Electrical integration in the power and water industries

A consistent system that helps saving time and costs and provides for effective risk management.

A future oriented control system for the power and water industries must be able to cover more tasks than just the usual automation and optimization of plant processes. In the power generation and water industries, as well as in other process industries that are characterized by a high utilization of resources, there is a growing demand for more cost efficiency, environmental compatibility and more flexible plant operation. A traditional process control system is capable of achieving these objectives only to a limited extent, if at all. In addition, process control systems increasingly serve as a central and integral platform for additional applications used at a business and enterprise level (for maintenance management, online trading systems, energy management, balancing, etc).

In order to support and implement more efficient operation and maintenance processes, a process control system needs to have access to a larger volume of information, including relevant information from the electrical installations that supply the process with power. In particular, the integration of electrical systems needs to be improved as compared to the state-of-the-art implemented in former plant configurations. As fewer and fewer personnel are available for operation and maintenance tasks, the need for integrated process control systems that include both the process and the electrical installations has become evident. Control room operators wish to have a single user interface, consistent user guidance and common database management available for their operating and monitoring and diagnosis and plant management activities that concern the entire plant.

However, process and substation automation systems cannot easily communicate with each other. Up to now, making the data obtained from the electrical installations available to the process control system has been difficult and rather costly.

Traditional process control and substation control systems have evolved from different historical backgrounds because of their different technical tasks: high input of work is necessary to make them compatible and suitable for integration. Historically, the data needed from electrical installations was communicated to both systems via parallel cabling.

In some industries, where the life cycles of plants are especially long (eg, more than 40 years), it is also necessary to adapt the operational and management activities to currently ongoing processes, ie, the process control system must be able to be adaptable to current demands.

With the growing number and complexity of the tasks to be handled by a process control system, the volume of information needed from the process and electrical systems has increased so much that the use of traditional communications is no longer practical due to the high costs of design, operation, and maintenance. An up-to-date and future-proof process control system concept therefore needs to provide an IT solution that effectively links process control and substation control functions to bridge the gap between the two technologies. The use of open interfaces and standards is required.

On the one hand, certain technical prerequisites need to be fulfilled in order to physically implement such an integrated system. The huge volume of information, on the other hand, calls for a processing and use of the data oriented to create added value for the company. To achieve this goal, the process control system must be a high-performance system that offers the appropriate technologies, methods and tools.

The system supplier must have comprehensive expertise in industrial and power supply processes in order to be able to implement applications that will improve these processes.

To reach higher levels of operator efficiency, availability, operational reliability and cost efficiency, the integration of the process and substation automation systems is required. With these formerly autonomous systems linked, increased functionality and a higher quality level is achieved.

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Electrical integration in power and water industries

In this context, a typical industrial or utility process can be divided into three major areas: process control, process electrification, and power distribution and management.
- The process control equipment includes instrumentation, safety systems, and controllers. The devices communicate via fieldbus protocols
- Process electrification includes low-voltage actuators, motors, substations and circuit breakers. These devices typically communicate with the process control system via PROFIBUS and Modbus
- Power distribution and management systems communicate with the substation automation system, which includes medium and high-voltage systems, along with the associated protective relays (intelligent electronic devices - IEDs), transformers, converters, and meters

Benefits of electrical integration
Electrical integration allows industrial and utility processes to be run at a higher level of availability and energy efficiency, and provides for a reduction of operational and investment costs. This is achieved through:
- Fewer control systems in the plant
- A smaller number and variety of the operational equipment as well as simplified spare parts supply and maintenance tasks
- Less training required
- Shorter engineering, installation and commissioning periods thanks to less complexity
- Optimized life cycle costs thanks to a future-proof system based on open standards and interoperability
- Reduced project risk thanks to the possibility of working with integrated project teams
- Lower energy costs thanks to effective energy management, (eg, by optimizing the purchase and generation of electricity)

Electrical integration enables and promotes cross-unit collaboration and effective asset management for the electrical subsystems. Integrated process and power automation increases the level of productivity and reduces downtime through:
- Comprehensive visualization of the production processes
- Maximized production results and quality

In the past, implementing an integrated process and substation automation system was complicated by the fact that not enough open and internationally accepted standards were available. Organizational barriers in operations often made integration even more difficult. A modern process control system using open standards, such as fieldbuses and IEC 61850, helps in improving integration while reducing operation obstacles.

Electrical integration in the process and utility industries
Three typical areas in the process industries that are relevant in this context – instrumentation (sensors, actuators), electrification of the process, and power generation and distribution – were often traditionally operated using autonomous and equipment-specific communication protocols.

Today, future-oriented process control system concepts provide for seamless integration into one common system environment. All information is archived in a common database and can be made available to any of the areas involved. The entire plant is covered by one process control system and can be used efficiently by all trained personnel.

Different objectives for the power system
The process industries have varying objectives that can be achieved through electrical integration, but can hardly be attained without it.

In the power generation business, optimizing the use of generation capacity and assuring power supply reliability are major objectives. These factors are gaining even more importance in the light of an increasing share of renewable energy that calls for more flexible plant operation.

Often potential opportunities for cost cutting and quality enhancement are not realized because of a lack of adequate visualization and means of evaluation.

Regardless of this, all industries are looking for ways to cut costs in the areas of installation, planning and future reliability during the entire lifetime of their systems. The answer to all these demands is integration.

1 Wind farm synoptic

Moreover, starting from the successful contribution of the IEC 61850 standard to substation automation, the extension of the standard to different power plant types (coal fired, combined cycle, waste-to-energy, hydro, etc.) promises to open significant new perspectives, providing the unification of the vision of any power plant as an assembly of basic, universally accepted and well-known functional abstract components.

A system architecture that increases the efficiency of plant engineering and operation

As stated, the high costs associated with traditional integration methods have restricted the amount of data passed between the two systems.

With the introduction of intelligent electronic devices (IEDs), more information is available in electrical systems and results in cost efficient operation and maintenance. Initially, serial interfaces were used in substation automation systems in order to enable direct access to all equipment information. Since traditional control systems did not directly support such serial interfaces, a separate substation control system was often installed for the purpose of controlling and monitoring the electrical systems.

Optimized and cost-efficient use of the power plant requires information from the entire plant. Not all of this information can be provided by serial communications. In order to avoid duplicate inputs and to assure a consistent design, a common data basis is the best solution. Electrical integration based on open standards such as IEC 61850 is required.

The traditional structure of a power plant automation system is divided into three distinct areas:
- Instrumentation, which uses optional fieldbuses
- Low-voltage systems, which are linked to the process control system via PROFIBUS, Profinet and Modbus
- High and medium-voltage equipment, which is connected to a separate process control system via the IEC 61850 protocol

Except for some data that is communicated to the process control system via local I/Os, the substation control system and the process control system are completely separate. In this arrangement, engineering effort and cabling costs make the task of increasing the amount of data volume a very expensive proposition. There is no common database management and, consequently, linking the information from both systems for the purpose of quality evaluation, is rather difficult. For example, it could be very time consuming to identify the root cause of a malfunctioning process unit if the actual disturbance is located in the electrical installation.

Typically, the workstations of both systems are located in separate control rooms. It is, therefore, difficult to trace a process disturbance back to a root cause that is located in the power supply installation.

The standards in use in distribution control/electrical control systems and in substation automation are very different. The fieldbus standards PROFIBUS and Foundation Fieldbus are established standards in process automation. Due to the varying substation automation requirements, different serial protocols are in use in electrical systems. These include IEC 60870-5-101, IEC 60870-5-104, DNP3.0, Modbus RTU, LON, and other manufacturer-specific protocols.

When both areas are to be integrated, many protocol standards require support. Due to the large number of standards and their incompatibility, the interfaces need to be implemented on a project-specific or equipment-specific basis. Gateways or protocol converters have an increasing effect on the cost of hardware, maintenance and engineering, since these devices need to be configured, tested and documented.

In addition to a number of other disadvantages, a major challenge is the fact that data exchange between each engineering tool is complex.

A large step forward in terms of simplifying the integration of electrical systems has been taken with the introduction of the IEC 61850 standard.

The relevance of the IEC 61850 standard for electrical integration

An optimal solution for integrating the process control and substation control systems into a single system can be implemented using the IEC 61850 standard. Although IEC 61850 was developed to enable communication between all substation functions, it is far more than a communication protocol. Its chief benefit is interoperability: protection and control devices from one or several manufacturers can exchange information with each other and utilize the data for their own functions. The IEC 61850 standard supports all substation communication requirements, both horizontally and vertically.

An object-oriented data model serves as a basis for control system integration. It abstracts all the relevant components and functions of a substation - like circuit breakers and overcurrent protection - into so-called 'logical devices' and 'logical nodes'. The logical nodes of the components, along with their data attributes, are described in the data model using binding, standardized semantics. For this purpose, the IEC 61850 defines a substation configuration language (SCL) that covers all aspects of a substation control system.
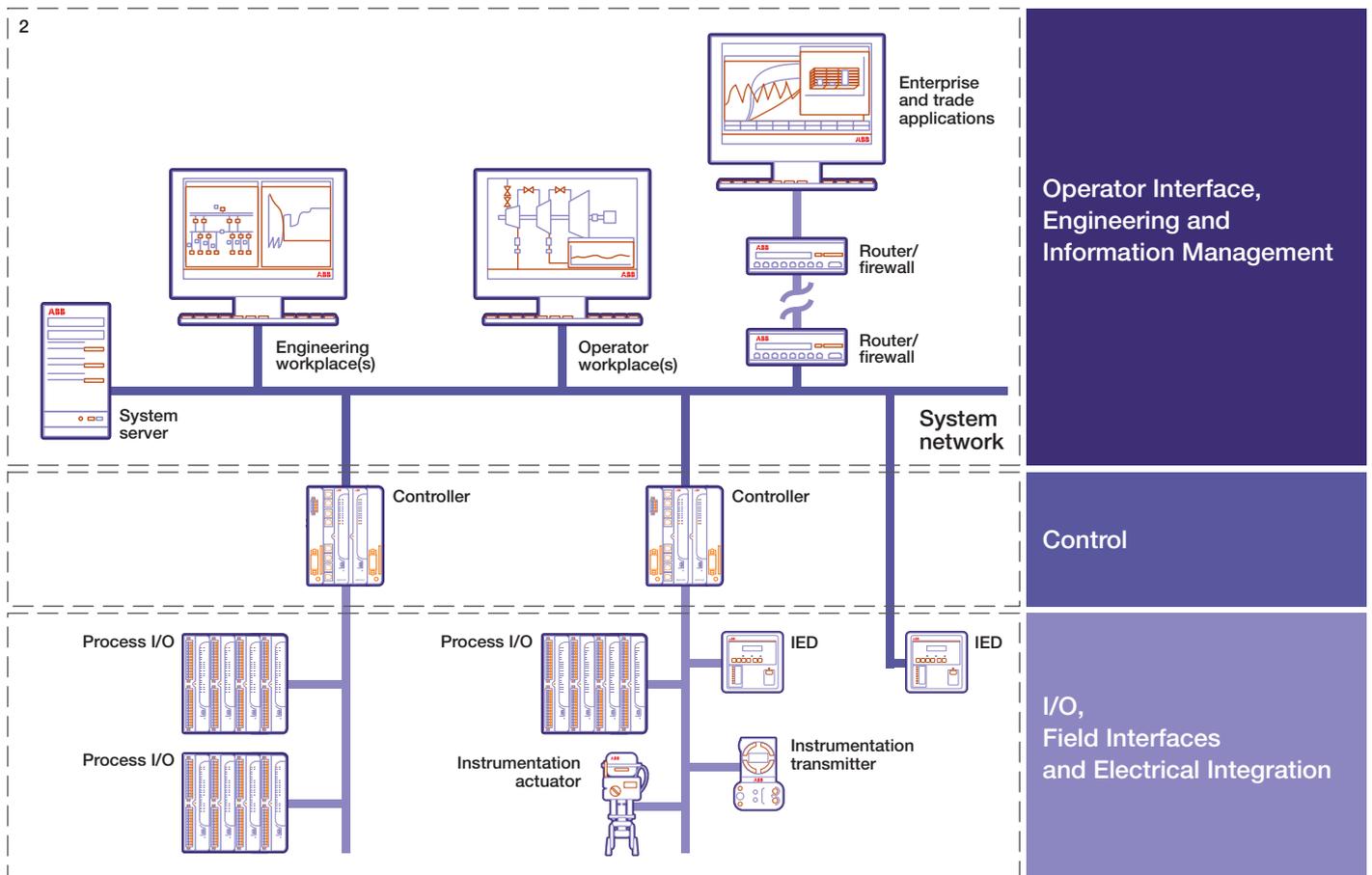
2 System functional levels: operations / engineering, controller, and I/O and field interfaces

SCL is used to describe all relevant data: the substation, its voltage levels, the complete block diagram, the protection and control devices installed, the relationship between the components and the block diagram, the internal communication among the individual components, and the communication network.

The SCL description of a substation can be used as a complete system documentation for various purposes, such as maintenance. The extensible markup language (XML) format of SCL enables easy data exchange between the configuration tools of different manufacturers.

For vertical communication between protection and control devices and the operations level, the IEC 61850 standard uses the Ethernet-based manufacturing message specification (MMS) protocol. For horizontal communication between protection and control devices, IEC 61850-GOOSE, is used and can fulfill the requirements for very quick transmission of protection or interlocking signals via the Ethernet station bus. Thus, this standard replaces most of the fixed wiring or serial communications between the protection and control devices and the process control system. It separates the substation control functions from

the assigned communication services. This makes for a future-oriented standard and takes into account that the development of communication technology advances much faster than substation control and electrical protection technology. The IEC 61850 standard protects the capital investment made in substation control systems.

Of course, IEC 61850 is not the only solution for electrical integration. A good level of integration can be accomplished in systems supporting Modbus TCP; ABB boasts well-documented success in this system and provides application solutions based on this technology.

A future-oriented, open architecture for process control systems
The introduction of open standards such as IEC 61850 translates into simplified system structures. A suitable process control system makes use of these advantages and helps to develop a consistent technology concept.

Both the vertical and horizontal communication of protection and control devices, as well as their data exchange with the automation level of the process control system (eg, turbine protection or controller), is implemented on the basis of the IEC 61850 standard and Ethernet. Other central or remote I/Os of the process automation system can be connected via HART or Modbus fieldbuses.
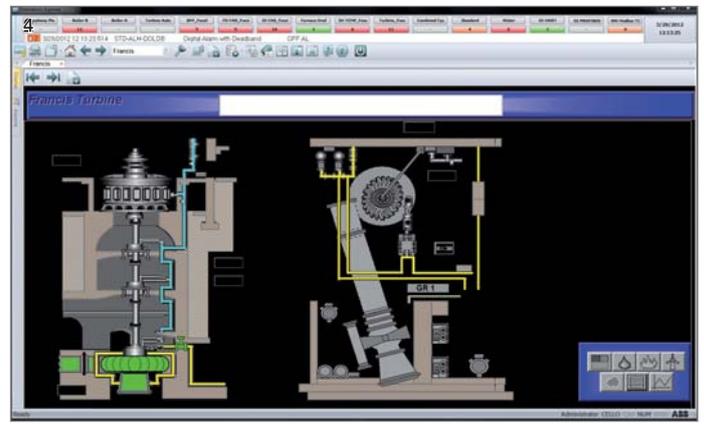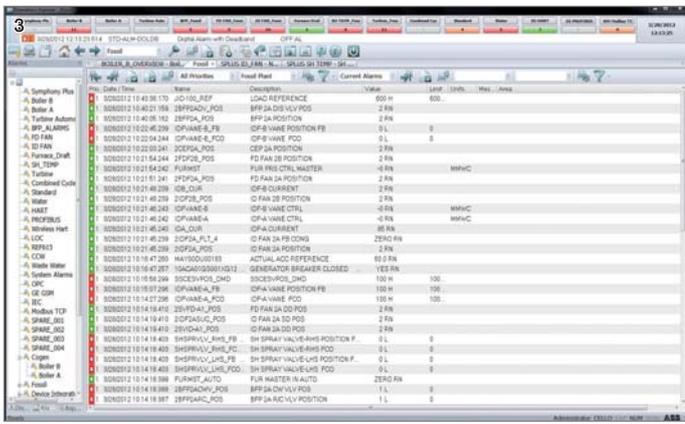
3 S+ Operation alarm page | 4 Francis turbine synoptic

All data on the process and the electrical installations are archived in the system server in a comprehensive common information base. The powerful information base integrates historical and current data from different sources in the plant. As needed, the process and enterprise data can be retrieved and displayed to serve as supporting information.

Technologies, methods, tools
Thanks to comprehensive integration, and the new devices and new communication standards, more information is made available than in traditional solutions. In order to use this information and create added value, intelligent technologies, methods and tools are needed. In the overall concept, they will be used to channel and seamlessly distribute the mass of information to the control room operators, the maintenance engineers, and the optimization engineer.

The availability of information is an important prerequisite for economical and operational reliability.

Operator workplaces must be optimized to assure the greatest possible user convenience. They are provided with navigation options that are designed in accordance with advanced ergonomic principles. They provide process information to the operator and make operation easier, safer and more effective. In an integrated system concept, all relevant information is presented in a way that offers the best possible benefit to the user.

Symphony Plus information management and HMI
The main limit to increased productivity is having to aggregate data from different sources and transform it into meaningful information that can be presented to operations, maintenance and engineering personnel in their respective contexts.

This aspect is even more critical when simultaneously treating process data, electrical data and supervision data.

Symphony® Plus provides easy and flexible data access in order to facilitate operational decisions.

S+ Operations, the system's human machine interface (HMI), provides the user with intuitive process overview displays.

Direct access navigation elements lead to alarms and events, clearly illustrated trend data, and various reports. State-of-the-art graphics, such as sophisticated machine faceplates, provide the operators with well-designed and detailed access into any control point of the plant.

Quick and direct cross navigation provides operators as well as engineers with seamless access to operational displays and engineering layer.

S+ Operations IEC61850 connectivity
S+ Operations provides native MMS communication with IEC 61850 IEDs in order to acquire and display typical measurements relevant to the electrical integration: three phase current, voltage and all protection values.

Direct native communication within S+ Operations represents an easy and fast solution that reduces the cost of the application and makes S+ Operations an integrated IEC 61850 device.

Moreover S+ Operations allows full control of the electrical structures modelling the most relevant power system applications. Our offering includes all relevant bay models such as transformer, generator, incoming, measuring, outgoing, busbar, variable speed drive and motor bay.
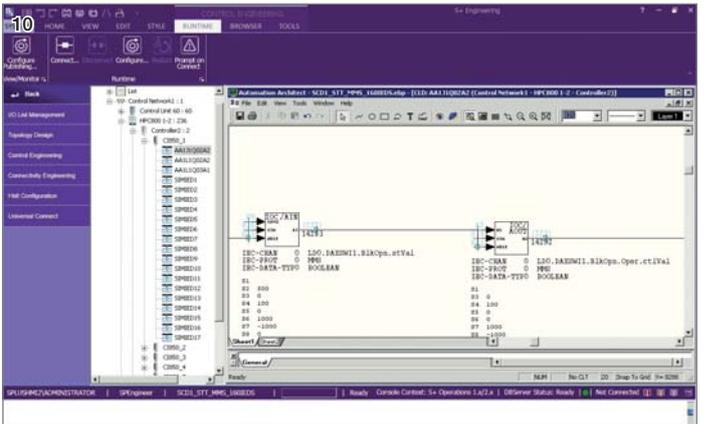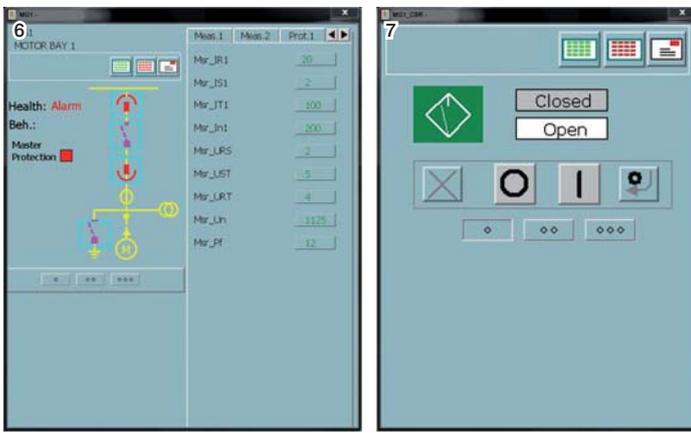
6 and 7 IEC 61850 faceplates | 8 Relion® series | 9 SD Series CI850 IEC61850 integration interface module | 10 S+ Engineering IEC61850 tools

Electrical data and bay models have their own graphic representation on S+ Operations HMI, providing high level integration functions that enable the operator to:
- Create the proper links between electrical and process objects
- Support complete navigation from process to electrical views
- Group electrical data in the faceplate of the bay to which they belong
- Represent electrical equipment (circuit breakers, switches, etc.) in terms of the complete set of signals and conditions acquired via IEC 61850

S+ Operations provides electrical and process operators with an ergonomic environment that offers a process graphics in line with the users' expectations, and which enables them to explore different aspects of the application either during normal plant operations or fault diagnosis.

Controller IEC61850 device integration
S+ Control's SD Series CI850 IEC61850 module provides connection between SD Series controllers and Intelligent Electronic Devices (IEDs). This allows for easy integration of intelligent devices such as bay control units and generator protection units. Each device's resident information can then be used in control strategies and higher level applications.

CI850 IEC61850 module features include:
- Data modeling according to IEC 61850-7-3 /4
- MMS client functionality according to IEC 61850-7-2
- GOOSE publisher and subscriber functionality
- Capability to send Single and Double Commands
- Capability to send Select Before Operate Commands
- Supports up to 20 IEDs connected to a single CI850
- Dual high-capacity 32 bits CPUs.

Engineering IEC61850 device integration
Since the very first experiences in electrical integration with IEC 61850, system engineering and configuration is the critical point in the integration process, due to the complexity of the task and to the number of tools involved.

The system's engineering tool, S+ Engineering, provides an innovative approach to engineering, based on the following key points:
- Single front-end for all system engineering tools
- Consistent checking of the system design
- Single-point entry of data and the simple reuse of this data
- Seamless data exchange between the integrated tools

Moreover, S+ Engineering provides a common graphical and procedural approach to engineering, regardless of the kind of device being engineered and configured.

Due to the increasing demand for integration of third party IEC 61850 devices, systems are required to provide, not only interoperability but inter-configurability as well, and in a way that is transparent to engineers.

Symphony Plus and Relion IEDs
Symphony Plus is designed to integrate ABB Relion® IEDs. The Relion family offers the widest range of products for the protection, measurement and supervision of power systems, and is designed to harness the full benefits of the IEC 61850 standard. Symphony Plus is completely interoperable with all third-party IEDs and in accordance with the standard's specifications.

Life cycle benefits of system integration

Integrated process control systems offer a multitude of benefits throughout the entire system life cycle from design and engineering stage to operation and maintenance and future system extensions.

The operational input and the capital investment needed are significantly reduced. The benefits provided by centralizing the different control system functions lies, on one hand, in the advantages of a common operating and monitoring interface. A much greater benefit though – and this is of vital interest – lies in the possibilities offered by a common information base and by common access to correlated data that are of interest to other areas of the enterprise. It is now possible to identify cause and effect in a way that was not previously possible with traditional technologies.

A common database can be used simultaneously by operators, maintenance and service personnel, as well as by plant engineers who may be working on operational optimization. This improves, for instance, the quality and effectiveness of failure analyses. The plant's efficiency and profitability can be increased substantially. Moreover, it is possible to generate balances that deliver information about the energy efficiency of equipment, or to analyze operation and production data. Condition-based and predictive maintenance activities can be scheduled reliably, simply by connecting the process control system to higher-level enterprise systems and maintenance management systems, thus preventing unexpected and costly downtime beforehand.

Glossary

HSI	Human System Interface for operating and monitoring tasks.
DeviceNet	Fieldbus that is mainly used in automation engineering, widely used in the U.S. and Asia, less so in Europe.
CI850	S+ Control IEC 61850 Module
GOOSE	Generic Object Oriented Substation Event is a communication protocol defined in the IEC 61850 standard; it supports quick data communication from one IED to another.
HART	Highway Addressable Remote Transducer is a standardized communication system. The data is modulated to a conventional 4.20 mA signal.
IEC 61850	Communication protocol defined by the International Electrical Commission (IEC) for protection and control equipment in electrical substations in the medium-voltage and high-voltage range. The standard defines the communication within the substation, as well as an object-oriented language for components and functions.
IED	Intelligent Electronic Device, intelligent, electronic protection and control devices, primarily for medium and high-voltage systems.
Modbus	Communication protocol for the communication of programmable logic controllers.
PROFIBUS	An open, digital communication system with a wide scope of possible applications, especially in industrial automation. It is used for numerous distributed processes and complex tasks.
Profinet	An Ethernet-based communication system.
SCADA	Supervisory Control and Data Acquisition: data acquisition for the purpose of monitoring and controlling the basic functionality of any network control system.
SCL	Substation Configuration Language defined in IEC 61850.
Symphony® Plus	Process control system for the utility and process industries, made by ABB.

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