Speed and quality

Shifting into high gear with IEC 61850-based substation automation engineering

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The publication of the international standard IEC 61850 for the automation of substations effective since 2005 is considered a breakthrough in electrical power technology by the protection and substation automation community. This big step was the result of the application of state-of-the-art information and communication technology to a field that traditionally just transmitted bits and bytes over wires.

Once the transition to information and communication technology was made, a whole world of new opportunities opened up to improve the complex task of substation automation system engineering. ABB has taken the next step, developing a powerful engineering environment for substation automation, from automation system specification to system testing. Using this extensive toolbox, ABB is delivering thoroughly tested SA systems and is providing smooth operation at customer sites when rebuilding or maintenance is required.

Substations are important nodes in a transmission and distribution grid. Within substations, the electric power is transformed to the appropriate voltage level – high voltage for transmission, medium voltage for distribution. The transformation is made by power transformers, which can take the size of a residential house. Along with the transformation, the electric power flow has to be switched on and off by circuit breakers to feed the required lines. Circuit breakers can, under the control of protection devices, interrupt very high currents in a few milliseconds in an emergency; ie, they can isolate faults in switch yard equipment and lines, thus preventing their effect(s) from spreading throughout the whole network. Substations are also equipped with various measuring devices to record the actual current and voltage of the lines, as well as the power flow.

Modern switchgear is equipped with a number of sensors and electronics to acquire the huge amount of information. An example of such an intelligent device is the hybrid switchgear 1, integrating powerful circuit breakers, disconnectors and protection and measuring units into one component. The internal control electronics to read the sensors and trigger the actuators can communicate the data and analyze them to give real-time status information.

For the operator of a grid, which may span a whole country and feeds power to numerous areas, the substations are the control points for the flow and the stability of the grid. Substations thus must guarantee reliable and safe operations.

In view of these quality and safety requirements, engineers who design, build and test a substation must apply the utmost diligence. Besides the proper physical operation of all the devices in the setup, the substation automation system that controls the real-time response of the substation must be able to cope with any possible situations occurring in a complex electrical grid.

Paradigm shift

Decades ago, the main goal of substation engineers was to develop reliable components like transformers or circuit breakers and connect them in a simple way to fulfill the requirements of a substation. The signals necessary for controlling the substation operations were transmitted with low bandwidth via direct cable connections. Engineers designed the control systems so that the number of bytes to be transmitted for a reliable operation was as small as possible. The protocols required for data communication were designed to cope with this severe bandwidth limitation. Later on, when more powerful communication technology like Ethernet and networking protocols such as TCP/IP became widespread, the traditional protocols were adapted to run over TCP/IP-Ethernet.

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Although the use of Ethernet and TCP/IP offered more possibilities for substation control, it was a halfhearted approach, as it supported the very same basic electric power system capabilities as the serial link version, but not more than that. Engineers continued to use the same protocols previously designed for minimizing the bytes on wires and did not take advantage of the huge additional possibilities offered by modern information technology concepts.

When it became clear that further significant progress should come from more versatile applications the IED Technical Commitee TC57 – designed a new protocol for substation automation, effective since 2005 as the IEC 61850 standard [1]. Within a very short time, IEC 61850 became the global standard for power utility automation, and today customers request that suppliers follow this standard for almost every new substation built worldwide.

The major step behind this standard is the consequent application of concepts of modern information and communication technology, making IEC 61850 the trendsetter for other automation areas [2]. With this approach, the physical objects in a substation can be described by a set of aspects such as their position in the substation, their main purpose, their physical status and their control requirements.

Giving standardized names to all the components (called logical nodes in the abstract presentation of the substation) and their various aspects provides a setup that is neutral with regard to the specific supplier of the equipment. The standard also describes the way logical nodes communicate with each other and with higher control systems within the substation or with any external control system.

1 ABB'S compact Pass MO 170 kV hybrid switchgear combines various functions

Intelligent devices

To make full use of the possibilities of the powerful communication systems, the devices in a substation must be able to communicate and provide a broad set of data. This requirement is also reflected in their IEC 61850 name – Intelligent Electronic Devices (IEDs). IEDs host logical nodes, which represent a typical function part, which, for instance, can abstract some physical equip-

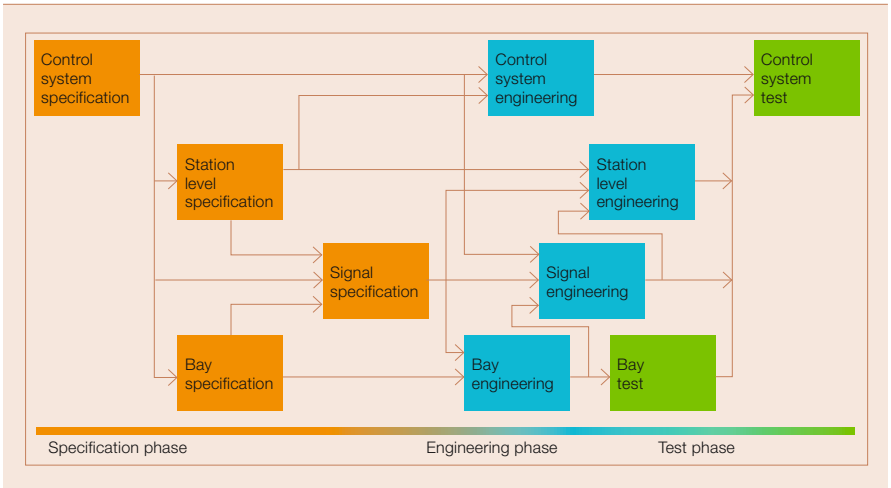
ment, expose control means over such equipment or represent a protection function.

Take for example a circuit breaker. The standard defines a specific logical node to identify a circuit breaker within the network, and, as a container for the information about its switch position (open, closed), the number of operations, the accumulated switched amperes, the remaining operating capability or the status of its drive mechanism, to mention a few. The communication with the IED through IEC 61850 allows the substation automation system to automatically identify the device when it is plugged in. "Plug-and-operate" is a feature known to every PC user, when an external device is connected. Plug-and-operate facilitates the installation of a substation [3].

Mastering the information and data flow

With all the boundary conditions of the IEC 61850 provided, it is the task of the engineer to master the enormous amount of data that describe and control the operation of a substation 2. This task already starts in the specification phase of a new substation when the overall model of the substation is defined and tuned to the specific needs of the customer.
The next step is the detailed specification of bay[1)] functionality and needed signals, followed by the engineering phase, in which all elements of the automation system must be realized. Before any onsite operation can be carried out, the whole system must be thoroughly tested, which is done in the factories as well as onsite.

2 Engineering phases of the design of a substation automation system



3 Main elements of a substation automation system

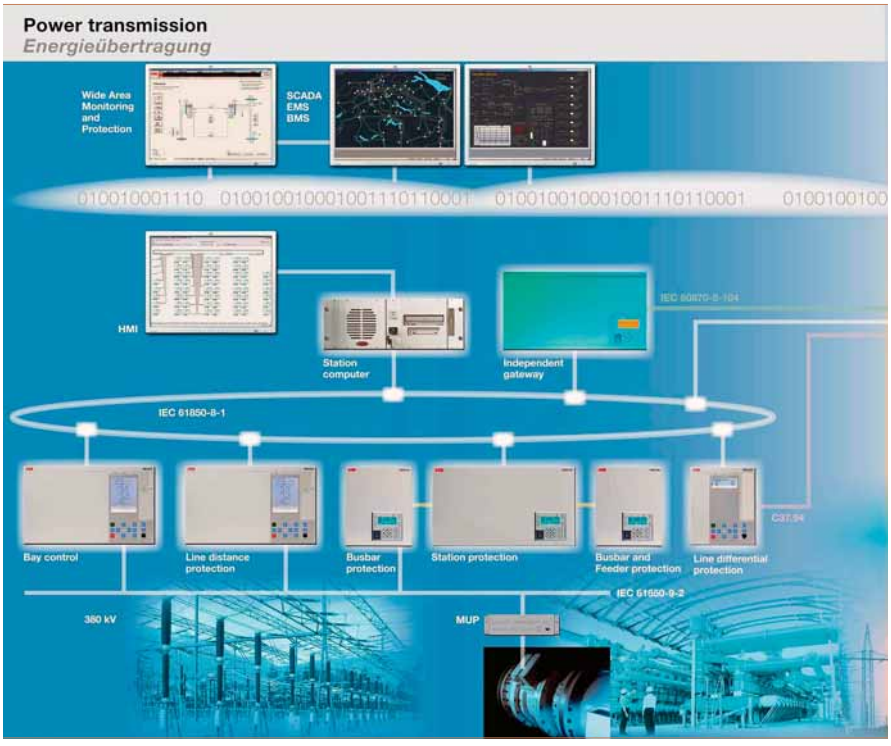


ABB made great progress in this direction and is now able to use a full-fledged engineering environment for substation automation from the specification to the site acceptance test.

New opportunities for customers

The IEC 61850 standard has been designed to give engineers the opportunity to realize all the features described above. But the way forward from a mere opportunity to a real tool that makes efficient use of these possibilities is a big challenge for engineers – many technical hurdles must be overcome by employing the creativity of information technology experts. ABB made great progress in this direction and is now able to use a full-fledged engineering environment for substation automation from the specification to the site acceptance test. This engineering environment not only supports the design process but also offers additional value when existing substations must be refurbished or extended and when the older parts of the setup do not comply with the new IEC 61850 standard.

The innovative steps that were taken are an almost classic example of the process of innovation as such -methods and tools developed in software engineering, like the automated testing of codes and consistency checks of architectures, are consequently

applied in the traditional field of substation automation, a typical approach for cross fertilization of technology. Following are just a few examples that demonstrate the powerful applications of system testing tools based on IEC 61850 modeling concepts.

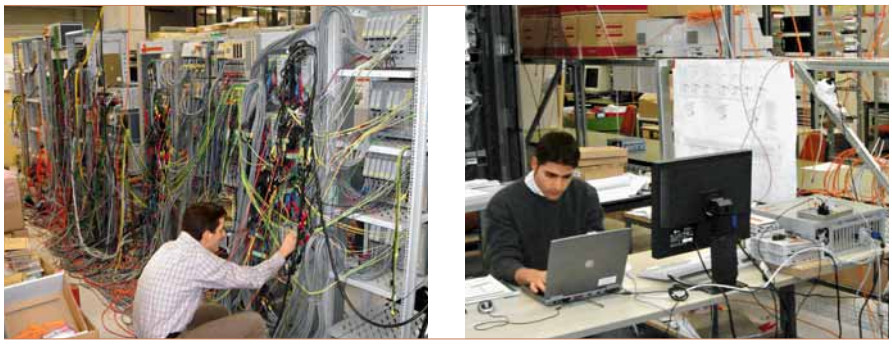
3 shows the main elements of a substation automation system designed according to the IEC 61850 standard. On the bay level, IEDs can communicate sampled values of voltages and currents via appropriate periodic communication services; the different bays then exchange data on events, defined by the GOOSE[2] service, typically via a station bus. This bus, which makes the physical connection to the supervisory level, also transports the vertical communication to station-level devices and network control centers using the MMS protocol[3].

With the definitions given in the IEC 61850 standard, a virtual model of the substation can be generated, mapping all features of the IEDs and the communication channels. In the design process of a new substation, the engineers design the substation automation system, which can be loaded into the new testing tool to set up the virtual model of the substation from the very beginning. The testing tool can also generate this virtual model when connected to an existing substation, provided it is configured according the IEC 61850 standard. This step assures the necessary completeness and consistency, and no further examination via the SAS[5] system is required.

The SAS system itself can be tested in a similar way when connected to the tool. The tool checks for the proper definition of names or the configuration of reports and events, for example, and simulates all the devices in the substation to be addressed by SAS. This offers the huge advantage of being able to run tests already in an office environment rather than in the field.

4 directly illustrates the paradigm shift in testing when the new IEC 61850 tool enviroment is used. While in the traditional approach, the devices had to be physically present and connected to the SAS, the new tool simulates the IEDs, which are pre-checked for their consistency, and allows for fast and efficient tests in an office environment.

4 Significant simplification of testing with the new IEC 61850 tool environment



The alternate method is possible as well. If real IEDs are available without a SAS installed, the IEDs can be connected to the tool that in this case will simulate the missing SAS.

The examples given demonstrate the versatility of this unique engineering tool now available to ABB engineers.

Of course, the GOOSE traffic also can be tested for proper operation with the new program. When real IEDs, possibly combined with simulated IEDs, are checked for their response to the interlocking logic, any flaws in the substation automation system can easily be detected. Various test cycles, examining the full spectrum of possible real cases, can thus be executed in a short time.

Customer benefits

The examples given demonstrate the versatility of this unique engineering tool now available to ABB engineers.

It facilitates up engineering and testing processes, allowing fast delivery of SA systems to customers. It significantly increases the reliability and plug-and-operate performance of substations, short-cutting commissioning phases with carefully pre-tested systems. It also shortens outage times at the customer site in cases of refurbishment or maintenance due to the manifold possibilities of testing within the virtual engineering environment. The development of such a powerful engineering tool is a model case for a process innovation providing significant value for ABB and its customers.

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Footnotes

[1] A bay is the group of devices required to supervise, control and protect a line in the grid.
[2] GOOSE: Generic Object-Oriented Substation Event.
[3] MMS: Manufacturing Message Specification. This ISO protocol originally designed for a manufacturing environment has been chosen for IEC 61850 as the most appropriate existing standard for this type of information flow.
[4] SCADA: Supervisory Control and Data Acquisition.
[5] SAS: Substation Automation System

References

[1] IEC 61850: Communications, networks and systems in substations, International Standard, 2003.
[2] **Kostic, T., Preiss, O., Frei, C.** (2005). Understanding and using the IEC 61850: a case for meta-modelling. *Elsevier Journal of Computer Standards and Interfaces*, 27/6, 679–695.
[3] **Frei, Ch., Kostic, T.** More than meets the eye. *ABB Review 4/2006*, 30–33.