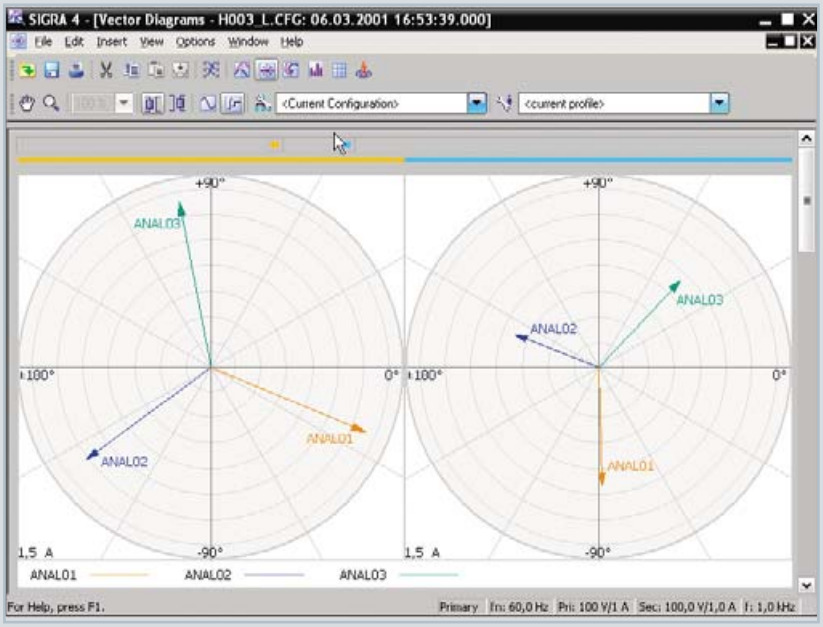

Fig. 5.14 SIGRA phasor diagram

Holistic workflow – Effective fault analysis with SIGRA

Overview of functions

- 6 diagram types:
  - Time-signal representation (standard)
  - Locus diagram (for example for RX)
  - Vector diagram (reading of angles)
  - Bar chart (for example for visualizing harmonics)
  - Table (with values of several signals at the same point in time)
  - Fault location determination (display of fault location)
- Calculation of additional values, such as e.g. positive sequence impedances, RMS values, symmetrical components, phasors, etc.
- 2 measuring cursors that are synchronized in all views
- High-performance panning and zoom functions (e.g. section enlargement)
- User-friendly project engineering via drag & drop
- Innovative signal routing in a clearly structured matrix
- Time-saving user profiles, which can be assigned to individual relay types or series
- Addition of further fault records and synchronization of multiple fault records with a common time basis
- Simple documentation through copying of the diagrams e.g. into MS Office programs
- Offline fault location determination
- Commenting of fault recorders, and commenting of individual measuring points in diagrams and free placement of these comments in diagrams
- Application of mathematical operations to signals.

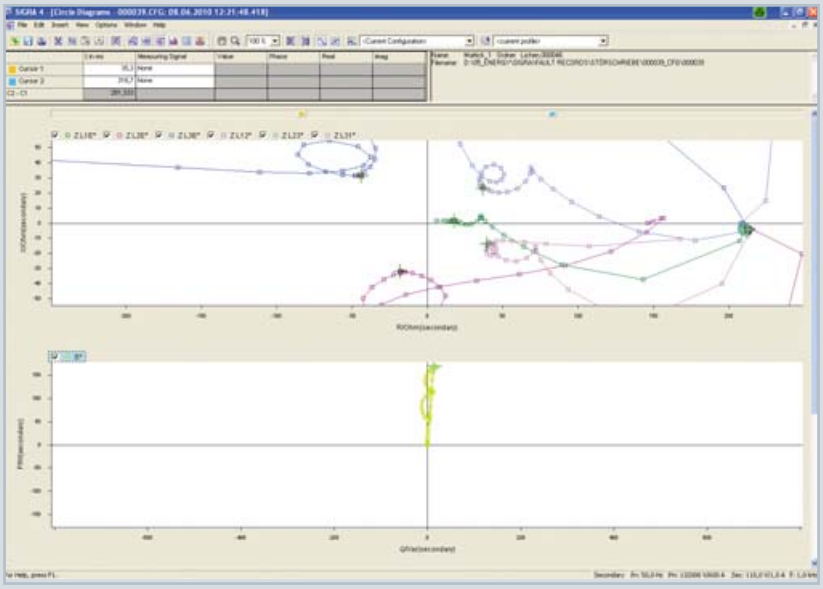

Fig. 5.15 SIGRA locus diagrams

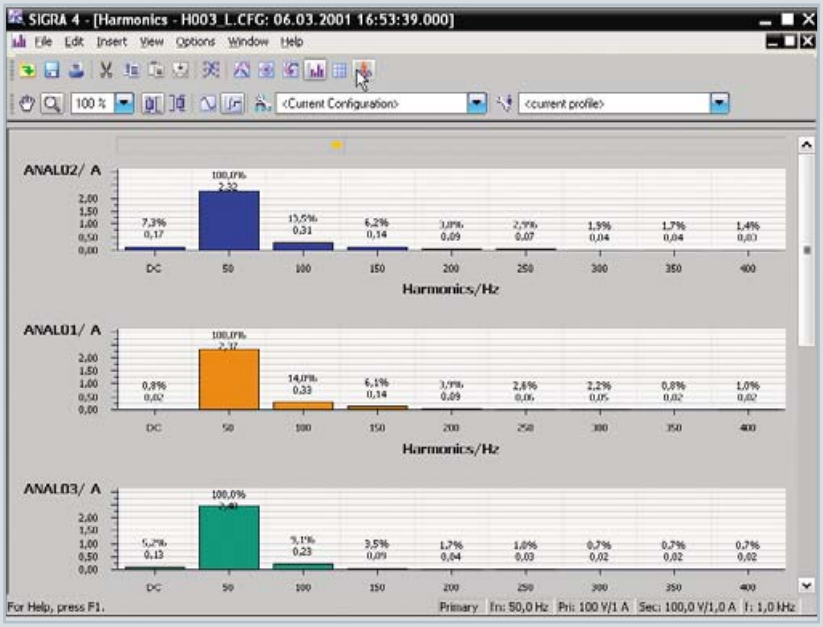

Fig. 5.16 SIGRA harmonics

DIGSI 5 assists you in an optimal and holistic manner for your SIPROTEC 5 project:

- **Integrated system and device engineering**
- **Graphical user interface simplifies and accelerates project engineering**
- **Application templates and function groups as image of the primary application and the primary objects, such as the line or circuit breaker, guarantee a user-oriented working method and perspective**
- **Test and simulations tools offer optimal plausibility checks**

SIPROTEC 5 devices are equipped with high-performance communication interfaces. These interfaces are integrated or extendable via plug-in modules to offer a high degree of flexibility. The concept of plug-in modules and loadable protocols enables exchangeability and retrofitting.

For you, Designed to communicate in SIPROTEC 5 means:

- **Up to 8 interfaces available**
- **Data exchange via the IEC 61850 protocol for up to 6 clients**
- **Flexibly retrofittable plug-in modules for communication**
- **Many protocols available**

SIPROTEC 5 devices are equipped with high-performance, pluggable communication interfaces and thus support optimal migration concepts in system modernizations.

USB connections on the front side

On the front side of the base module there are 2 USB connections. A PC with operating program DIGSI 5 is directly connected to the device via a standard USB cable through an USB-B port. The complete configuration and setting of the device is carried out via this point-to-point connection.

Fig. 6.1 Front view of the device with USB interfaces

An USB stick can be plugged into the device via a second USB-A socket. In the future, this interface will support reading of diagnostic data, fault data and fault records. Data written to an USB stick can be evaluated and archived in the office with DIGSI 5. Fig. 6.1 shows the device with a stick plugged in.

Integrated interfaces on the rear of the base module

The base module offers various, permanently installed interfaces on the rear. For even greater flexibility, 2 slots are available for communication modules. For this, please observe the connection diagrams in the appendix, page 71.

Integrated Ethernet interface (port J)

This electrical RJ45 interface serves to connect DIGSI 5 via a local Ethernet network. In this way, several devices can be operated from DIGSI 5 via an external switch. DIGSI 5 detects the devices even without an IP configuration on the local network and can then assign them network addresses.

Time-synchronizing interface (port G)

Via the 9-pole Sub-D socket (connection compatible with SIPROTEC 4), the time in the device can be synchronized. The set clock telegram IRIG-B00 of a GPS receiver can be fed with 5 V, 12 V or 24 V levels. In addition, the Central European DCF77 format with summer and winter time changes is supported. An additional second pulse input enables microsecond-precise synchronization of the device from a highly precise time source, e.g. a special GPS receiver. This accuracy is needed for special protection and measuring tasks. In this way, devices can be precisely synchronized to the microsecond supra-regionally. For this, Siemens provides a pre-fabricated complete solution with time receiver, optical fiber converters and appropriate connection cables.

Fig. 6.2 Rear view of the device with integrated interfaces and module slots

Designed to communicate – Plug-in modules for communication

Connecting a detached operation panel (port H)

A detached operation panel provided together with the connection cable can be connected to this interface. The maximum distance is 2.5 meters.

Connecting the extension unit CB202 (port K)

The base module offers slots for 2 plug-in modules. If further plug-in modules are needed, these can be provided via a special expansion module CB202. This module is connected via port K. The expansion module is delivered with an appropriate cable and is connected with port L on the module. The CB202 has its own wide-range power supply. A great advantage here is that the switch integrated in an Ethernet module can execute its data forwarding function for neighboring devices even if the power supply of the base device is switched off provided the CB202 is still supplied. Thus an Ethernet ring is not disconnected when a device is in service.

Via plug-in modules the devices can be extended with protocol interfaces and analog inputs. The devices can be ordered with assembled modules or be extended with modules retroactively. An expansion module CB202 (right photo in Fig. 6.2, page 45) can also be assembled with plug-in modules. The modules are easy to service, and can be plugged in without having to open the device. Since the modules have their own processor, the base functions of the device, e.g. the protection functions and the protocol application, are largely independent.

Modules are delivered without configured protocols or applications. One or more appropriate modules are suggested in the order configurator corresponding to the desired protocol on a module. There are serial modules with 1 or 2 electrical and optical interfaces. Different applications can run on both interfaces, e.g. synchronous protection communication of a differential protection on one interface and an IEC 60870-5-103 protocol on the second interface. Electrical and optical modules for Ethernet are still available. For example, the IEC 61850 protocol as well as auxiliary services may be executed for each module.

Plug-in module positions of the device

The base module can be extended via module slots E and F. All available modules can be installed there. The expansion module CB202 is designed for 3 additional plug-in modules if the two slots in the base module are not sufficient. Any additional plug-in modules can be installed in slots N and P. Analog expansion modules can be plugged into slot M. This slot does not support serial or Ethernet modules.

Serial plug-in modules

Serial electrical plug-in modules are used for asynchronous serial protocols, e.g. IEC 60870-5-103, DNP3, MODBUS or PROFIBUS DP. Optical 820-nm/1300-nm and 1550-nm modules can also be configured as protection interface for the point-to-point connection.

Serial electrical RS485 module

This module has either 1 (USART-AB-1EL) or 2 (USART-AC-2EL) RS485 interfaces. The use of RJ45 sockets enables the construction of an economical serial RS485 bus with patch cables, which are simply looped through. This saves on wiring time and cable costs. Fig. 6.3 shows an electrical serial module with 2 interfaces on which 2 independent serial protocol applications are executed.

Serial optical 820-nm module

This module exists with 1 (USART-AD-1FO) or 2 (USART-AE-2FO) optical 820-nm interfaces (Fig. 6.4), with which distances between 1.5–2 km can be bridged via 62.5-/125-µm multimode optical fibers. The optical connection is made via ST connectors. Apart from serial protocols, the synchronous serial protection interface can be operated on the module, and enables optical direct connections via multimode optical fibers. 2 devices can thus either exchange data, e.g. of the differential protection via a short direct connection, or they can be connected through communication networks via a 7XV5662 converter. Additionally, the module can be connected directly with an optical multiplexer input in accordance with standard IEEE C37.94.

Fig. 6.3 Serial electrical double module (USART-AC-2EL)

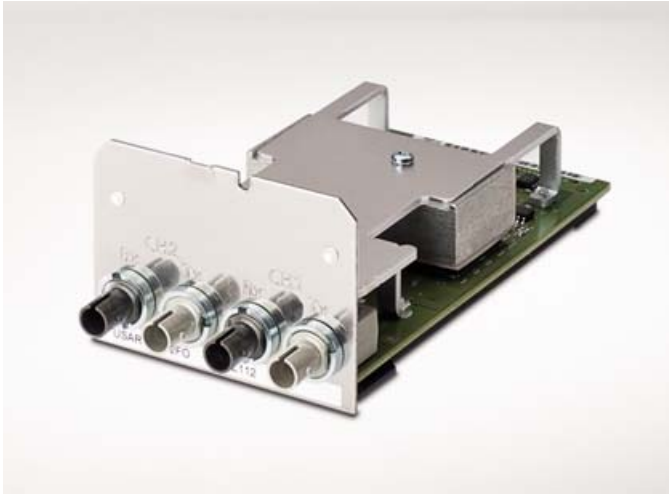

Fig. 6.4 Serial optical 820 nm double module (USART-AE-2FO)

Serial optical 1300 nm/1550 nm module

Long distance modules are used for synchronous serial data exchange of protection communication via multimode optical fibers or single mode fibers. They are available with 1 or 2 interfaces (Table 6.1). The optical connection is made via LC duplex plugs.

Long distance modules for different distances for point-to-point connections of protection interfaces

Optical wavelength	Module designation with 1 or 2 interfaces	Application
1300 nm	USART-AF-1LDFO, USART-AU-2LDFO	max. 24 km via 2 single mode fibers or max. 4 km via 2 multimode optical fibers
1300 nm	USART-AG-1LDFO, USART-AV-2LDFO	max. 60 km via single mode fibers
1550 nm	USART-AK-1LDFO, USART-AY-2LDFO	100 km via single mode fibers

Table 6.1 Long distance modules for different distances for point-to-point connections with 2 fibers

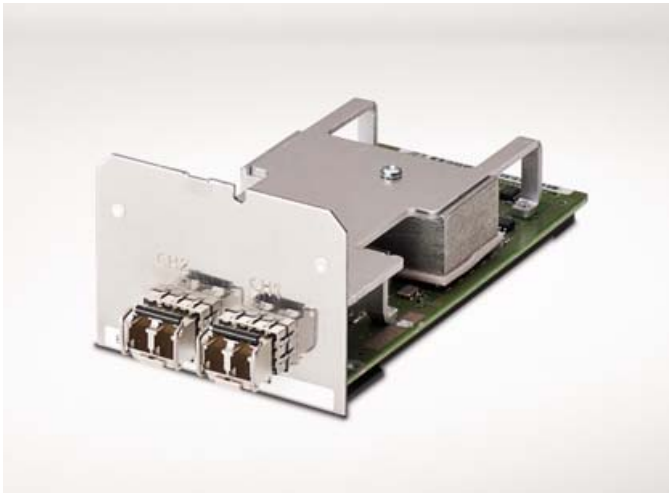

Fig. 6.5 Serial, optical double module for wide-range connections via optical fibers (for module designation see Tables 6.1 and 6.2)

Special modules enable bi-directional data exchange via one optical fiber. This saves one fiber per data connection on optical fiber lines, without functional limitations in comparison with connections with two fibers. These modules transmit at 1300 nm or 1550 nm, but must be used in pairs (see Table 6.2 and Fig. 6.5). The optical connection is made via LC simplex plugs.

Plug-in modules for Ethernet

Ethernet modules are used for Ethernet-based protocol applications e.g. IEC 61850, DNP3 IP, time synchronization via SNTP, network management via SNMP, DIGSI 5 via TCP etc. Several applications can run in parallel, whereby unused applications can be switched off for security reasons.

Electrical Ethernet module

The ETH-BA-2EL module has 2 RJ45 interfaces (Fig. 6.6). It can be configured with or without an integrated switch. The maximum electrically permitted distance via CAT 5 patch cables is 20 m.

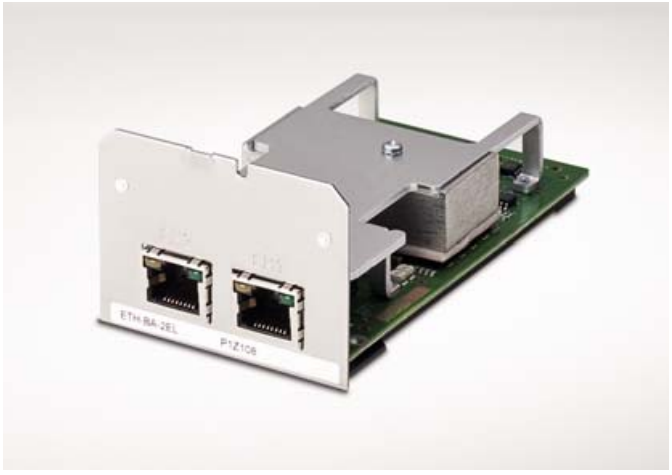

Fig. 6.6 Electrical Ethernet module (ETH-BA-2EL)

Optical Ethernet module

The ETH-BB-2FO module has 2 optical LC duplex 1300 nm interfaces (Fig. 6.7). It can be configured with or without an integrated switch. The maximum optically permitted distance via 50/125-µm or 62.5/125-µm multimode optical fibers is 2 km. The optical transmission and receiving level is measured in the module and can be displayed with DIGSI 5.

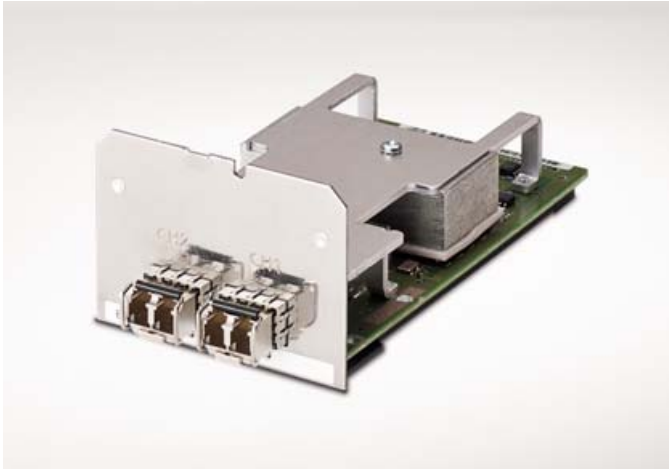

Fig. 6.7 Optical Ethernet module (ETH-BB-2FO)

Use of modules in pairs

Optical wavelength	Module designation with 1 or 2 interfaces	Application
1300 nm/1550 nm	USART-AH-1LDFO <–> USART-AJ-1LDFO USART-AX-2LDFO <–> USART-AY-2LDFO	max. 40 km via a single mode fiber (with integrated fiber optic multiplexer)

Table 6.2 WAN modules for point-to-point connections with one fiber

Designed to communicate – Plug-in modules for communication

Port or plug-in module	Front interface	Port G: Time synchronization	Port J: Integrated Ethernet	Module type: USART-AB-1EL	Module type: USART-AC-2EL	Module type: USART-AD-1FO	Module type: USART-AE-2FO	Module type: ETH-BA-2EL	Module type: ETH-BB-2FO
Physical connection									
USB-A	•								
9-pole Sub-D socket		•							
1 x electrical Ethernet 10/100 Mbit/s, RJ45			•						
1 x electrical serial RS485, RJ45				•					
2 x electrical serial RS485, RJ45					•				
1 × optical serial, 1.5 km, 820 nm, ST connector						•			
2 × optical serial, 1.5 km, 820 nm, ST connector							•		
2 x electrical Ethernet 10/100 Mbit/s, RJ45, 20 m								•	
2 × optical Ethernet 100 Mbit/s, 2 km, 1300 nm, LC duplex plug									•
Applications									
DIGSI 5 protocol	x		x					x	x
IRIG-B, DCF77, highly accurate 1-s pulse		x							
IEC 61850-8-1 server (incl. GOOSE, reporting to 6 clients)								x	x
IEC 61850-8-1 server (without GOOSE, reporting to 6 clients)			x						
IEC 60870-5-103 (extended)				x	x	x	x		
DNP3 (serial)				x	x	x	x		
DNP3 IP (via Ethernet)								x	x
Synchrophasor protocol (IEEE C37.118-IP) [1]								x	x
Protection interface (Sync. HDLC, IEEE C37.94) *						x	x		
Additional Ethernet protocols and services									
DHCP, DCP (automatic IP configuration)			x					x	x
RSTP (Ethernet ring redundancy)								x	x
SNTP (time synchronization over Ethernet)			×					x	x
SNMP V3 (network management protocol)								x	x
Note: The plug-in modules of the type USART and ETH can be used in slots E and F in the base module, as well as in slots N and P in the expansion module CB202. They are not intended for use in slot M in the CB202 expansion module.									
* Additional plug-in modules for protection interface: see Table 6.4 [1] in process									

Table 6.3 Communication applications and plug-in modules

Plug-in module	Module type: USART-AF-1LDFO	Module type: USART-AU-2LDFO	Module type: USART-AG-1LDFO	Module type: USART-AV-2LDFO	Module type: USART-AK-1LDFO	Module type: USART-AY-2LDFO	Module type: USART-AH-1LDFO [1]	Module type: USART-AJ-1LDFO [2]	Module type: USART-AX-2LDFO [3]	Module type: USART-AY-2LDFO [4]
Physical connection										
1 × optical serial, 24 km, 1300 nm, LC duplex plug	•									
2 × optical serial, 24 km, 1300 nm, LC duplex plug		•								
1 × optical serial, 60 km, 1300 nm, LC duplex plug			•							
2 × optical serial, 60 km, 1300 nm, LC duplex plug				•						
1 × optical serial, 100 km, 1550 nm, LC duplex plug					•					
2 × optical serial, 100 km, 1550 nm, LC duplex plug						•				
1 × optical serial, bi-directional via 1 optical fiber, 40 km, 1300 nm/1550 nm, LC simplex plug [1]							•			
1 × optical serial, bi-directional via 1 optical fiber, 40 km, 1550 nm/1300 nm, LC simplex plug [2]								•		
2 × optical serial, bi-directional via 1 optical fiber, 40 km, 1300 nm/1550 nm, 2 x LC simplex plug [3]									•	
2 × optical serial, bi-directional via 1 optical fiber, 40 km, 1550 nm/1300 nm, 2 x LC simplex plug [4]										•
Application										
Protection interface (Sync. HDLC, IEEE C37.94)	×	×	×	×	×	×	×	×	×	×
Note: The plug-in modules of the type USART can be used in slots E and F in the base module, as well as in slots N and P in the expansion module CB202. They are not intended for use in slot M in the CB202 expansion module. [1] USART-AH-1LDFO only in connection with USART-AJ-1LDFO or USART-AY-2LDFO on the opposite side [2] USART-AJ-1LDFO only in connection with USART-AH-1LDFO or USART-AX-2LDFO on the opposite side [3] USART-AX-2LDFO only in connection with USART-AJ-1LDFO or USART-AY-2LDFO on the opposite side [4] USART-AY-2LDFO only in connection with USART-AH-1LDFO or USART-AX-2LDFO on the opposite side										

Table 6.4 Plug-in modules for applications with protection interface

Plug-in module	Module type: ANAI-CA-4EL
Physical connection	
8-pole screw-type terminal strip	•
Application	
Measuring transducer, 4 inputs, DC ± 20 mA	×
Note: The plug-in module of type ANAI can be used in both slots in the base module (ports E and F), as well as in all slots in the expansion module CB202 (ports M, N and P)	

Table 6.5 Plug-in module for additional applications

Designed to communicate – Protocols

Plug-in modules are delivered without a protocol application. According to Table 6.3 (page 48) a module can be initialized via DIGSI 5 with a protocol application. Every interface is assigned the desired application via software. Assignments can be erased and re-configured. This enables a high degree of flexibility when configuring the modules.

DIGSI 5 protocol

The DIGSI 5 protocol works with TCP services, which can be routed via IP networks. Worldwide remote access to devices via secure connections is an integral component of the communication concept. Notes on secure access via networks can be found in Chapter 9 of this catalog. The protocol is available on the USB interface and all Ethernet interfaces. Optionally, DIGSI 5 can also be operated via its own Ethernet module if systems control functions and access for operating and maintenance are to be kept strictly separate.

IEC 61850 client-server communication via the integrated Ethernet interface (port J)

This interface can be used in addition to DIGSI 5 as a simple IEC 61850 systems control interface. It supports a client-server connection with a reporting function (GOOSE is not supported on port J). Messages, measured values and fault records can be read from an IEC 61850 client. Parameters in the device can be changed via the client and the time of the device can be set via an SNTP server.

IEC 61850 client-server communication on Ethernet modules

Messages, measured and metered values can be transferred via the client-server communication in static and dynamic reports to a maximum of 6 clients (substation controller). Dynamic reports are created and read by the client without resetting the parameters of the device. The static reports are created in the device via DIGSI 5 and the integrated system configurator and are permanently saved in the device as indication lists. Fault records can also be polled in binary Comtrade format. Extensive control functions are available from the client, e.g. for the safe switching of a circuit breaker. The setting parameters of the device can be read and also changed via the IEC 61850 protocol. The devices can be integrated in interoperable, intelligent smart grids without difficulty. Changing the device settings during operation is possible through systems control equipment, in order to adapt selected setting parameters to the operating conditions. Redundant solutions can be realized with 2 Ethernet modules.

Areas of use of IEC 61850 GOOSE inside and outside of the substation

GOOSE has been established as a worldwide standard for cross-communication between devices, in order to transfer messages and measured values between devices. In addition to GOOSE between devices within a substation, GOOSE is also supported between devices in different substations. The exchanged information is described in data terms via standard-conforming SCL files, which are defined in Edition 2 of IEC 61850. The exchange itself occurs via high-performance IP network connections or direct connection via optical fibers. This data exchange can also be realized via an Ethernet module used exclusively for this purpose.

GOOSE in the application

GOOSE messages contain time-critical signals that must be transferred within a few milliseconds. In this case, GOOSE connections replace transfer via contacts and binary inputs; for protection signals, transfer times under 10 ms are required, and under 20 ms for switch positions and interlockings. Measured and metered values are transferred in less than 100 ms. For this, GOOSE applications are generated in DIGSI 5. These data are exchanged in a high-performance manner via GOOSE messages. Further attributes of a GOOSE message are also configurable with DIGSI 5.

Receivers of GOOSE messages can constantly monitor the receipt of indications and measured values for a break of the connection. The state of missing indications is automatically updated at the receiver, in order to attain a secure state. This allows a constant, high-quality monitoring of GOOSE communication to be realized. GOOSE messages transmitted during the test mode of a device are ignored in the receivers if these are in normal operation. A test of a device can be performed with disconnection from the communication network.

Serial IEC 60870-5-103 protocol

The serial protocol is transferred via RS485 or an optical 820 nm interface. The compatible or Siemens specific extended IEC 60870-5-103 protocol is supported. The implementation is compatible with existing solutions, e.g. with SIPROTEC 4 devices, which will enable a trouble-free exchange and extension of devices even in the very long term. In addition to indications, measured values and fault records, metered values and customer-specifically defined indications of control functions are also available in protocol extensions. Control commands for switching devices can also be transferred via the protocol. Setting values in the device can also be read or changed via the generic services of the protocol. Information about the device can be routed to the protocol interface by the user with DIGSI 5. Information types and function numbers can be freely configured here. This enables adaptation to existing solutions and the interchangeability of devices without changes in the substation controller. This is an important contribution to investment security.

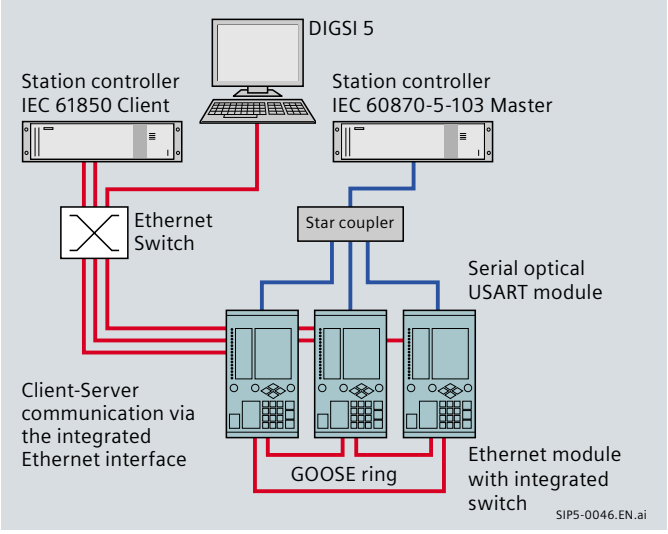

Fig. 6.8 Separate client-server and GOOSE communication via IEC 61850 with further serial connection to an IEC 60870-5-103 master

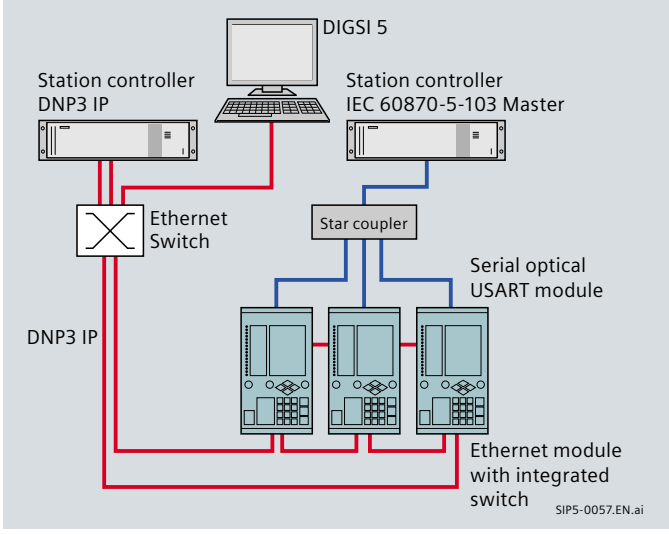

Fig. 6.9 Separate DNP3 IP client-server and serial connection to IEC 60870-5-103 master

Designed to communicate – Protocols

Serial DNP3 or DNP3 IP

DNP3 is supported as a serial protocol via RS485 or an optical 820 nm interface, and as an Ethernet-based IP variant via the electrical or optical Ethernet module. In conjunction with Ethernet, the switch integrated in the module can be used such that redundant ring structures for DNP3 can be realized. In this way, e.g. connection to a DNP3 device via a redundant optical Ethernet ring can be established. Information about a device can be routed and transferred to the DNP3 protocol, and also the fault records of the device. Switching commands can be executed in the control direction (Fig. 6.9).

Redundant connection to 2 serial substation controllers can be established via 2 modules or 1 serial double module. With Ethernet, 2 Ethernet modules that can work independently from one another via 1 or 2 networks are to be provided for a redundant connection.

For DNP3, the network topologies shown in Figs. 6.18 to 6.20, page 55 can also be used for Ethernet-based or serial communication.

Synchrophasors – protocol via Ethernet (IEEE C37.118)

SIPROTEC 5 devices optionally calculate synchrophasors and work as a Phasor Measurement Unit (PMU). These measured values, which are synchronized across large geographic areas via a highly-accurate second pulse, allow for assessment of grid stability. These values are transferred via an Ethernet network with the IEEE C37.118 protocol to a data concentrator. Transfer occurs via an optical or electrical Ethernet module. SIPROTEC 5 devices also offer these synchrophasors via the IEC 61850 protocol in special, logical measured value nodes (Fig. 6.10).

Further Ethernet-based protocols and services

Besides the actual protocol application, these services can run in parallel on an Ethernet module, and can be switched on and off by the user with DIGSI 5.

Ring redundancy with RSTP

The electrical and optical Ethernet module supports the construction of redundant ring structures in Ethernet with the Rapid Spanning Tree Protocol (RSTP). This occurs completely independently from the selected Layer 7 protocol, e.g. IEC 61850 or DNP3. This process is activated by default on the Ethernet modules, but can also be switched off with DIGSI 5. Up to 40 devices can be operated in a ring. Single or multiple rings can be established (Fig. 6.19, page 55), together with external switches that support this process.

Short reconfiguration times, typically under 25 ms, can be attained through optimization if the component fails. Thus, interruptions are barely noticeable, e.g. for cross-communication between devices via GOOSE.

Time synchronization with SNTP

The device can poll the absolute time from 1 or 2 time servers via an SNTP server. In redundant operation, both servers are read and the time of the 1st server is used for setting the device clock with a precision of 1 ms. If this server fails, time synchronization takes place via the second server. In addition to Ethernet modules, SNTP can also be used via the integrated Ethernet interface (port J).

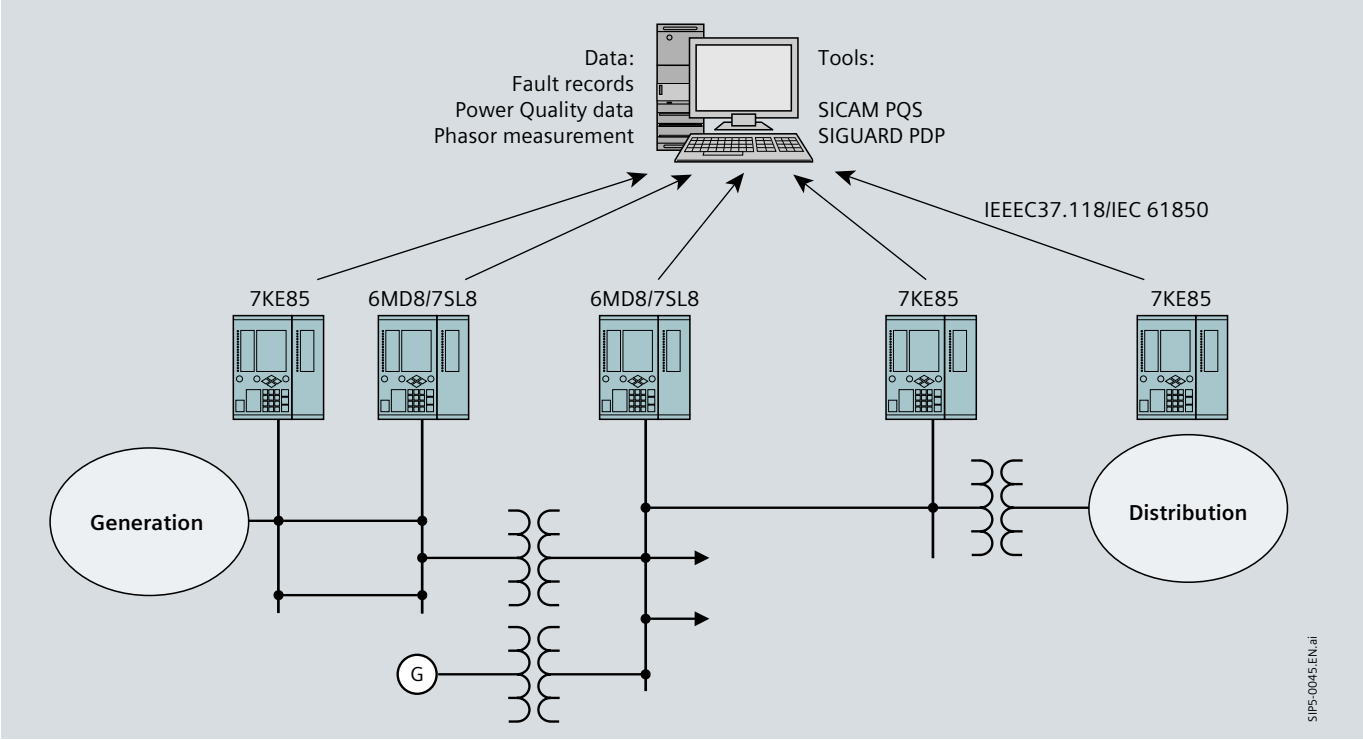

Fig. 6.10 Central evaluation of fault records and phasors

Further Ethernet-based protocols and services (continued)

Network monitoring with SNMP

The device can be integrated in network monitoring or network management systems via the SNMP V3 protocol. Extensive monitoring variables, e.g. the state of the Ethernet interfaces, their data throughput etc., can be made known to the monitoring system via MIB (Management Information Base) files. These variables are described in data-specific terms in MIB files and can be cyclically read out and monitored by the monitoring system. No values can be changed in the device via SNMP. It serves exclusively as a diagnosis interface.

Transfer of data via the protection interface

The protection interface and protection topology enable data exchange between the devices via synchronous serial point-to-point links from 64 kBit/s to 2 MBit/s. These links can be established directly via optical fibers or via other communication media, e.g. via dedicated lines or communication networks.

A protection topology consists of 2 to 6 devices, which communicate point-to-point via communication links. It can be structured as a redundant ring or as a chain structure (see Fig. 6.11), and within a topology the protection links can have different bandwidths. A certain amount of binary information and measured values can be transmitted bi-directionally between the devices depending on the bandwidth. The connection with the lowest bandwidth determines this number. The user can route the information with DIGSI 5.

This information has the following tasks:

- Topology data and values are exchanged for monitoring and testing the link
- Protection data, for example differential protection data or direction comparison data of the distance protection, is transferred.
- Time synchronization of the devices can take place via the link, in which case a device of the protection topology assumes the role of timing master.
- The link is continuously monitored for data faults and failure, and the runtime of the data is measured.

Protection links integrated in the device have previously been used for differential protection (Fig. 6.11) and for teleprotection of the distance protection. In addition to these protection applications, you can configure protection links in all devices in SIPROTEC 5. At the same time, any binary information and measured values can be transferred between the devices. Even connections with low bandwidth, e.g. 64 kBit/s can be used for this. Protection links that mainly serve to transfer data for the differential protection are designated type 1 links and are used in the 7SD8 and 7SL8 devices. Links for transferring any data that can be configured in the other devices (e.g. 7SA8, 7SJ8), are type 2. Protection interfaces must be of the same type on both sides.

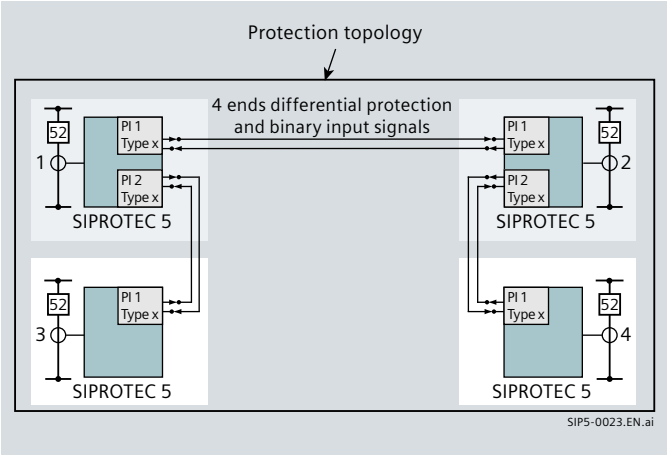

Fig. 6.11 Protection communication of the differential protection and transfer of binary signals

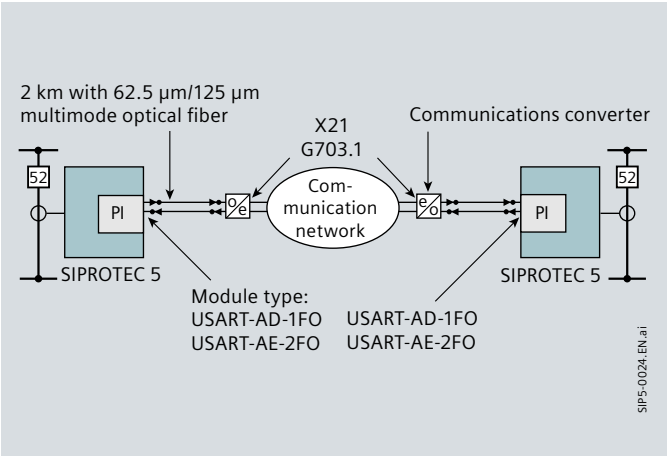

Fig. 6.12 Protection communication via a communication network with X21 or G703.1 (64 kBit/s / G703.6 (2 Mbit)) interface

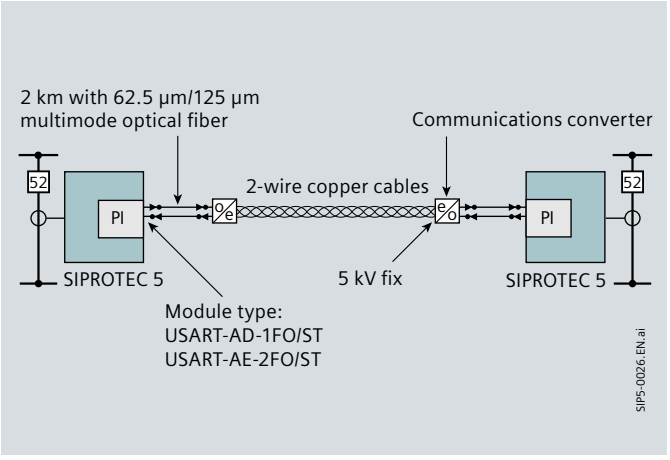

Fig. 6.13 Protection communication via a copper connection

Designed to communicate – Protocols

Use of the protection link for remote access with DIGSI 5

Access with DIGSI 5 to devices at the remote ends is possible via the protection interface. This allows devices at the remote ends be remotely read out or parameters to be set using the existing communication connection.

Figs. 6.12 to 6.17 show possible communication variants for establishing protection communications.

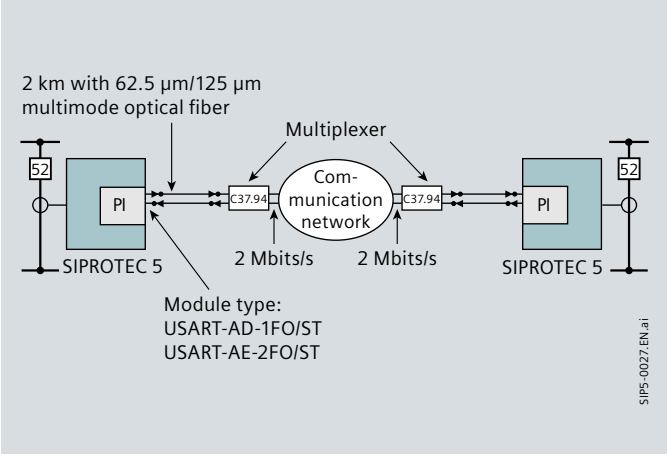

Fig. 6.14 Protection communication via an IEEE C37.94 (2 MBits/s) interface – direct fiber optic connection to a multiplexer

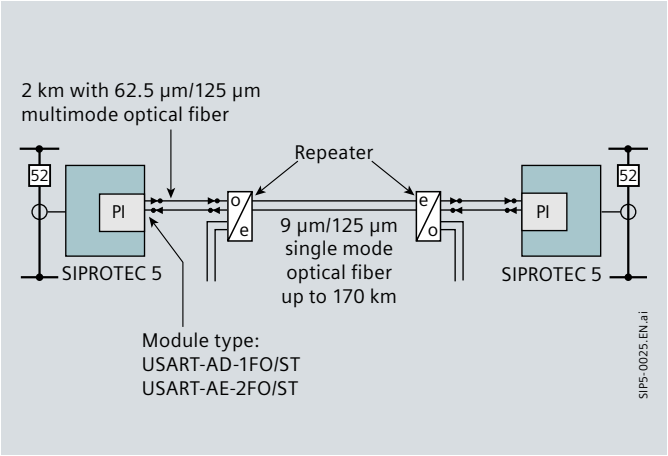

Fig. 6.15 Protection communication via single mode fiber and repeater

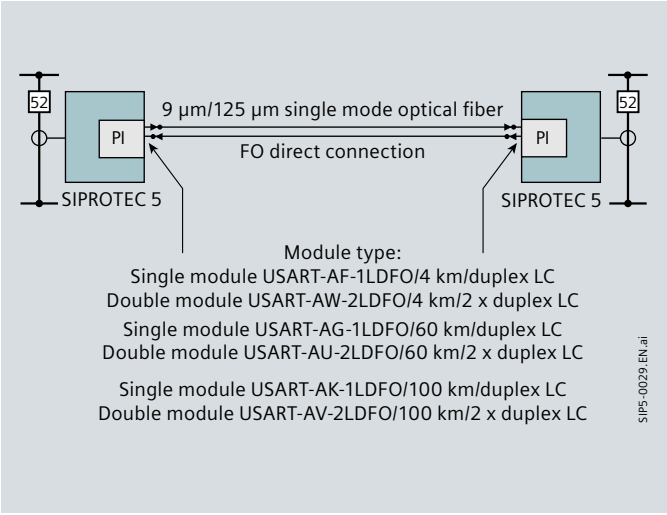

Fig. 6.16 Protection communication via direct fiber optic connections

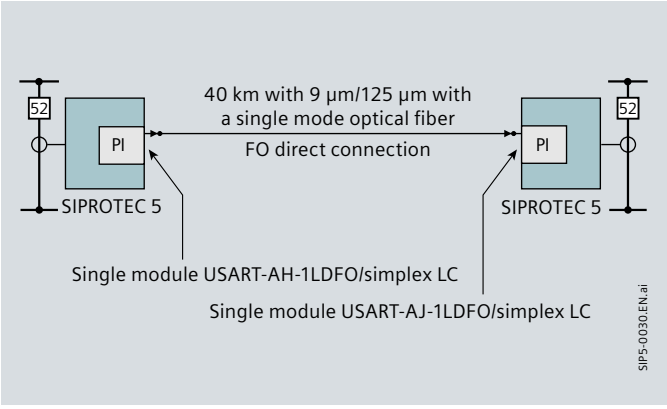

Fig. 6.17 Protection communication via a single mode fiber

Ethernet – Network topologies

Regardless of the selected protocol (IEC 61850, DNP3) the electrical and optical Ethernet module are supported by different network topologies.
If the module works without an integrated switch that can be switched off through DIGSI 5, it is connected to external switches individually or redundantly. In the case of a double connection, only one interface processes the protocol applications (e.g. IEC 61850). The second interface works in Hot Standby and the connection to the switch is monitored.
In the case of failure of interface 1, a switch is made to interface 2 within just a few milliseconds (Fig. 6.18).
Electrical or optical rings with a maximum of 40 devices can be established with an integrated switch (Fig. 6.19). Both interfaces of the module transmit and receive simultaneously. Mixed operation with SIPROTEC 4 devices is possible in the ring with a maximum of 30 devices. A special ring redundancy process, based on RSTP, ensures short recovery times in case of failure of a device, so that the protocol applications continue running nearly interruption-free. This configuration is also independent of the protocol application that runs on the Ethernet module.

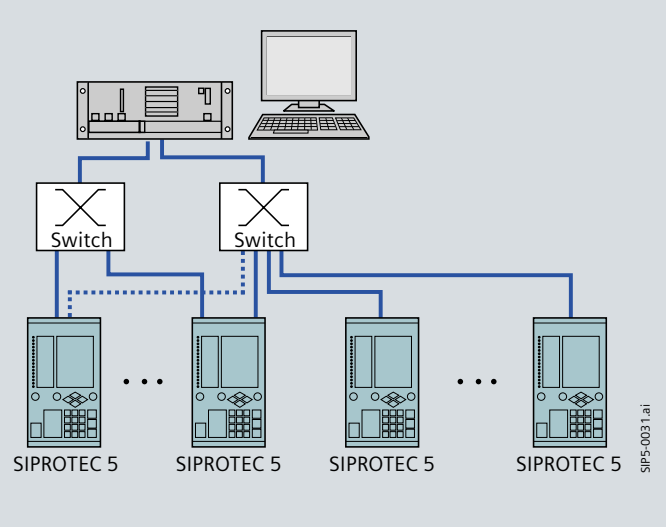

Fig. 6.18 Simple or redundant connection to external switches

Serial redundancy

Redundant connection to 2 substation controllers, e.g. SICAM PAS, is possible via 2 independent, serial plug-in modules or a serial double module. The serial IEC 60870-5-103 protocol or the serial DNP3 protocol, for example, can run on the modules. Mixed operation is also possible. Fig. 6.20 shows a serial optical network that connects each of the serial protocol interfaces of the device to a master. The transfer occurs interference-free via optical fibers. For the IEC 60870-5-103 protocol special redundancy processes are supported in the device. Thus, a primary master can be set that is preferred over the 2nd master in the control direction. The current process image is transferred to both masters.

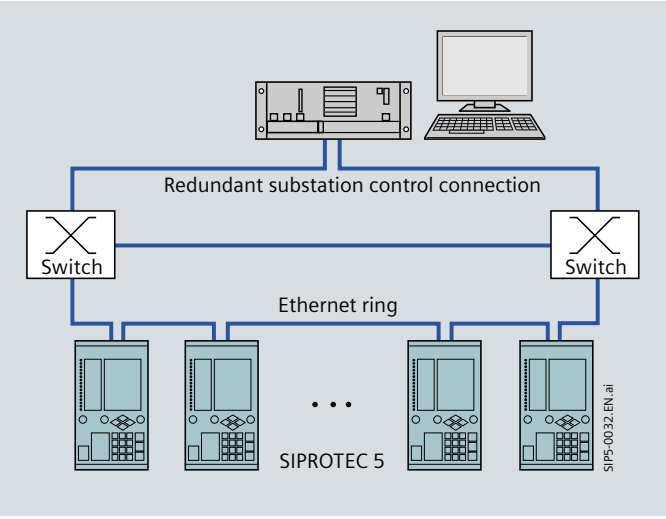

Fig. 6.19 Circuit operation with integrated switch and ring redundancy

Redundancy in communication

You as the user can realize different levels of redundancy.
The number of independent protocol applications running in parallel is limited by the 4 plug-in module positions.
A serial protocol can be run 2 times on a double module. But it can also be realized on 2 modules. Different serial protocols can be run in the device simultaneously, e.g. DNP3 and IEC 103. Communication occurs with one or several masters.

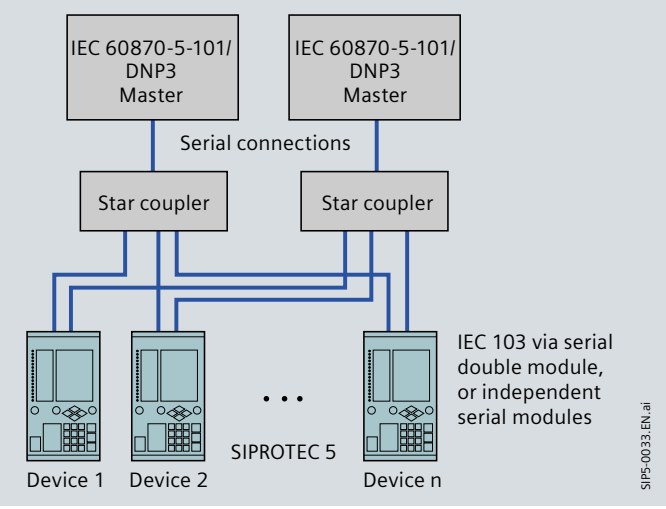

Fig. 6.20 Redundant optical connection of devices to IEC 60870-5-103 or DNP3 master (e.g. SICAM PAS)

Designed to communicate – Applications for communication

Redundancy in communication (continued)

The Ethernet module can be plugged into the device one or more times. This allows the same or different protocol applications to be executed multiple times. For IEC 61850 several networks are possible, e.g. one for client-server communication to a substation controller and a 2nd for the GOOSE connections between the devices that could be assigned to the process bus (Fig. 6.21). Through the client-server architecture of IEC 61850, one server (device) can simultaneously send reports to a maximum of 6 clients. The doubling of the interfaces on the Ethernet module enables the establishment of redundant network structures, e.g. optical rings or the redundant connection to 2 switches.
Protection links can be implemented in double. If one connection fails, a switch is made to the 2nd connection.

Integrated setting of communication in DIGSI 5

A communication protocol is configured with DIGSI 5. According to module type, DIGSI 5 offers the user the selection of the respective, permissible protocols/applications. The protocol parameters are set (e.g. baud rate, IP address etc.). Then the module is initialized with the protocol application and, for example, a serial module with the IEC 60870-5-103 and DNP3 protocol and the communication parameters are loaded.

For an application template of a device there is an appropriate communication mapping (Fig. 6.22). In a communication matrix, the user modifies this mapping and erases and completes his own information. This mapping file is finally loaded by DIGSI into the device, and determines the scope of information that is provided via the protocol. Protocol mappings can be copied between devices, if they contain the same functions, and can be exported into substation control applications.

Time synchronization

Time synchronization can occur through 1 or 2 timers. Depending on time source, precision of 1 ms is attained. Events are logged with a date and time with 1 ms resolution (Fig. 6.23). The following sources are possible, and can be configured independently as a 1st or 2nd timer:

- Port G for IRIG-B- or DCF77 telegram.
  A highly precise second pulse can also be launched there for special applications
- Protocol interfaces via plug-in modules
  (SNTP in IEC 61850, IEC 60870-5-103, DNP3 etc.)
- SNTP via port J (integrated Ethernet interface)
- Via a protection interface from the timing master
- Via the DIGSI 5 protocol (not cyclical)
- Internal time with integrated Quartz
- The device is prepared for a highly precise synchronization via an Ethernet module with the IEEE 1588 (accuracy 1 µs).

Time synchronization in the device is battery-buffered. Thus the internal clock continues to run with the Quartz precision of the device even in case of failure of the auxiliary voltage.

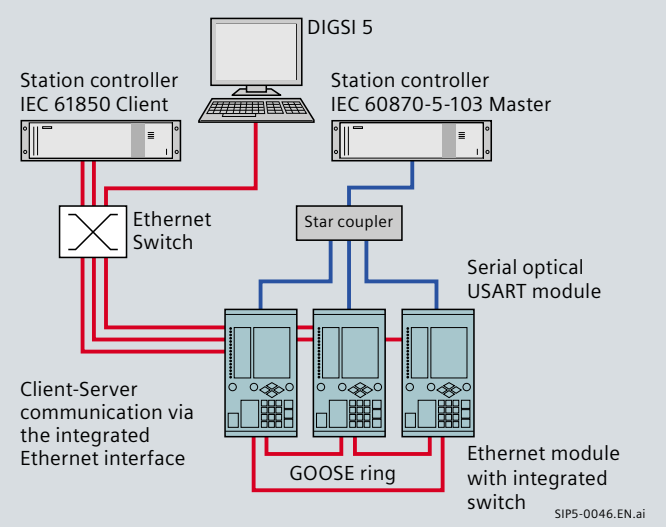

Fig. 6.21 Separate client-server and GOOSE communication via IEC 61850 with further serial connection to an IEC 60870-5-103 master

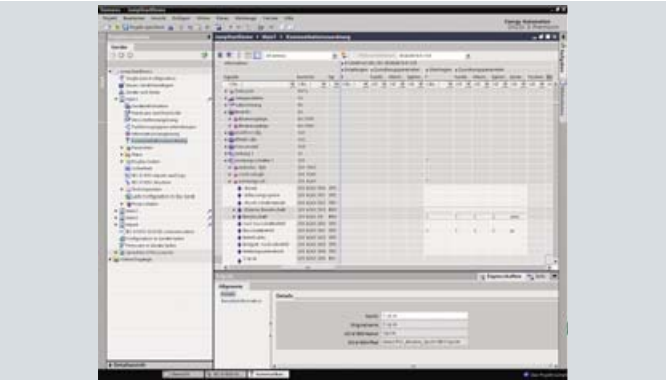

Fig. 6.22 Communication assignment with DIGSI 5 for the IEC 60870-5-103 protocol

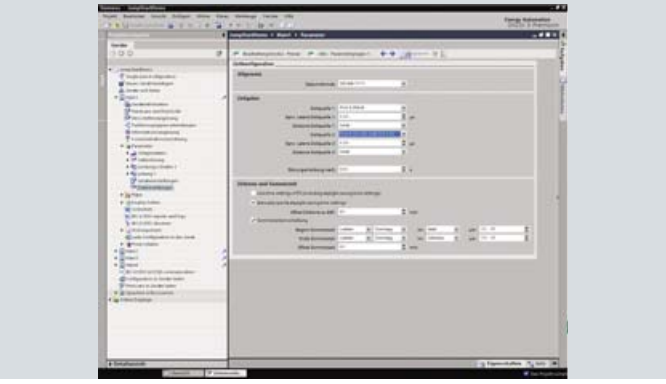

Fig. 6.23 Time settings in DIGSI 5

For you, designed to communicate in SIPROTEC 5 means:

- **Adaptation to the topology of your communication structure using settings (ring, star or network)**
- **Scalable redundancy in hardware and software (protocols) to match your requirements**
- **Pluggable, upgradeable communication modules**
- **Extensive routines for testing connections, functions and operating workflows**

Simply usable – Engineering in user language

IEC 61850 is more than just an Ethernet-based substation control protocol. It comprehensively defines the engineering process, data and service models, conformity testing, and end-to-end communication in control systems.
In Edition 2, the influence of the standard is extended to more sectors of the energy industry.

For you, IEC 61850 – simply usable means:

- **IEC 61850 system specification and system description**
- **DIGSI 5 helps to make the IEC 61850 data model easy to manage**
- **DIGSI 5 supports the IEC 61850 engineering process and the system specification**
- **Flexible data object engineering enables simple, efficient operating concepts**
- **Interoperability with IEC 61850 Edition 1**

Ethernet-based substation automation protocol

IEC 61850 is more than just a substation automation protocol. The standard comprehensively defines data types, functions and communication in station networks. In Edition 2, the influence of the standard is extended to more sectors of the energy industry. Siemens actively participated in designing the process of adapting Edition 1 for Edition 2 for the purposes of the standardization framework. Edition 2 fills in certain omissions and defines additional applications. As a global market leader with Edition 1 SIPROTEC 4 devices, between Editions 1 and 2 we have solved the issues of interoperability, flexibility and compatibility: Cooperation with Edition 1 devices is possible without difficulties.

The internal structure of SIPROTEC 5 devices conforms to IEC 61850. The net result is that first time integrated, end-to-end system and device engineering – from the single plant line to device parameterization – conforming to the guiding principles of IEC 61850 is possible.

DIGSI 5 with integrated IEC 61850 engineering covers the complexity of the standard with a sophisticated operator guidance system. In standard engineering, you as the user will not be required to deal with the details of IEC 61850: you will be addressed in your user language.

In the user language, distance protection is distance protection with zones and dependent functions, not a collection of logical nodes. Reports are message lists in which information about the systems control is configured. GOOSE connections are simply configured in the system configurator with source and target information – or even easier: You simply use the signals from other devices where you need them. You work in your language, with functions and messages associated with a device. If you wish, you can view the allocated IEC 61850 objects in the IEC 61850 protocol language. This bilingualism is supported throughout the user interface by DIGSI 5 and the export files on the substation control system. As the user you can even add helpful notes to the data points you define in your language, and then export them for data purposes in the ICD and SCD description.

You will not be distracted from your primary task by switching to the station configurator, because IEC 61850 is fully integrated in DIGSI 5 and the device. Proven usage, short paths, easier, faster, these are the objectives of simple engineering.

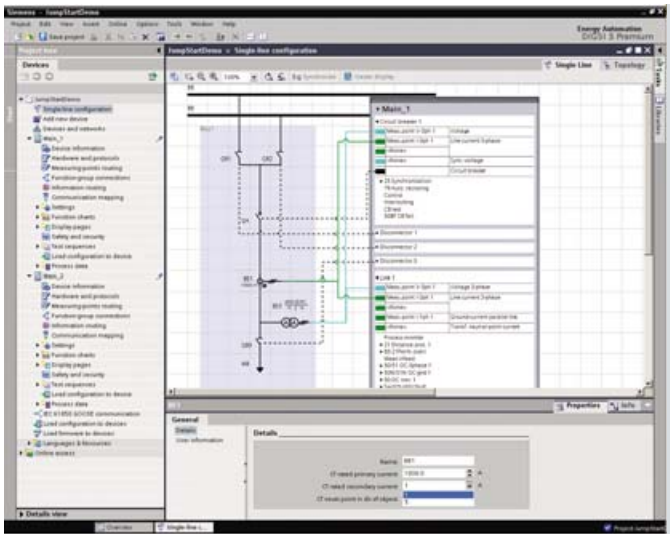

Fig. 7.1 System specification and configuration in DIGSI 5 – the complexity of IEC 61850 does not reach the interface

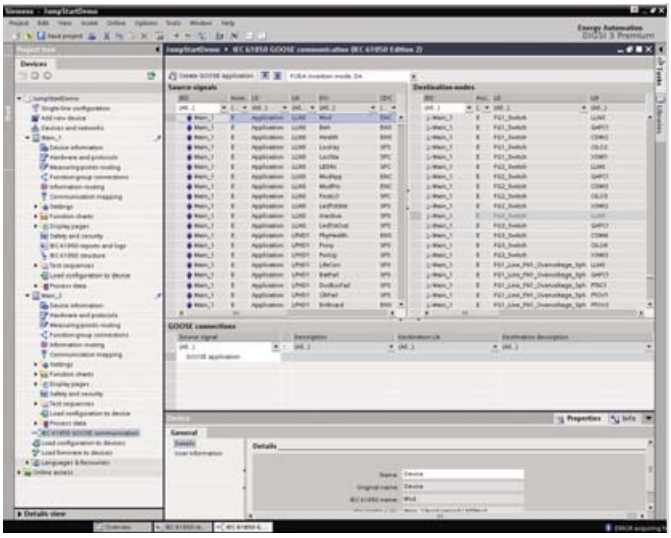

Fig. 7.2 GOOSE editor in DIGSI 5

IEC 61850 – Simply Usable

Simply usable – Flexible engineering

Flexible engineering offers IEC 61850 experts a wide range of freedom with regard to designing their own IEC 61850 structure, including with user-defined functions and objects. Flexible object modeling, freedom in addressing objects and flexible communication services assure the highest possible degree of interoperability and effective exchange and expansion concepts.

The name of the logical device (IdName) is freely editable. For example, the standard-conforming name CTRL can be changed to CONTROL. Structural changes can also be made by changing the logical device (LD), so that the interface structure can be flexibly adapted to the user's own requirements. Rigid manufacturer specifications are a thing of the past. Prefix and instance of the logical node (LN) can also be edited.

The standard fixes the length and rules that are checked by DIGSI 5 when they are entered.

Function levels of a device, which the standard maps to Logical Nodes (LN), can be deleted, copied, and extended with the user's own objects. Messages can be added to a switching object such as the LN XCBR, e.g., monitoring messages for a circuit breaker that have not been defined in the original LN. As the user, you can organize all of the information associated with a given switching object in a Logical Nodes (LN).

Logical Nodes (LN) can be added from a library. These instructions can be supplemented with your own objects. You can also define and create generic nodes. For example, there are Logical Nodes (LN), whose functionality is extended by the user. These user-defined functions can be loaded into the device and run there. Monitoring functions can be created and expanded as required.

A high degree of flexibility in communication is offered for configuration GOOSE messages and reports. Addresses, dataset names etc, can be set by you the user.

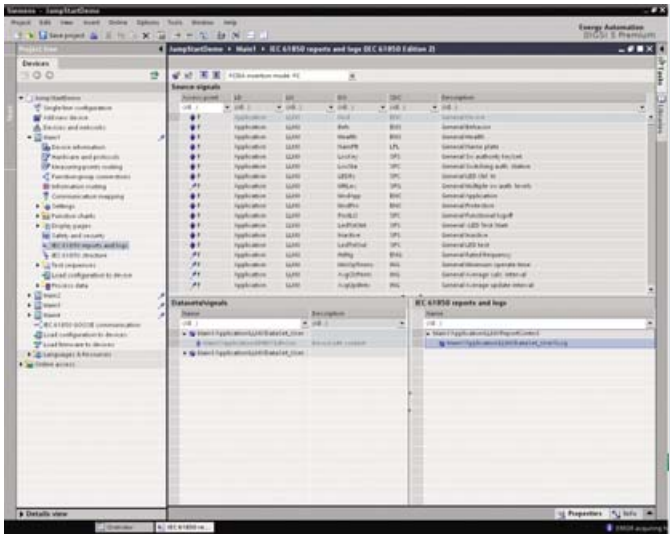

Fig. 7.3 Generating datasets and reports for IEC 61850

Flexible engineering offers a high degree of design freedom on many levels, enhancing interoperability for more complete communication interchangeability.

With the single line diagram, you as the customer can view the topological structure of the system. DIGSI 5 has been prepared so that it can export this topological structure of a system to the IEC 61850-conforming SSD file. This description as an extension of the SCD file represents the primary system for technical data purposes. In the future, the objects of the device with which processes of the primary system are controlled can be adapted flexibly to reflect the customer's specifications. Flexible engineering is the key to bringing the system view into harmony with the IEC 61850 structure of the device.

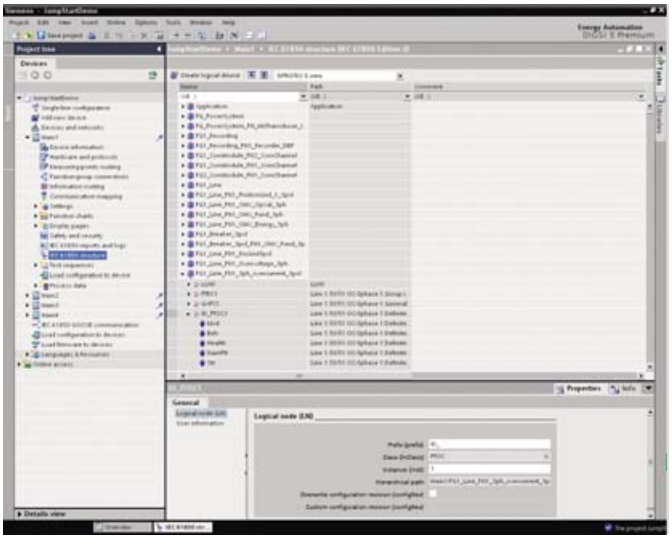

Fig. 7.4 Editor for adapting the IEC 61850 structure in the SIPROTEC 5 view

"IEC 61850 – simply usable" with SIPROTEC 5 means:

- **Converting the complexity of the IEC 61850 data model into your familiar user language**
- **Integrated, consistent system and device engineering (from the single line to the complete system and device parameterization on the basis of the IEC 61850 data model)**
- **Flexible object modeling, freedom in addressing objects and flexible communication services assure the highest possible degree of interoperability and effective exchange and expansion concepts**
- **Full compatibility and interoperability with IEC 61850 Edition 1**

SIPROTEC 5 devices are equipped with extensive test and diagnostics functions. These are available to users in SIPROTEC 5 in conjunction with DIGSI 5 and they shorten the testing and power-up phase significantly.

The DIGSI 5 Test Suite offers:
- **Hardware and wiring test**
- **Testing for functions and protection functions**
- **Circuit-breaker test and AR test functions**
- **Communication test including loop test**
- **Protocol test**

The integrated test sequencer

The objective of the extensive test and diagnostic functions that are made available to the user with SIPROTEC 5 together with DIGSI 5 is to shorten testing and power-up times. All test functions are integrated in DIGSI 5. This enables engineering including the device test to be carried out with one tool. The most important functions should be listed as examples here. There are also other specific test functions depending on the device type.

An innovative concept enables functions to be tested via the test sequencer integrated in the device. Normally, the device receives analog and binary signals from the process or from an external secondary test equipment. Previously, the protection functions and communication were tested with variables such as these. With SIPROTEC 5 devices these variables can now be substituted with values supplied from an integrated test equipment in a simulation mode. For this, the analog and binary inputs are decoupled from the process and connected to the integrated test sequencer.

The tester uses DIGSI 5 to create a test sequence, e.g., a short-circuit sequence, loads it into the device and runs it in simulation mode. The test sequencer in DIGSI 5 is capable of handling test sequences consisting of up to six test steps. When loaded into the device, this test sequence is run in real time and simulates the functions of the device like a real process at binary and analog inputs. Protection functions, control, logic functions, and communication can thus be tested in real time without secondary test equipment.

The test sequence is started manually from DIGSI 5 or controlled via a binary input. This also makes it possible to test the interaction between several devices.

Hardware and wiring test

In the hardware test, the state of the binary inputs can be read out by DIGSI 5, and contacts and LEDs can be switched or routed through DIGSI 5 for test purposes.

The parameters measured at voltage and current inputs are represented in vector diagrams – divided according to magnitude and phase angle (Fig. 8.1). Thus it is easy to detect and check if the connections in the measurand wiring are transposed, as well as the vector group or the direction between current and voltage. In devices that are connected via protection interfaces, even analog measurement points of remote ends can be represented as vectors.
This makes it easy to check the stability of a differential protection.

In the wiring test, the wiring connections between devices are tested. If the devices are connected to a network via Ethernet, this test can be carried out with unprecedented ease. For this, the contact on a device is closed with the aid of DIGSI 5.
This contact is connected to a binary input of one or more SIPROTEC 5 devices via a wire connection. These automatically send a report to DIGSI 5 to the effect that the binary input has been activated by the closing of the contact. The tester can then log this test and check the wiring between the devices.

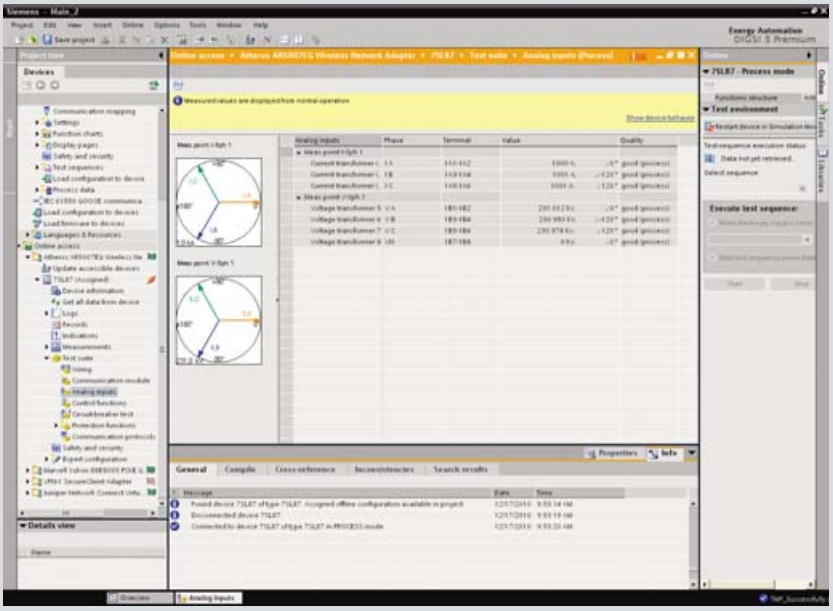

Fig 8.1 Display of analog measuring points in vector diagrams

Holistic workflow – DIGSI 5 Test Suite

Testing device functionality and protection functions

The graphical representation of characteristic curves or diagrams of protection functions not only help the engineer who parameterizes the test functions, but also the engineer who tests them (Fig. 8.2).

In this test, the operating point of a protection function is represented graphically in the diagrams, e.g., the calculated impedance of a distance protection in the zone diagram. Additionally, messages relating to the protection function are logged, e.g. pickup or operate.

This test can be carried out with signals from the process or with the test equipment integrated in the device.

Circuit-breakter test and AR test function

Switching sequences can be initiated via DIGSI 5 to test the automatic reclosing (AR). However, this is only possible if remote switching via the key switch is permitted. In addition, a security prompt (confirmation ID) must be entered for switching authorization via DIGSI 5. There are additional security prompts for non-interlocked switching. This provides protection against unauthorized use or inadvertent actuation during operation.

A circuit-breaker test can also be deactivated and activated without an interlocking check.

Communication testing

Since communication is an integral component of the devices and they are interconnected either directly or via a substation control system, they must be thoroughly tested at commissioning and monitored continuously during operation. The integrated test tools assist the user in ensuring that the communication paths are tested and monitored efficiently.

Loop test for the protection interface

This test is launched by DIGSI 5 for a communication module and a selected interface. It is used to detect faults in subsections when inspecting the physical connection of the communication path (Fig. 8.3). Test telegrams are sent from the transmitting side Tx of an interface, and these are measured again at the receiving interface Rx. The user thus has the capability to insert loops at various points in the communication network and to test the connection of the loop. The number of telegrams sent, received and corrupted is displayed continuously in DIGSI 5, so that the quality of the connection can be monitored.

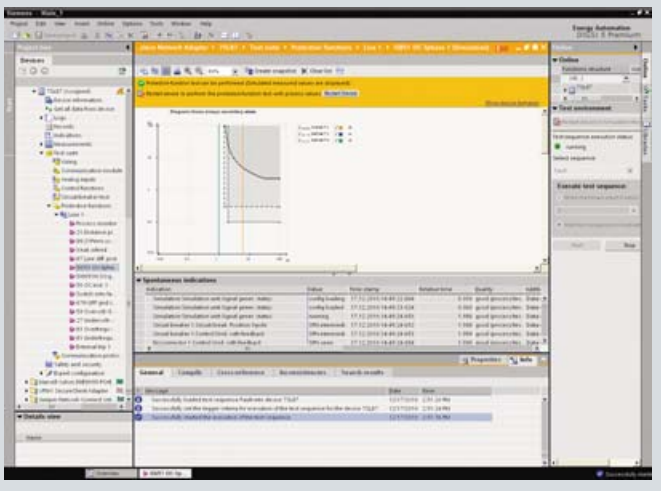

Fig. 8.2 Test of protection function with operating point of the protection function in response characteristic curve

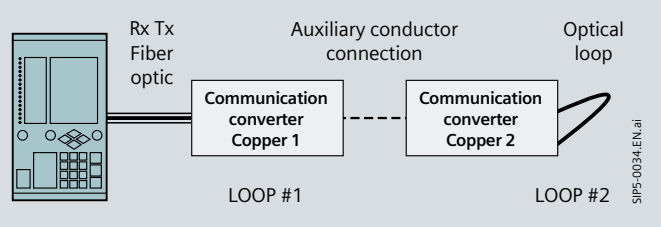

Fig. 8.3 Loop test for protection interfaces

Online monitoring of communication connections

The data flow at communication interfaces can be constantly monitored. To do this, the number of telegrams that are sent, received and corrupted per time unit for serial connections and Ethernet intefaces during operation is constantly measured and displayed. If faults occur, an alarm can be issued.

A network management and monitoring system performs detailed monitoring of Ethernet modules via the SNMP protocol.

For protection interfaces the delay time of the signals is also monitored, and it is calculated during synchronization by means of a highly precise second pulse in the transmit and receive direction. Additionally, the communication topology is also monitored constantly there and displayed in DIGSI 5.

GOOSE connections can be monitored permanently at the receiving site during operation. This means that an outage is detected within a few seconds.

Protocol test

For the protocol test, specific signal values are set and reset using DIGSI 5 (Fig. 8.4). The test mode itself is configurable. The device sends the selected value to the client using the configured communication protocol e.g., IEC 61850. In this case, a report is generated or a GOOSE message is sent automatically when this information is switched correspondingly.

The device can be used to test substation control information for all protocols (e.g., IEC 61850, IEC 60870-5-103, serial DNP3, DNP3 IP) without the going through the process of generating signal states with a test equipment. Signals that are transmitted across protection interfaces can also be tested.

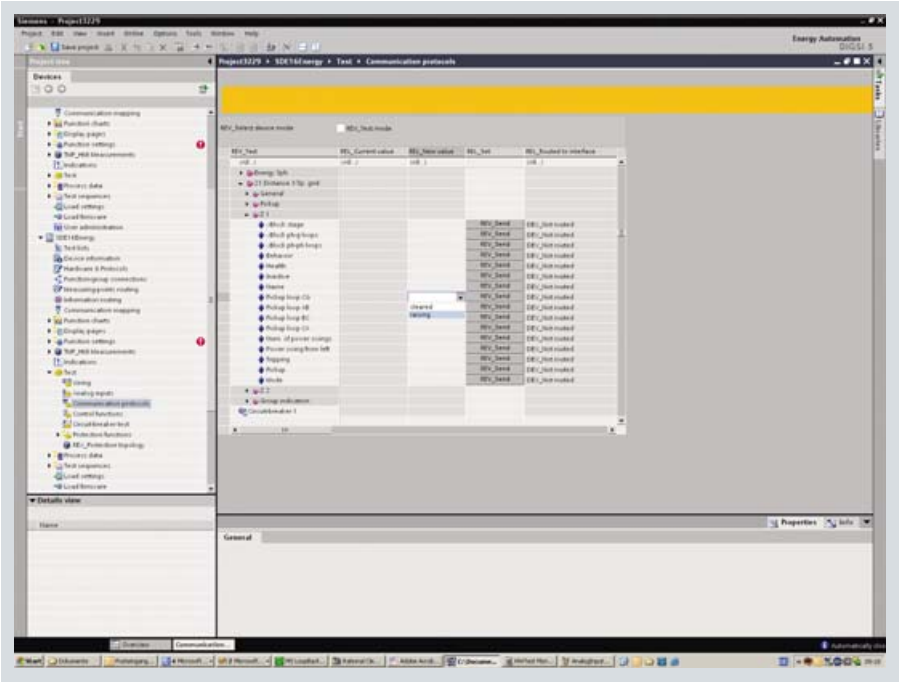

Fig. 8.4 Protocol test for substation automation technology or for GOOSE and protection interfaces

Test and display of external timers

If the system time of the device is set externally using 1 or 2 timers, this time can be read out in the device or with DIGSI 5. When the time protocol returns these values, it indicates which timer is setting the system time and issues a statement regarding the quality of the time source. Synchronization via external clocks can thus be monitored and displayed during operation (Fig. 8.5).

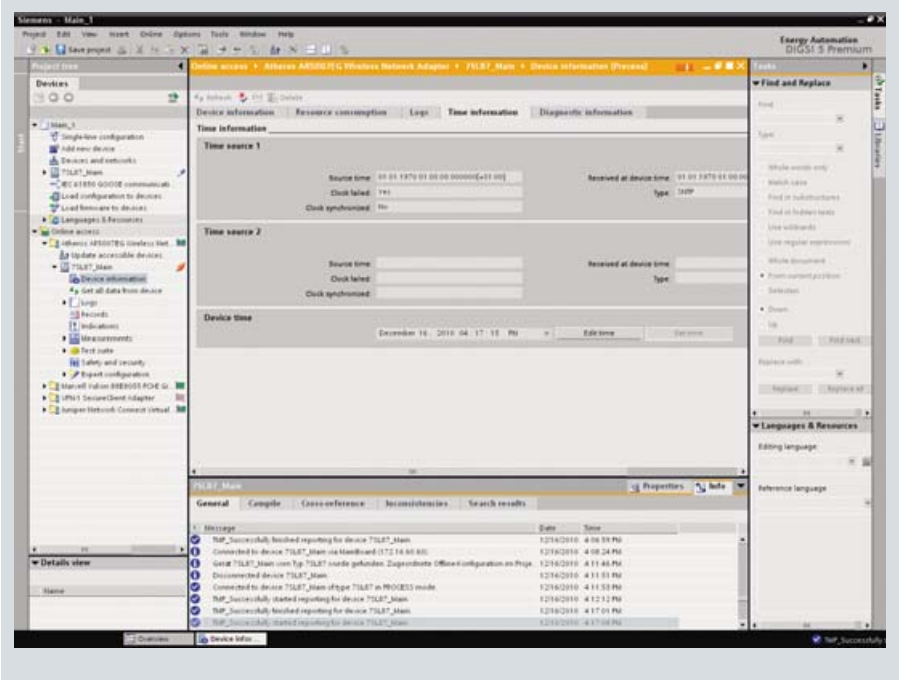

Fig. 8.5 Test of external timers

Holistic workflow – DIGSI 5 Test Suite

Analysis of function charts (CFC debugging)

Logic plans prepared in the form of function charts (CFCs) can be tested offline in DIGSI 5. To this end, test sequences can be generated with the DIGSI 5 Sequencer to act on logical inputs of the function chart or the analog and binary inputs of the device. This makes it possible to test not only the function chart but also its interaction with upstream and downstream functions. During this test, the values of variables are displayed and changes over time are logged in records that can be analyzed later, e.g., with SIGRA. This enables even complex temporal dependencies to be analyzed with ease. Function charts (CFC) can thus be created offline in the office and tested without using a device.

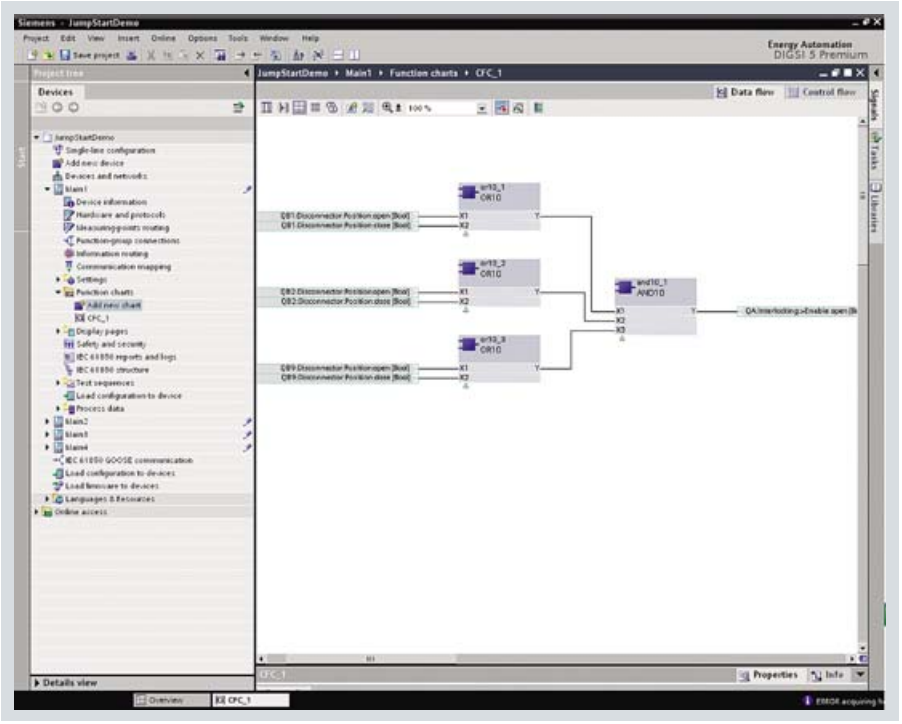

Fig. 8.6 Easy analyzing of function charts

For you, using the DIGSI 5 Test Suite means:

- **Considerably shorter testing and commissioning time**
- **Commissioning support personnel in the adjacent substation is no longer required**
- **All test routines performed are documented**
- **Testing without secondary test equipment is also possible**

Safety for personnel and equipment are first priority, but availability is also critically important. And as the plant landscape becomes more and more open and complex, the conventional security mechanisms are no longer adequate.

For this reason, a security concept has been implemented in the SIPROTEC 5 device architecture that is designed to address the multidimensional aspects of security in a holistic approach.

Multilayer safety mechanisms in all links of the safety chain provide you with the highest possible level of safety and availability.

Safety and Cyber Security includes:

- **Security concept in device design**
- **Information security against IT attacks (IT threats from the outside)**

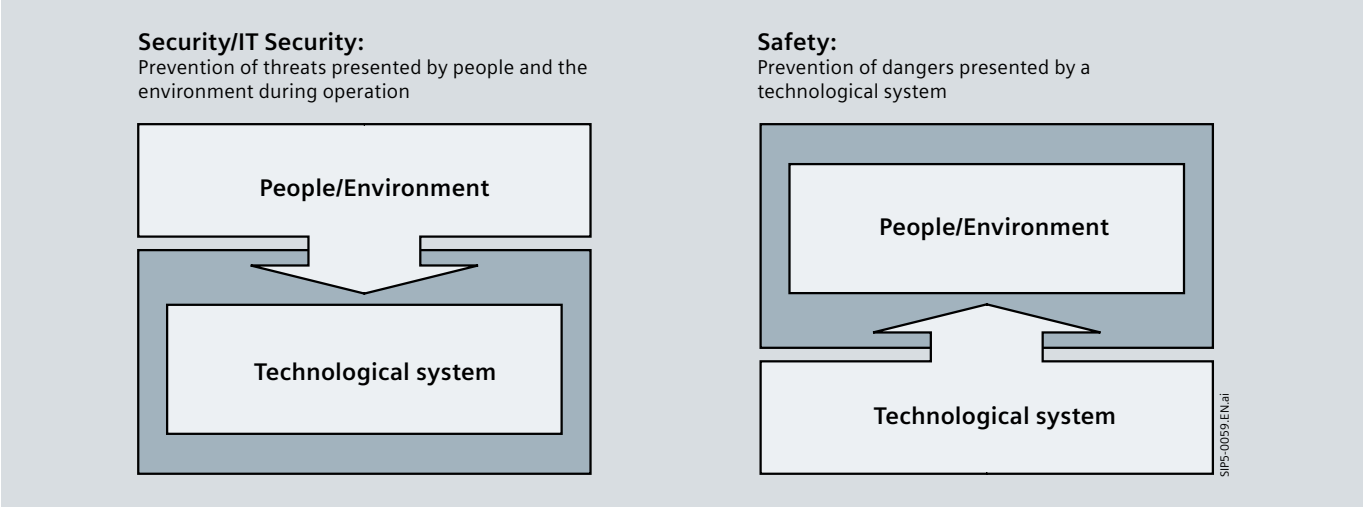

Fig. 9.1 Graphic of distinction between safety and security

Multilayer safety mechanisms

Safety comprises all aspects of protection for personnel and primary equipment installations. The devices and DIGSI 5 support this from the functional standpoint. Cyber Security measures ensure secure operations in networks.
The manufacturer can support the user with these measures. The responsibility to implement a comprehensive Cyber Security concept lies with the operator of the system. The concept must consider all system components with regard to all technical aspects of Cyber Security.

Safety in the hardware design

- The device system consisting of configured hardware building blocks, each with its own cooling system, reduces thermal load, prolongs service life and enables error-free operation in a wide ambient temperature range.
- High availability is achieved with the auxiliary power supply concept. Central wide range supply ensures the provision of a common voltage to all components. Individually required voltage levels are created in the modules concerned. Thus, the possible outage of a local voltage level causes only one module to malfunction, not the entire device. This selective outage is reported.
- Crossover wiring of internal analog/digital converters enables the device's analog inputs to be monitored effectively and potentially threatened functions to be blocked early, like differential protection if a current channel fails.
- Storage of calibration data in the analog acquisition module enables completely safe exchange or extensions within the module unit.
- Fully pluggable terminals and plug-in module mean that a wiring test is no longer necessary when devices or modules are replaced.
- Now that the current transformer is integrated in the terminal block (Safety CT-Plug), open secondary current circuits cannot occur anymore during replacement of a device or a module. When the terminal is pulled out, the transformer is always opened on the safe, secondary circuit.
- The device does not need to be opened to adjust binary input thresholds or adapt them to the rated current of the transformer (1 A, 5 A). The device does not need to be opened to replace the battery or change the plug-in modules.

Monitoring functions

Comprehensive monitoring functions ensure secure operation by fast detection of irregularities and automatic initiation of appropriate measures to avert incorrect responses. Depending on the severity of the irregularity detected, a warning may be issued, the functions concerned be blocked, or the entire device may be isolated by disconnecting the life contact. In all cases, the diagnostic buffer outputs the cause and appropriate take-action instruction.

Hardware monitoring

All hardware in the device is continuously monitored. This includes for example the CPU, the auxiliary voltage, the battery status, the internal clock, the storage modules, the analog inputs, the bus connections, the expansion and communication modules.

Monitoring of the analog inputs

As a data source for the protection functions, monitoring of the analog inputs is assured in multiple stages. Some monitoring functions are primarily dedicated to the commissioning (incorrect or missing connections) and only generate a warning indication. These include:

- Current and voltage balance
- Current and voltage sum
- Phase-rotation supervision.

Other monitoring functions detect outages during operation and rapidly initiate blocking of the affected functions:

- Fuse failure monitor (loss of voltage)
- Fast current sum supervision and broken wire monitoring for the power circuits.

In addition, the proper working method of all analog-digital converters is assured by plausibility monitoring at the sampling level.

Tripping circuit monitoring (ANSI 74TC)

The circuit-breaker coil and its feed lines are monitored via two binary inputs. If the tripping circuit is interrupted, and alarm indication is generated.

Communication connections

Telegrams are monitored for correct transmission. Faults are reported via warning messages. Data associated with protection and control is transmitted via protection interfaces and IEC 61850 GOOSE messages. The transmitted information is also monitored constantly on the receiving side.

Monitoring of protection interfaces

- 32-bit CRC checksum monitoring compliant with CCITT/ITU for detecting corrupted telegrams
- Invalid telegrams are flagged and are not used by the protection system
- Sporadic interference is ignored, persistent interference triggers blocking of the affected protection (differential protection) and control functions
- Propagation times are measured and taken into account for purposes of differential protection
- The topology of the protected area is monitored. Outages in the communication connections automatically trigger switching to other communication paths (ring to chain operation or hot standby), or otherwise to blocking the entire protected area. The same applies if outage of a device in the topology is detected.

Monitoring of IEC 61850 GOOSE messages

- CRC checksum monitoring, sequence number monitoring and repetition time monitoring for detecting incorrect or missing telegrams
- Applications consider the state of GOOSE messages that are corrupt or transmitted under test conditions and switch to safe mode.

Load management

The free configurability of protection functions and function charts (CFC) enables them to be adapted to an enormous range of applications. During engineering with DIGSI 5, the integrated load model calculates the resulting device load. This ensures that only viable configurations can be loaded into the device.

Standardized management of device modes

Test modes and the health status of information are forwarded and handled uniformly and consistently throughout the entire system. Analysis functions take the modes into consideration and guarantee secure operation. This is particularly critical when protection and control-related data is transmitted via protection interfaces and IEC 61850 GOOSE messages. But it applies equally for signal processing in the function charts (CFC).

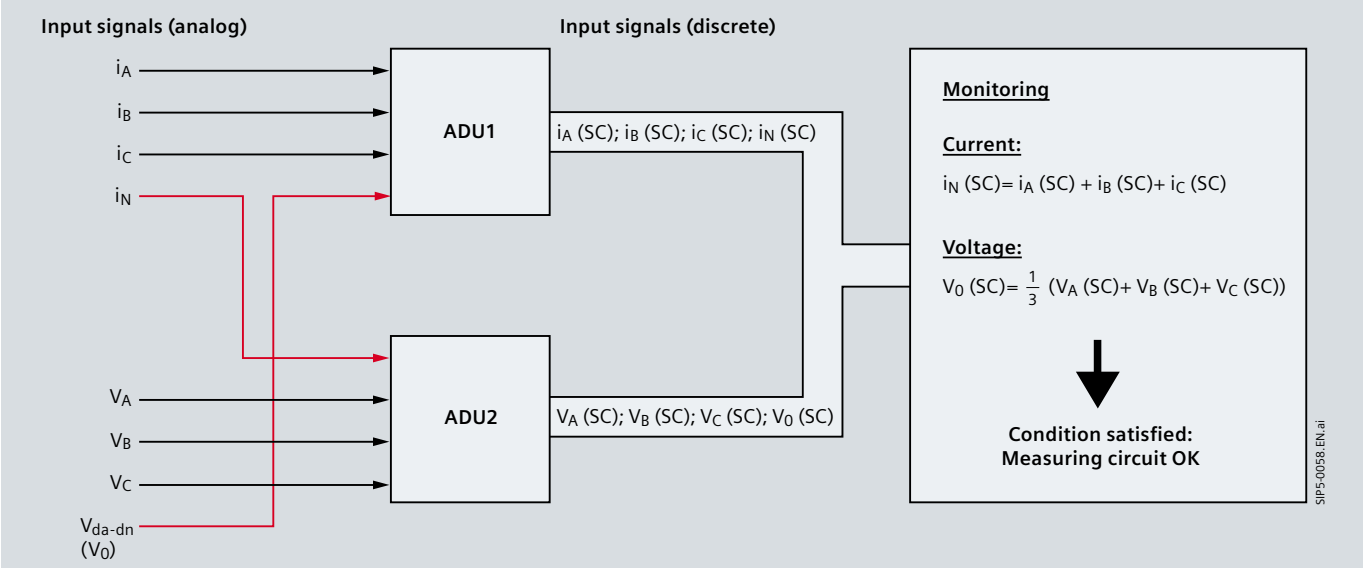

Fig. 9.2 Monitoring of analog input circuits for malfunctions during analog-to-digital conversion

Cyber Security

With the increasing integration of field devices in Ethernet-based communication networks, communication must be secured against internal faults and attacks from outside. Standards such as NERC CIP (North American Electric Reliability Corporation – Critical Infrastructure Protection) and the BDEW Whitepaper contain requirements for the safe operation of devices in the critical communications infrastructure, and are directed at both manufacturers and operators (requirements for secure control and telecommunication systems by the Bundesverband der Energie- und Wasserwirtschaft e.V. – German Association of Energy and Water Industries).

Cyber Security must be incorporated into the design of devices right from the start. This has been carried out systematically in the case of SIPROTEC 5. Measures in the hardware ensure that key material for protecting the communication and datasets of a device is stored in absolute security. Communication stacks that are hardened against cyber attacks, a multistage access concept in operation and permanent logging of all authorized and unauthorized access attempts and of critical Cyber Security actions provide the operator with a high degree of Cyber Security when the devices are integrated in the operator's network.

Unused Ethernet services can be disabled. For example, if the RSTP ring redundancy protocol is not being used, as the user you can disable it with DIGSI 5 (Fig. 9.3). This gives a potential attacker no open interfaces and only services that are really in use are activated in a network.

Product Security Blueprint

The Product Security Blueprint in conjunction with the "Spanning Security Blueprint" for SIPROTEC 5 devices provide you with valuable notes in integrating devices in your network and operating them securely. An overall security concept should be drawn up and maintained in a "Spanning Security Blueprint". This documents typical network configurations, the services used, and their ports. Measures for updating that components that are critical for Cyber Security, password protection and antivirus protection are also described.

Fig. 9.4 shows a recommendation of this kind for protecting a switchgear. The SIPROTEC 5 devices are integrated in optical Ethernet rings via switches. In these rings, the respective Ethernet-based substation automation protocol, e.g., IEC 61850 or DNP3 and the systems control run without loss of performance. Accesses from a non-secure external network are allowed via a gateway that is responsible for safeguarding the network. The accessing party is authenticated, e.g., by DIGSI 5, in the gateway, and communication is encrypted via VPN. This is fully supported by the communication services of DIGSI 5.

The technical control network and the network for remote access can also be separated entirely by appropriate selection of an independent Ethernet port for communication between the device and DIGSI 5. This falls within the scope of the operator's philosophy. With their concept of pluggable modules, the devices also enable solutions with separate networks. An extensive range of Cyber Security features have been integrated in SIPROTEC 5 and DIGSI 5, and these are described in the next section.

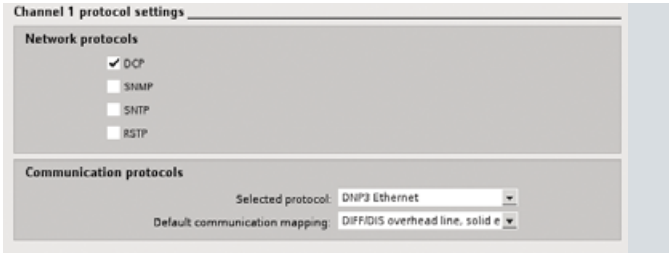

Fig. 9.3 Isolatable communication services during access via Ethernet networks

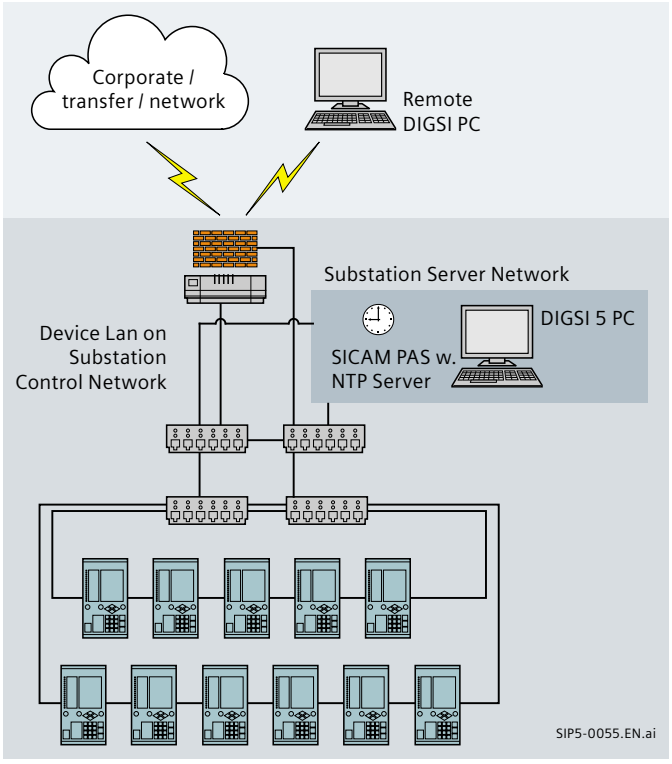

Fig. 9.4 Secure operation of devices within a switchgear with remote access from an external network

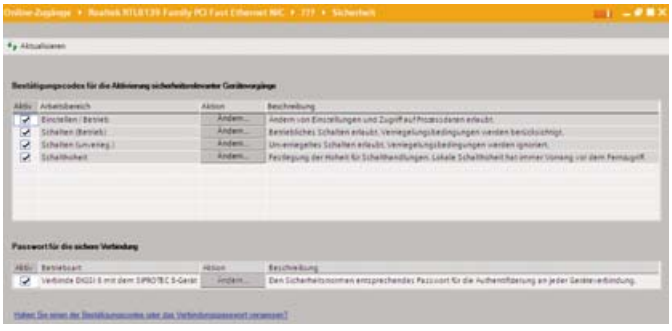

Fig. 9.5 Settings dialogs for passwords and security prompts

Safety and security inside – Cyber Security

Multilayer access security for device and DIGSI 5

DIGSI 5 offers many useful functions to help with configuration and testing. It is often not desirable to have to enter confirmation codes during this phase. In contrast, the reading of data in the operating state is at the focus. Reparameterization and switching are then Cyber Security-critical operations that lead to faults in the operating state if they happen inadvertently or without authorization. Comprehensive access security can be activated in the device after commissioning has been completed:

- Secure authentication take place between the device and DIGSI 5. This precludes another program from accessing the devices and reading or writing data there.
- Establishment of the remote connection via Ethernet only after the user's password has been entered. This connection password conforms to the Cyber Security requirements for assigning passwords defined in NERC CIP. It has 8–30 characters and must include upper and lower case letters, digits and special characters. Once the connection has been successfully established, the user has only read access to the device. Subsequent data exchange then takes place via an encrypted, uninterceptable connection through an Ethernet module.
- Then, confirmation codes are requested for security-critical actions that have write access to the device, for example changing parameters. These can be configured by the user and there are various confirmation codes for the protection and control functionality (Fig. 9.5, page 65).

These Cyber Security measures during remote access to the device with DIGSI 5 ensure secure communication. A further layer of protection for the user is provided by the query for individual passwords when logging into the device and carrying out write access actions, which are critical for Cyber Security purposes.

Incorrect password entries are identified and logged. An alarm can be triggered via an independent telecontrol link. Cyber Security critical operations such as remote access or reparameterization are recorded continuously. These entries cannot be deleted from the device. They can be transmitted to the substation automation unit and archived there. All data that can be loaded into the device via DIGSI 5 is signed. In this way, corruption from outside by viruses or trojans is reliably detected and prevented. It is not possible to load manipulated data into the device.

For you, safety and Cyber Security mean:

- **Long-lasting, rugged hardware with outstanding EMC immunity and resistance to weather and mechanical loads**
- **Sophisticated self-monitoring routines identify and report device malfunctions immediately and reliably**
- **Conformance with the stringent Cyber Security requirements defined in the BDEW Whitepaper and NERC CIP**
- **Encryption along the entire communication segment between DIGSI 5 and the device**
- **Automatic recording of access attempts and security-critical operations on the devices and systems**

Description

DIGSI 5 is the versatile engineering tool for parameterization, commissioning and operating all SIPROTEC 5 devices. Its innovative user interface includes context-sensitive user instructions. Simple connection to the device via USB enables you to work with a device easily and efficiently. The full capabilities of DIGSI 5 are revealed when you connect it to a network of protection devices: Then you can work with all of the devices in a substation in one project.

DIGSI 5 offers superior usability and is optimized for your work processes. Only the information you actually need to carry out your tasks is shown. These can be reduced further using expanded filter mechanisms. The consistent use of sophisticated, uniform mechanisms in the user interfaces requires less training.

Overview of functions

DIGSI 5 is tailored to specific requirements. The free software variant DIGSI 5 Compact provides everything that is required for a single device. For complex scenarios with multiple devices, the DIGSI 5 Standard version is suitable. DIGSI 5 Premium contains the full functionality you need to raise your productivity to a new level. The functionalities of the various DIGSI 5 variants are listed in Table 10.2 (page 69) “Overview of functions of the various DIGSI 5 variants”.

The available DVD contains all components in English. More languages will be added in the future. The delivered package includes USB cables for connecting directly to the PC, memory sticks with the licenses for installing the program, and a protection unit.

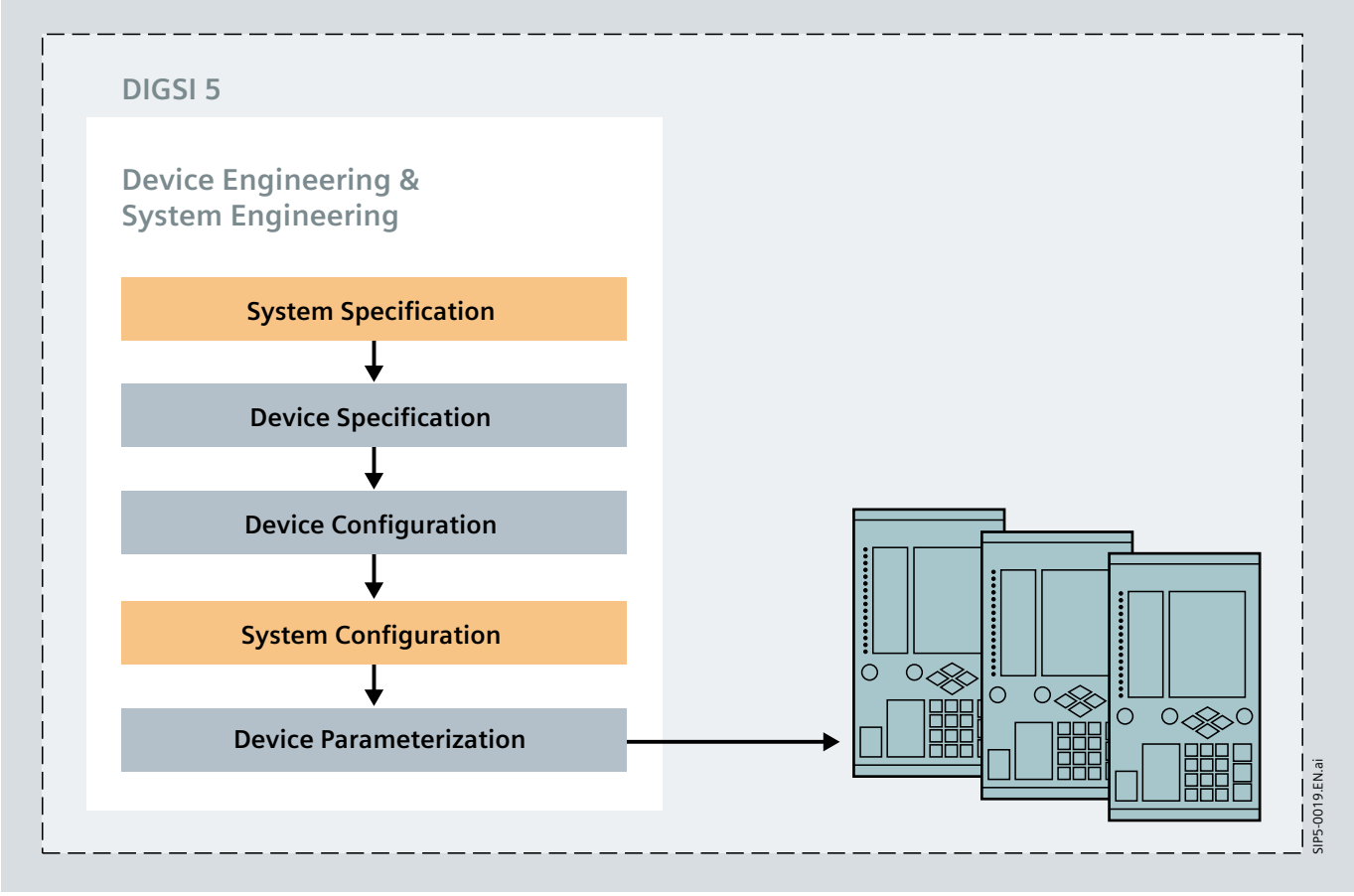

Fig. 10.1 Structure of the engineering process

Variants and system requirements

Hardware requirements

- Pentium 4 with 1.7 GHz processor or similar
- 2 GB available hard disk space
- 2 GB RAM (3 GB recommended)
- Graphic display with resolution of 1024×768 (1280×1024 recommended)
- DVD-ROM drive
- Keypad and mouse
- USB port

Software requirements

The following operating systems are supported:

- MS Windows XP Professional Edition (with Service-Packs 2 and 3)
- MS Windows 7 Home Premium
- MS Windows 7 Professional
- MS Windows 7 Enterprise
- MS Windows 7 Ultimate
- VM Ware Support for virtual machines running under one of the operating systems listed above

A complete list of supported operating systems is included in the product information for DIGSI 5. The delivered equipment contains device templates and an online manual, including service (download of updates via the internet, hotline).

Ordering data for DIGSI 5 variants

	DIGSI 5 Compact	DIGSI 5 Standard	DIGSI 5 Premium
Description	Software for configuration and use of individual SIPROTEC 5 protection devices manufactured by Siemens and reading out process data from SIPROTEC 5 devices (projects are limited to a single device).	As for DIGSI 5 Compact, but without constraint as to the number of SIPROTEC 5 devices supported per project, including system configurator for IEC 61850. The editors for function charts (CFC), graphic single line and device configuration are also included. SIGRA 4 for professional fault record analysis is available as an option.	As for DIGSI 5 Standard, but with integrated test and startup functionality, including the option to create test sequences and run them in the protection device without external test equipment. IEC 61850 also supports flexible engineering and functional naming.
Features	All features are listed in Table 10.2 “Overview of functions of DIGSI 5 variants”.	All features are listed in Table 10.2 “Overview of functions of DIGSI 5 variants”.	All features are listed in Table 10.2 “Overview of functions of DIGSI 5 variants”.
Authorization	No license key necessary	Authorization required using the license key on the USB stick; can be used on one computer per license.	Authorization required using the license key on the USB stick; can be used on one computer per license.
Available operating languages	German, English (selectable)	German, English (selectable)	German, English (selectable)
Included in the scope of delivery	• Program, device driver and online documentation on DVD-ROM • Product information (paper) • Includes a test license valid for 30 days, for free testing of DIGSI 5 Premium • USB cable for connecting a PC/laptop computer and all SIPROTEC 5 device types	• Program, device driver and online documentation on DVD-ROM • USB stick with the ordered number of licenses. The program can be used on one computer per license. • Includes a test license valid for 30 days for free testing of DIGSI 5 Premium • Product information (paper) • USB cable for connecting a PC/laptop computer and all SIPROTEC 5 device types	• Program, device driver and online documentation on DVD-ROM • USB stick with the ordered number of licenses. The program can be used on one computer per license. • Product information (paper) • USB cable for connecting a PC/laptop computer and all SIPROTEC 5 device types
Order no.	DIGSI-B1	DIGSI-C1000000A (1 license) DIGSI-C1000000B (5 licenses) DIGSI-C1000000C (10 licenses) For additional order numbers, for example for updates and upgrades, please refer to the order configurator.	DIGSI-D1000000A02 (1 license) DIGSI-D1000000B02 (5 licenses) DIGSI-D1000000C02 (10 licenses) For additional order numbers, for example for updates and upgrades, please refer to the order configurator.

Table 10.1 Ordering data for DIGSI 5 variants

Overview of functions for DIGSI 5 variants

	Compact	Standard	Premium
Project processing			
Maximum number of devices per project	1	unlimited	unlimited
Copy and paste complete	•	•	•
Multilingualism is supported	•	•	•
Single lines and device displays			
Single line editor with ANSI and IEC standard symbols available	—	•	•
Device display editor enables creation of user-defined displays and symbols	—	•	•
Setting parameters and routing			
Information allocations including filtering and sorting	•	•	•
Graphical visualization of protection parameters	—	•	•
Comparison of protection parameters for multiple parameter groups	—	•	•
Continuous function charts (CFC)			
Graphical function chart (CFC) editor included	—	•	•
Communication			
Assignment of communications to system interface	•	•	•
Assignment of communications to various protocols	•	•	•
Graphical network view of devices	—	•	•
Inter-device communication	—	•	•
IEC 61850			
IEC 61850 Edition 2 will be fully supported	—	•	•
IEC 61850 – Flexible engineering	—	—	•
Access and communication			
Via USB and Ethernet	•	•	•
Access to communication partners via system interface	•	•	•
Online			
Measured values (current values, minimum, maximum, average values) and storage in the project as snapshots	◦ only for 1 device	•	•
Messages (and storage in the project as snapshots)	◦ only for 1 device	•	•
Logs and records	◦ predefined only	•	•
Display fault records	• COMTRADE Viewer	• COMTRADE Viewer (SIGRA available as optional package)	• SIGRA
Loading settings for the selected device	• only for 1 device	• for all devices in the project	• for all devices in the project
Commissioning and testing			
Creating and running multistage test sequences, no external operating tools necessary	—	—	•
Test views for testing the device configuration	—	•	•
Offline function chart (CFC) analysis (debugging)	—	—	•

Table 10.2 Overview of functions for DIGSI 5 variants

Legend: • Feature available; ◦ Feature available but conditional, the constraint is described; — Feature not available

Variants and system requirements

Overview of functions for DIGSI 5 variants (continued)

	Compact	Standard	Premium
Export and import			
SCL formats (IEC 61850 formats)	—	• SCD, ICD, CID, SSD, IID, SED, MICS	• SCD, ICD, CID, SSD, IID, SED, MICS
Devices (full and partial)	•	•	•
Topology, settings, information allocations and communication assignments	•	•	•
Single lines/Topology	—	• WMF export only	•
Displays	—	•	•
Test object definition (XRIO)	•	•	•
Documentation			
Printing and exporting project documentation	—	◦ printing from the active editor only	• complete project documentation
Creation of user-defined print formats	•	•	•
Safeguarding and security			
Authorization of access to devices with NERC CIP-compatible password	•	•	•
Secure connection to the device	•	•	•
Configuration data protected from alteration	•	•	•
Confirmation codes for safeguarding critical activities (e.g. switching)	•	•	•

Table 10.2 Overview of functions for DIGSI 5 variants

Legend: • Feature available; ◦ Feature available but conditional, the constraint is described; — Feature not available

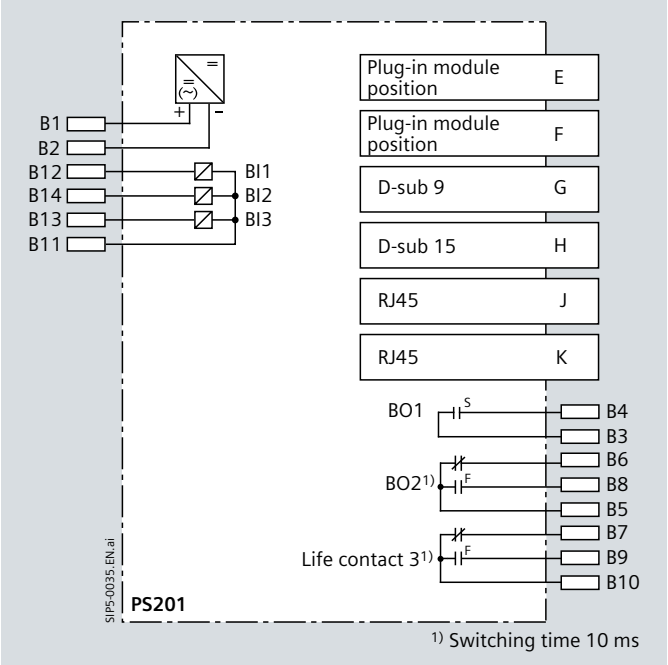

Fig. 11.1 Connection diagram for the PS201

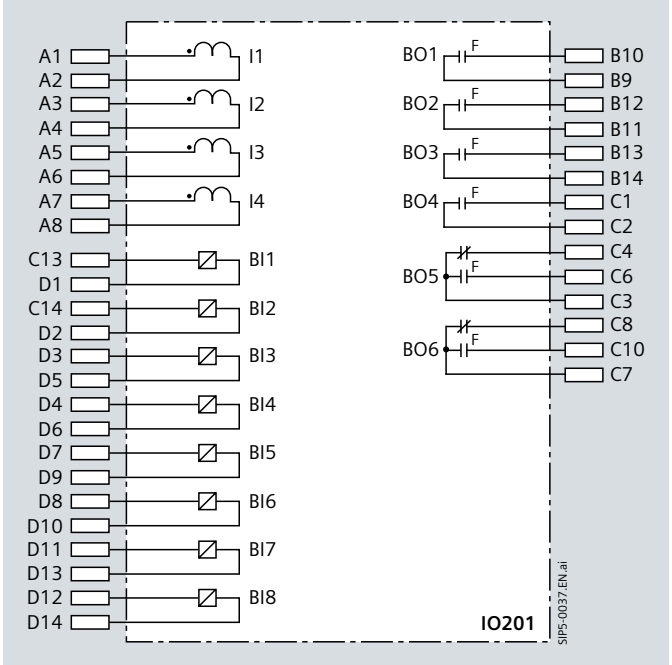

Fig. 11.3 Connection diagram IO201 (F: Fast relay)

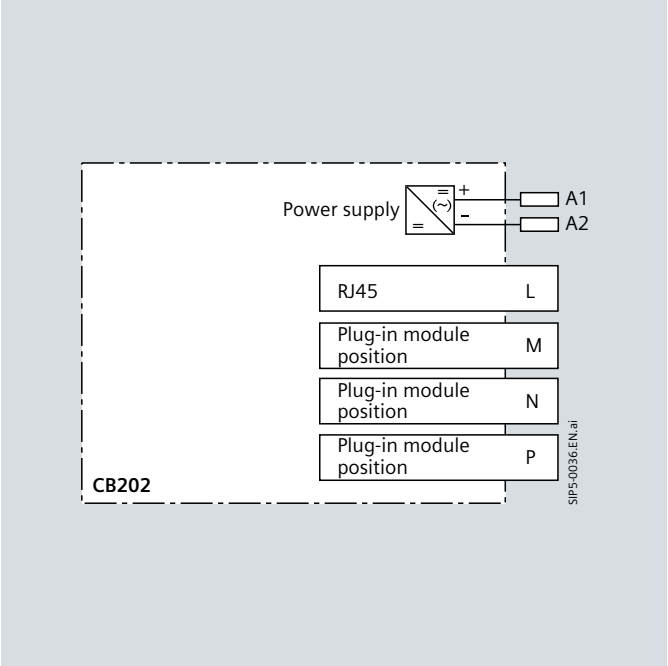

Fig. 11.2 Connection diagram for the CB202

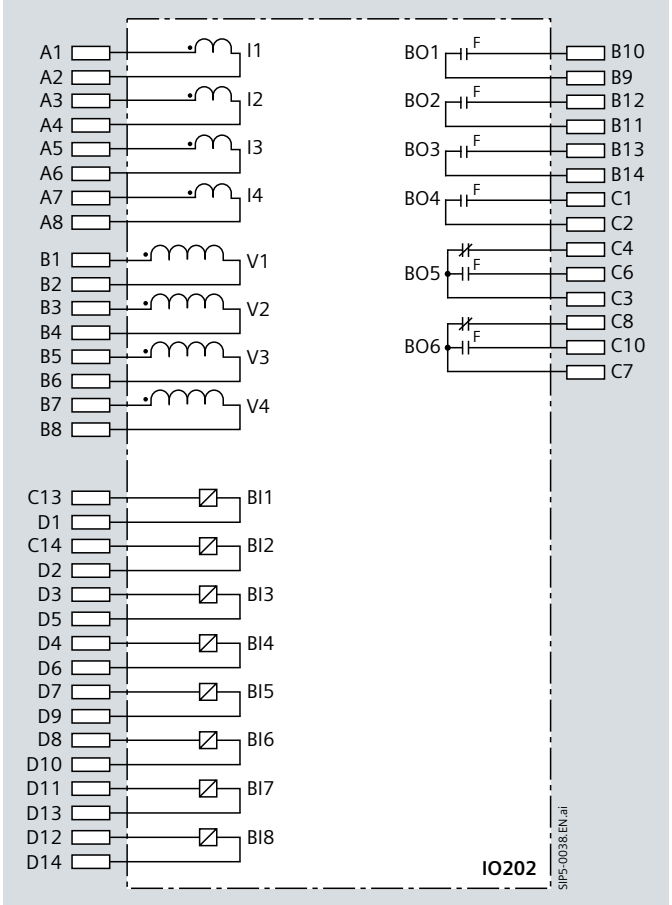

Fig. 11.4 Connection diagram for the IO202 (F: Fast relay)

Connection Variants

Connection diagrams

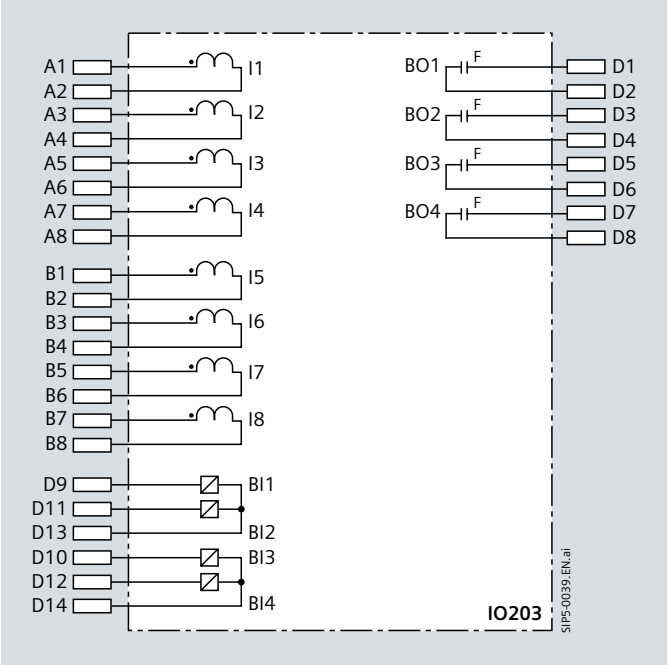

Fig. 11.5 Connection diagram for the IO203 (F: Fast relay)

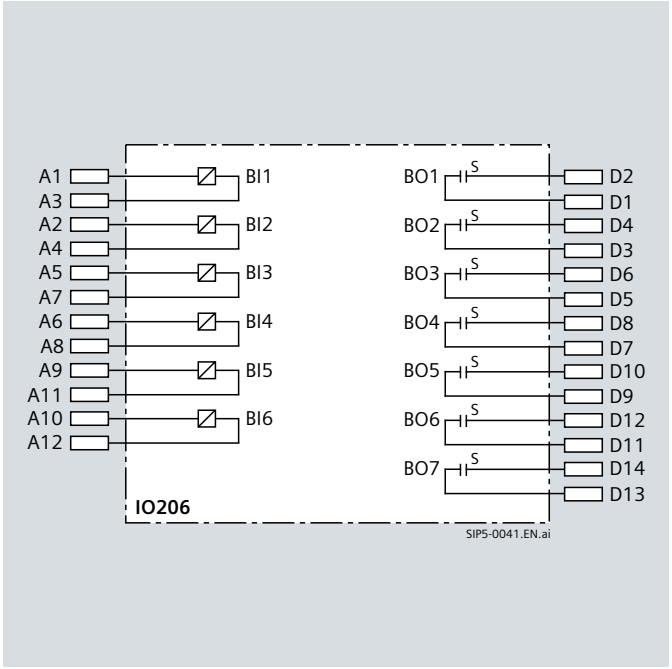

Fig. 11.7 Connection diagram for the IO206 (S: Standard relay)

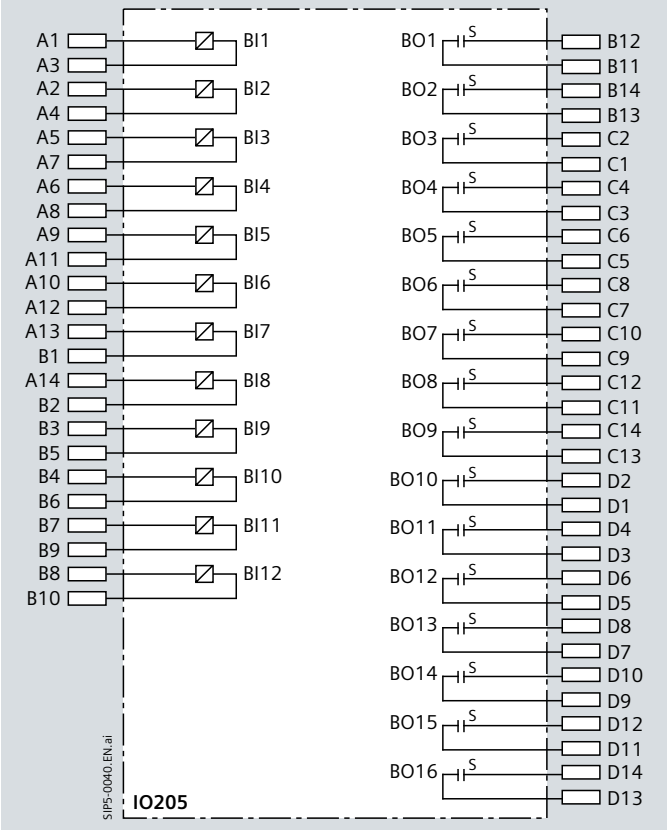

Fig. 11.6 Connection diagram for the IO205 (S: Standard relay)

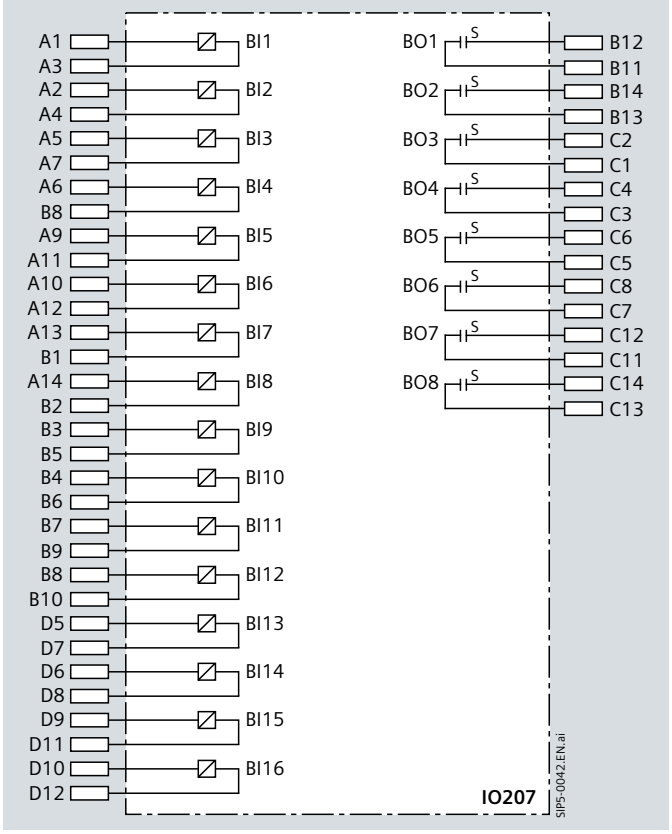

Fig. 11.8 Connection diagram for the IO207 (S: Standard relay)

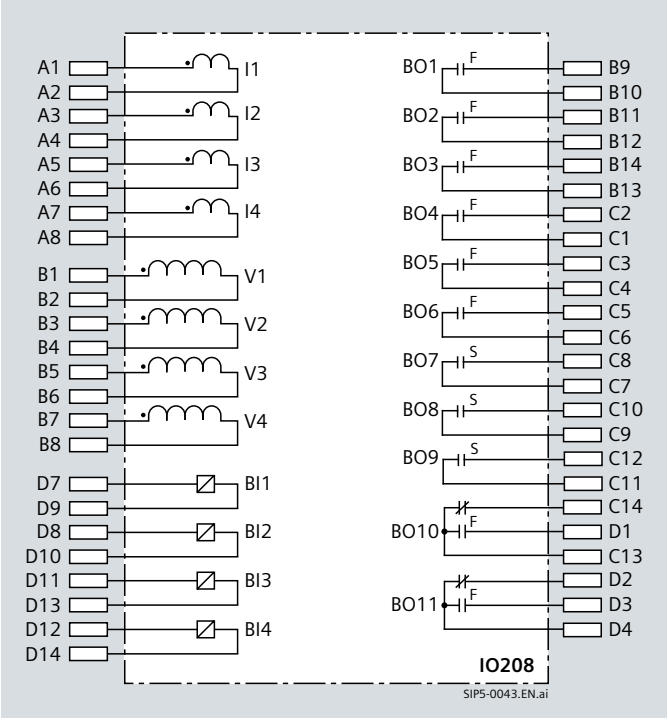

Fig. 11.9 Connection diagram IO208 (F: Fast relay, S: Standard relay)

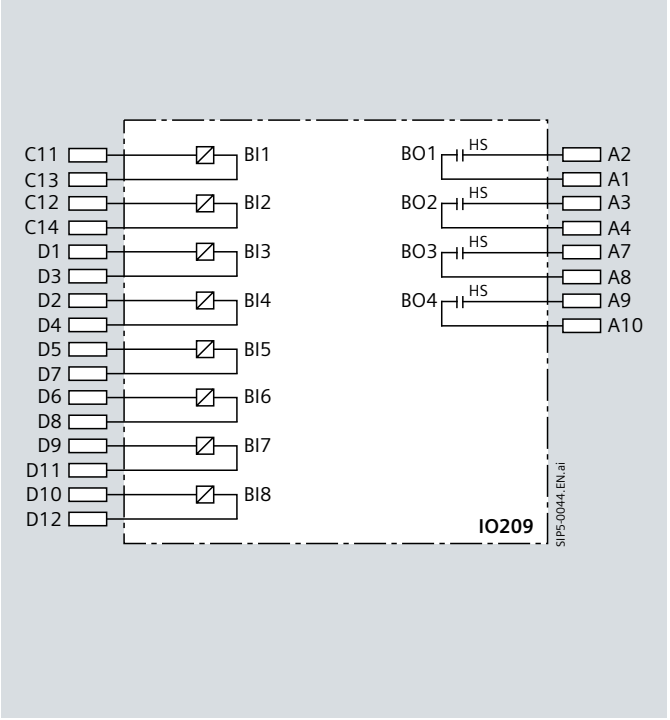

Fig. 11.11 Connection diagram IO209 (HS: High-speed relay)

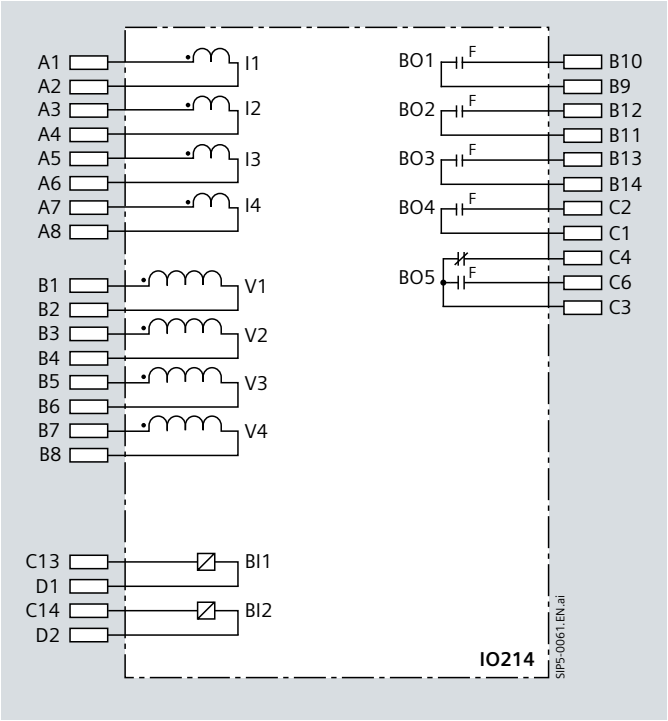

Fig. 11.10 Connection diagram IO214 (F: Fast relay)

Connection Variants

Grouping measured values

Grouping of base measured values

Measured value	Description
Operational measured values	Calculation of RMS and output according to definition Phase current I_{L1}, I_{L2}, I_{L3} Ground current I_N, I_{NS} (sensitive) Phase-to-ground voltages V_{L1}, V_{L2}, V_{L3} Phase-to-phase voltages V_{12}, V_{23}, V_{31} Residual voltage V_{NE} Frequency f P, Q, S (three-phase, phase-specific) Power factor λ
Fundamental and symmetrical components	Calculation of λ phasor variables with Fourier filter or according to transformation rule Phase currents $\underline{I}_{L1}$, $\underline{I}_{L2}$, $\underline{I}_{L3}$ Ground current $\underline{I}_N$, $\underline{I}_{NS}$ (sensitive) Phase-to-ground voltages $\underline{V}_{L1}$, $\underline{V}_{L2}$, $\underline{V}_{L3}$ Phase-to-phase voltages $\underline{V}_{12}$, $\underline{V}_{23}$, $\underline{V}_{31}$ Residual voltage $\underline{V}_{NE}$ Symmetrical components $\underline{I}_0$, $\underline{I}_1$, $\underline{I}_2$, $\underline{V}_0$, $\underline{V}_1$, $\underline{V}_2$
Protection-specific measured values	Measured values that are especially calculated for individual protection functions such as Distance protection (reactances and resistances of phase loops) Differential protection (differential and restraint current, charge currents per phase) ...
Energy values	Metered values are determined for active and reactive energy. Restore time, restore interval and counting mode are adjustable. Restoring can also be initiated via a binary input. The following metered values are available: Active energy W_{p+} (release), W_{p-} (uptake) Reactive energy W_{q+} (release), W_{q-} (uptake)
Statistical values	The following statistical values are formed: Total number of times the circuit breaker was triggered Number of times the circuit breaker was tripped, broken down by circuit breaker pole Total sum of primary breaking currents Sum of primary breaking currents, separately for each breaker pole

Grouping of measured values

Mean values	Mean values can be calculated on the basis of the operational measured values and the symmetrical components. The time slot for mean value generation and the output interval are parameterizable.
Minimum values and maximum values	The minimum/maximum values can be generated on the basis of operational measured values, symmetrical components and selected measured values (e.g., from average values). The display of minimum and maximum values contains the time of their occurrence. The calculation is stabilized against smaller value fluctuations in currents and voltages.

The following spare parts can be ordered for the SIPROTEC 5 module.
Selection is made in plain text in the SIPROTEC configurator.

Overview of spare parts

Designation	Comments
Voltage terminal, 14-pole	8 units in the bag
Voltage terminal, 2-pole	For connecting the power supply to the CB202; 2 units in the bag
Current terminal 4 × I protection	1 unit
Current terminal 3 × I protection, 1 × I sensitive	1 unit
Current terminal 4 × I measurement	1 unit
2-pole current terminal cross connector	For direct external connection of terminal points. 3 units in the bag.
2-pole voltage terminal cross connector	For direct external connection of terminal points. 6 units in the bag.
Current terminal cover	Cover for a removed terminal on the device side. 1 unit in the bag.
Cover for voltage terminal	Cover for a removed terminal on the device side. 8 units in the bag.
Cable set for operation panel of the surface mounting housing	1 unit. Is needed when extending a surface-mounting device that consists of only a base module before extension.
Cable set COM-link cable	1 unit. For connecting the CB202 to the base module (included with all CB202 modules)
Module cover panel	1 unit incl. screw. For covering unused module slots
LED/keypad labeling strips	Delivery unit: 1 sheet, contains 8 strips for LED labels and 6 strips for function key labels
Mounting bracket 1/2	1 set, consisting of 2 mounting brackets for top and bottom. Is needed if a surface-mounting device is to be expanded for the 1/2 19 inch wide device.
Mounting bracket 2/3	1 set, consisting of 2 mounting brackets for top and bottom. Is needed if a surface-mounting device is to be expanded for the 2/3 19 inch wide device.
Mounting bracket 5/6	1 set, consisting of 2 mounting brackets for top and bottom. Is needed if a surface-mounting device is to be expanded for the 5/6 19 inch wide device.
Mounting bracket 1/1	1 set, consisting of 2 mounting brackets for top and bottom. Is needed if a surface-mounting device is to be expanded for the 1/1 19 inch wide device.

Summary overview

Supply voltage

Integrated power supply

The following modules contain a power supply:

PS201 – Power supply of the base module and of the 1st device row

CB202 – Plug-in module assembly with integrated power supply, for example to accommodate communication modules

Auxiliary rated voltage V_H	DC 24 V / DC 48 V	DC 60 V / DC 110 V / DC 125 V / DC 220 V / DC 250 V or AC 115 V / AC 230 V, 50 Hz / 60 Hz
Permissible voltage ranges	DC 19 V to 60 V	DC 48 V to 300 V 80 V to 265 V
Overvoltage category, IEC 60255-27		III
Ripple voltage peak-peak, IEC 60255-11	≤ 15 % of the DC auxiliary rated voltage (applies only to direct voltage)	
Inrush current		≤ 18 A
Recommended external protection		Miniature circuit breaker 6 A, Characteristic C in accordance with IEC 60898
Internal fuse		2 A time-lag, AC 250 V, DC 300 V, UL recognized SIBA type 179200 or Schurter type SPT 5x20

Power consumption (life relay active)

	DC	AC 230 V / 50 Hz	AC 115 V / 50 Hz
1/3 base module without plug-in modules	13 W	33 VA	24 VA
1/6 expansion module	3 W	6 VA	6 VA
1/6 plug-in module assembly without plug-in modules	3.5 W	14 VA	7 VA
Plug-in module for base module or plug-in module assembly (e.g., communication module)	< 5 W	< 6 VA	< 6 VA
Stored-energy time on outage or short circuit of the auxiliary voltage	At least 60 ms		

Current inputs

Rated frequency 50 Hz / 60 Hz

All current, voltage and power data is specified as RMS value.

	Rated current I_{rated}	Measuring range (device-independent)
Protection-class current transformer Rated current measuring range adjustable with DIGSI	5 A	500 A
	5 A	100 A
	1 A	100 A
	1 A	20 A
Instrument transformers (sensitive ground current transformer) Rated current measuring range adjustable with DIGSI	5 A	8 A
	1 A	1.6 A
Consumption per current circuit at rated current	Approx. 0.1 VA	
Thermal rating (protection and measuring current transformer)	500 A for 1 s	
	150 A for 10 s	
	20 A continuously 25 A for 3 min 30 A for 2 min	
Dynamic load carrying capacity	1250 A one half wave	

Voltage inputs

Rated frequency 50 Hz / 60 Hz

All current, voltage and power data is specified as RMS value.

Measuring range	200 V
Input impedance	200 kΩ
Thermal rating	230 V continuously

MT ANAI-CA-4EL module

Connector type	8-pole terminal multiple contact strip
Differential current input channels	4
Measuring range	DC ± 24 mA
Error limit	0.5 % of measuring range
Input impedance	140 Ω
Conversion principle	Delta-sigma (16 bit)
Permissible potential difference between channels	DC 20 V
Galvanic separation to ground/housing	AC 500 V, DC 700 V
Permissible overload	DC 100 mA continuously
Measurement repetition	200 ms

Binary inputs

Rated voltage range	DC 24 V to 250 V (bipolar)
Current consumption, excited	Approx. DC 0.4 mA (independently of the operating voltage)
Pickup time	Approx. 3 ms
Dropout time	Approx. 4 ms
Switching thresholds	(adjustable with DIGSI)
Range 1 for 24 V and 48 V operating voltage	$V\ DC_{low} \leq 10$ V $V\ DC_{high} \geq 19$ V
Range 2 for 60 V, 110 V and 125 V operating voltage	$V\ DC_{low} \leq 44$ V $V\ DC_{high} \geq 88$ V
Range 3 for 220 V and 250 V operating voltage	$V\ DC_{low} \leq 88$ V $V\ DC_{high} \geq 176$ V
Max. permissible voltage	DC 300 V

Relay outputs

There are five different relay types available. To learn which assembly is equipped with which relay types, please refer to the description of assemblies on page 31.

Standard relay (normal speed)

Switching capacity	On: 1000 W/VA Off: 30 VA; 40 W ohmic; 25 W/VA at L/R ≤ 40 ms
AC and DC contact voltage	250 V
Permissible current per contact (continuous)	5 A
Permissible current per contact (switching on and holding)	30 A for 1 s (make contact)
Short-time current across closed contact	250 A for 30 ms
Total permissible current for contacts connected to common potential	5 A
Switching time	≤ 10 ms
Rated data of the output contacts	DC 24 V, 8 A, general purpose DC 48 V, 0.8 A, general purpose DC 240 V, 0.1 A, general purpose AC 240 V, 5 A, general purpose AC 120 V, 248.7 W AC 250 V, 373 W B300 R300
Interference suppression capacitor across the contacts	4.7 nF, ± 20 %, AC 250 V

Fast relay (type F)

Switching capacity	On: 1000 W/VA Off: 30 VA; 40 W ohmic; 25 W/VA at L/R ≤ 40 ms
AC and DC contact voltage	250 V
Permissible current per contact (continuous)	5 A
Permissible current per contact (switching on and holding)	30 A for 1 s (make contact)
Short-time current across closed contact	250 A for 30 ms
Total permissible current for contacts connected to common potential	5 A
Switching time	≤ 5 ms
Rated data of the output contacts	AC 120 V, 8.5 A, general purpose AC 277 V, 6 A, general purpose AC 277 V, 522.2 W AC 347 V, 4.5 A, general purpose B300 R300
Interference suppression capacitor across the contacts	4.7 nF, ± 20 %, AC 250 V

High-speed relay with semiconductor acceleration (type HS)

Switching capacity	On / Off: 1000 W/VA
Contact voltage	AC 200 V, DC 250 V
Permissible current per contact (continuous)	5 A
Permissible current per contact (switching on and holding)	30 A for 1 s (make contact)
Short-time current across closed contact	250 A for 30 ms
Total permissible current for contacts connected to common potential	5 A
Switching time	≤ 1 ms
Rated data of the output contacts	B150 Q300

Light-emitting diodes

Base module: 1 × red (error) 1 × green (run) 16 × 2-color (red/green; routable) definable with DIGSI 5 Only the defined color can be used in operation.
Expansion module: Available optionally with or without 16 × red LEDs (routable)

Technical Data

Summary overview

Reference conditions

Measurand current I	I_{rated} ± 1 %
Measurand voltage V	V_{rated} ± 1%
Frequency f	f_{rated} ± 1%
Sine waveform, total harmonic distortion	≤ 5 %
Ambient temperature T_V	23 °C ± 1 °C
Auxiliary voltage V_H	V_{Hrated} ± 1%
Warm-up time	≥ 15 min
External fields/external influences	None

Influencing quantity on pickup and dropout thresholds

Auxiliary voltage 0.8 V_{HN} to 1.2 V_{HN}	≤ 0.2 %
Ambient temperature –10 °C to +55 °C	≤ 0.5 % / 10 K
Frequency 45 Hz to 65 Hz	≤ 1 %
Harmonics • Up to 10 % of 3rd harmonic • Up to 10 % of 5th harmonic	 ≤ 1 % ≤ 1 %
Warm-up	≤ 0.3 %
Transient excess pickup in fundamental component measurement method for τ > 100 ms (with complete asymmetry)	≤ 5 %
EMC interference	≤ 5 %

Approvals

Base module	IND. CONT. EQ. 69CA
Expansion module	IND. CONT. EQ. 69CA

Dimensions and weights

Base module

Type of construction	Width x height x depth in mm (inch)	Weight
Flush-mounting device	145 × 268 × 228.5 (5.71 x 10.55 x 9)	5.0 kg
Surface-mounting device with integrated front operation	145 × 314 × 337 (5.71 x 12.36 x 13.27)	8.4 kg
Surface-mounting device with detached front operation	145 × 314 × 230 (5.71 x 12.36 x 9.06)	7.8 kg

Expansion module

Type of construction	Width x height x depth in mm (inch)	Weight
Flush-mounting device	75 x 268 x 228.5 (2.95 x 10.55 x 9)	3.3 kg
Surface-mounting device with integrated front operation	75 x 314 x 337 (2.95 x 12.36 x 13.27)	4.9 kg
Surface-mounting device with detached front operation	75 x 314 x 230 (2.95 x 12.36 x 9.06)	3.8 kg (without on-site operation)

Complete units

Dimensions

Type of construction	Device size (Width x height x depth in mm (inch))				
	1/3	1/2	2/3	5/6	1/1
Flush-mounting device	145 × 268 × 228.5 (5.71 x 10.55 x 9)	220 × 268 × 228.5 (8.66 x 10.55 x 9)	295 × 268 × 228.5 (11.61 x 10.55 x 9)	370 × 268 × 228.5 (14.57 x 10.55 x 9)	445 × 268 × 228.5 (17.52 x 10.55 x 9)
Surface-mounting device with integrated on-site operation panel	145 × 314 × 337 (5.71 x 12.36 x 13.27)	220 × 314 × 337 (8.66 x 12.36 x 13.27)	295 × 314 × 337 (11.61 x 12.36 x 13.27)	370 × 314 × 337 (14.57 x 12.36 x 13.27)	445 × 314 × 337 (17.52 x 12.36 x 13.27)
Surface-mounting device with detached on-site operation panel	145 × 314 × 230 (5.71 x 12.36 x 9.06)	220 × 314 × 230 (8.66 x 12.36 x 9.06)	295 × 314 × 230 (11.61 x 12.36 x 9.06)	370 × 314 × 230 (14.57 x 12.36 x 9.06)	445 × 314 × 230 (17.52 x 12.36 x 9.06)

Weights

Type of construction	Device size				
	1/3	1/2	2/3	5/6	1/1
Flush-mounting device	4.8 kg	8.1 kg	11.4 kg	14.7 kg	18.0 kg
Surface-mounting device with integrated front operation	7.8 kg	12.6 kg	17.4 kg	22.2 kg	27.0 kg
Surface-mounting device with detached front operation	5.1 kg	8.7 kg	12.3 kg	15.9 kg	19.5 kg

	Size	Weight
Detached on-site operation panel	1/3	1.9 kg
Detached on-site operation panel	1/6	1.1 kg

Degree of protection according to IEC 60529

For the equipment in the surface-mounting housing	IP50
For the equipment in the flush-mounting housing	Front IP51 Rear panel IP50
For operator protection	IP2X for current terminals IP1X for voltage terminals
Degree of pollution, IEC 60255-27	2

Tests and standards

Electrical tests

Standards	IEC 60255 (product standards)
	IEEE Std C37.90
	UL 508
	VDE 0435
	Further standards are listed for the individual tests.

Insulation test

Standards	IEC 60255-27 and IEC 60870-2-1
Voltage testing (component testing), current measurement inputs, voltage measurement inputs, relay outputs	AC 2.5 kV 50 Hz
Voltage testing (component testing), auxiliary voltage, binary inputs	DC 3.5 kV
Voltage testing (component testing), only isolated communication and time synchronization interfaces and analog inputs (module positions E, F, M, N, and P)	AC 500 V / 50 Hz or DC 700 V
Impulse voltage testing (type testing), all circuits except communication and time synchronization interfaces and analog inputs, class III	5 kV (peak value) 1.2 µs/50 µs 0.5 J 3 positive and 3 negative impulses at intervals of 1 s

EMC interference immunity tests (type tests)

Standards	IEC 60255-6, IEC 60255-22 and IEC 60255-26 (product standards) EN 61000-6-2 (generic standard) VDE 0435
High-frequency test IEC 60255-22-1, class III	2.5 kV (peak value) 1 MHz τ = 15 µs 400 impulses/s Test duration 2 s R_i = 200 Ω
Discharging static electricity IEC 60255-22-2, class IV IEC 61000-4-2, class IV	8 kV contact discharge 15 kV air discharge Both polarities 150 pF R_i = 330 Ω
Irradiation with high-frequency field Frequency sweep IEC 60255-22-3, class III IEC 61000-4-3, class III	10 V/m 80 MHz to 1 GHz and 1.4 GHz to 2.7 GHz 80 % AM 1 kHz
Irradiation with high-frequency field Single frequencies IEC 60255-22-3 IEC 61000-4-3, class III	10 V/m 80 MHz/160 MHz/380 MHz/ 450 MHz/900 MHz/ 1.85 GHz/2.15 GHZ 80 % AM 1 kHz Operational time > 10 s

EMC interference immunity tests (type tests)

Fast transient disturbance variables/bursts IEC 60255-22-4, class A IEC 61000-4-4, class IV	4 kV 5 ns/50 ns 5 kHz Burst length 15 ms Repetition rate 300 ms Both polarities R_i = 50 Ω Test duration 60 s	
High-energy surge voltages/ surge installation, class III IEC 60255-22-5, IEC 61000-4-5	Pulse: 1.2 µs/50 µs	
	Auxiliary voltage	Common mode: 4 kV 12 Ω 9 µF Differential mode: 1 kV 2 Ω 18 µF
	Measurement inputs, binary inputs and relay outputs (no differential mode testing)	Common mode: 4 kV 42 Ω 0.5 µF Differential mode: 1 kV 42 Ω 0.5 µF Or varistor
Line-borne HF, amplitude-modulated, class III IEC 60255-22-6, IEC 61000-4-6		10 V, 150 kHz to 80 MHz, 80% AM, 1 kHz
Magnetic field with power engineering frequency	IEC 60255-6 0.5 mT	IEC 61000-4-8, Class IV 30 A/m (continuous) 300 A/m for 3 s
Oscillatory surge withstand capability IEEE Std C37.90.1	2.5 kV (peak value) 1 MHz τ = 15 µs 400 impulses per s Test duration 2 s R_i = 200 Ω Common mode and differential mode testing	
Fast transient surge withstand capability IEEE Std C37.90.1	4 kV 5 ns/50 ns 5 kHz Burst length 15 ms Repetition rate 300 ms Both polarities R_i = 50 Ω Test duration 60 s Common mode and differential mode testing	
Radiated electromagnetic interference IEEE Std C37.90.2	20 V/m 80 MHz to 1 GHz 80 % AM 1 kHz	
Attenuated oscillations IEC 61000-4-18	100 kHz, 1 MHz, 2.5 kV (peak value) 3 MHz, 10 MHz, 30 MHz, 2 kV (peak value)	

Summary overview

EMC emitted interference tests (type tests)

Standards	IEC 60255-25 (product standard) EN 61000-6 (generic standard)
Disturbance voltage on lines, only auxiliary voltage and telecommunication lines IEC-CISPR 11	150 kHz to 30 MHz limit class A
Disturbance-field strength IEC-CISPR 11	30 MHz to 1 GHz limit class A
Harmonic currents on the mains supply line at DC 230 V IEC 61000-3-2	The device must be allocated to class D (only applies for devices with > 50 VA power consumption).
Voltage fluctuations and flicker on the mains supply line at DC 230 V IEC 61000-3-3	Limits are complied with

Mechanical tests

Vibration and shock stress in stationary use

Standards	IEC 60255-21 and IEC 60068
Oscillation IEC 60255-21-1, class II and IEC 60068-2-6	Sinusoidal 10 Hz to 60 Hz: ±0.075 mm amplitude 60 Hz to 150 Hz; 10 m/s^2 acceleration Frequency sweep 1 octave/min 20 cycles in 3 axes perpendicular to one another
Shock IEC 60255-21-2, class I	Semi-sinusoidal Acceleration 50 m/s^2 Duration 11 ms 3 shocks each in both directions of the 3 axes
Oscillation in an earthquake IEC 60255-21-3, class II and IEC 60068-3-3	Sinusoidal 1 Hz to 35 Hz Vertical axis: frequency sweep 1 octave/min 1 cycle in 3 axes perpendicular to one another 1 Hz to 8 Hz: ±7.5 mm amplitude (horizontal axes) 1 Hz to 8 Hz: ±3.5 mm amplitude (vertical axis) 8 Hz to 35 Hz: 20 m/s^2 acceleration (horizontal axes) 8 Hz to 35 Hz: 10 m/s^2 acceleration (vertical axis)

Vibration and shock stress during transport

Standards	IEC 60255-21 and IEC 60068
Oscillation IEC 60255-21-1, class II and IEC 60068-2-6	Sinusoidal 5 Hz to 8 Hz: ±7.5 mm amplitude 8 Hz to 150 Hz: 2 m/s^2 acceleration Frequency sweep 1 octave/min 20 cycles in 3 axes perpendicular to one another
Shock IEC 60255-21-2, class I and IEC 60068-2-27	Semi-sinusoidal Acceleration 150 m/s^2 Duration 11 ms 3 shocks each in both directions of the 3 axes
Continuous shock IEC 60255-21-2, class I and IEC 60068-2-29	Semi-sinusoidal Acceleration 100 m/s^2 Duration 16 ms 1000 shocks each in both directions of the 3 axes

Climatic stresses

Temperatures

Type testing (according to IEC 60068-2-1 and IEC 60068-2-2, test Bd for 16 h)	–25 °C to +85 °C / –13 °F to +185 °F
Permissible for short periods during operation (tested for 96 h)	–20 °C to +70 °C / –4 °F to +185 °F Readability of the display may be impaired below –10 °C and above +55 °C / +14 °F to +131 °F
Recommended for uninterrupted duty (in compliance with IEC 60255-6)	–10 °C to +55 °C / +14 °F to +131 °F
Limit temperatures for continuous storage	–25 °C to +55 °C / –13 °F to +131 °F
Limit temperatures for transport	–25 °C to +70 °C / –13 °F to +158 °F

Humidity

Permissible humidity stress	≤75 % relative humidity on the annual mean Up to 93 % relative humidity on 56 days a year air humidity.
	Devices suffering from condensation are not capable of operating! Arrange the devices so that they are not exposed to direct sunlight or extreme temperature changes. This will prevent condensation in the devices.

Use

Up to 2000 m above sea level

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.

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