





Substation retrofit

Retrofitting Sils substation with IEC 61850 technology

MARCEL LENZIN – The introduction of the IEC 61850 standard marked an unprecedented revolution for the integration and communication needs of substations. Utilities across the world were quick to adopt this standard, enabling high levels of interoperability between devices (even from different manufacturers) and providing an advanced means of communication. Besides its relevance for new installations, many utilities are seeking to introduce the standard to existing substations as part of retrofit work.

The Swiss utility KHR (Kraftwerke Hinterrhein) operates a 380/220 kV air-insulated substation in Sils. This substation is an important node in the Swiss transmission network (itself part of the European UCTE network).

The retrofit in the Sils substation was initiated because the entire secondary infrastructure and parts of the primary equipment of the 380 kV voltage level had reached the end of their lifecycle. KHR decided to replace most of the secondary part, while retaining most of the primary equipment. As the lifecycle of secondary equipment is typically half that of primary devices, such a retrofit scenario is quite common in industrialized countries. To ensure the investment would serve the needs of the next 10 to

15 years, KHR chose to make the secondary system compliant with the new IEC 61850 standard.

The retrofit challenge

Retrofit projects are, by their nature, more challenging than projects in which everything is built from scratch. The old and new parts must be compatible and the continuity of the substation's operation must be assured during the transition → 1. Outages must be used only where no other possibility exists; and their duration must be as short as possible. The operation of the overall transmission network must be unaffected by the work. Project teams must therefore carefully analyze and gain a detailed understanding of the existing system.

1 The continuity of the substation's operation must be assured during the retrofit



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2 Substation control room at Sils



The solution based on IEC61850

The secondary part of a substation has two main purposes: It controls the primary equipment and protects it from damage by electrical faults. These functions are provided by so-called IEDs (intelligent electronic devices). An IED has an I/O (input / output) connection to the system's primary equipment and controls either a bay or part of a bay. The protection functions are specific to the type of bay (transformer, line, coupler, etc).

In their control role, IEDs are responsible for control and interlocking functions. They ensure that a primary device can be operated only if certain prerequisites are fulfilled. In their protection role, they constantly monitor the electrical behavior of the substation (on the basis of voltage and current measurements). Should a fault that could lead to damage of primary equipment be detected, the necessary parts of the station must be shut down and the faulty equipment isolated. Alarms to inform the central control system are transmitted via the IEC61850 bus.

The communication bus connects the IEDs to the substation control system, from which the complete system can be operated and monitored. A substation is just one node in a complete electrical network, therefore consolidated substation information must be reported to a network control center, typically located many kilometers away → 2. Depending on the network operation authority concept, it may also be possible to control primary equipment from the network control center. The interface to a remote control center is provided by a gateway.

In the Sils substation, ABB's Relion® 670 series IEDs were adopted for control and protection functions. Utilities often require that devices from different suppliers are installed in parallel to provide backup. In Sils, the protection devices for this purpose were supplied by a third party and fully integrated using the IEC 61850 standard. This integration capability is one of the main strengths of IEC 61850.

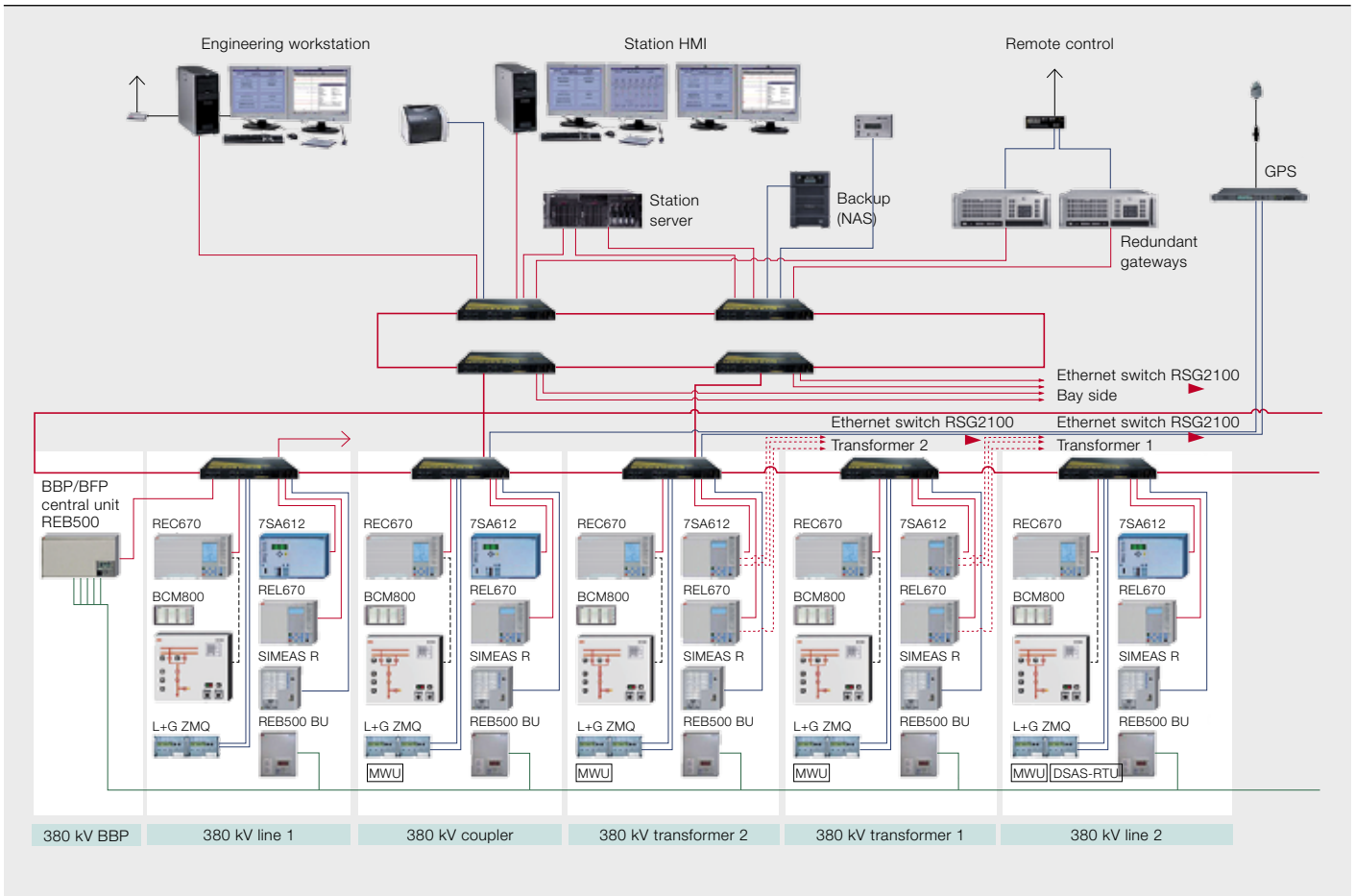
The functionality of the IEDs was engineered to serve the needs of the existing equipment, but also to take advantage of newer technology such as the bay-to-bay communication protocol GOOSE¹ for example.

All IEDs are connected to the IEC 61850 communication bus → 3. The bus is divided into several physical rings, one as station LAN² and the others for communication between station-level and bay-level devices. The ring configuration was chosen to increase the availability of the network. The control system uses ABB's MicroSCADA Pro and runs on a high-end server, equipped with redundant power supply and RAID³ storage system. For backup software functionality, a separate storage server is connected to the station's LAN.

Ensuring a redundant gateway as the interface to the network control center, two independent IEC 61850 clients are

Footnotes

- 1 GOOSE: generic object oriented substation event.
- 2 LAN: local area network.
- 3 RAID: redundant array of independent disks.



connected directly to the bus. This allows the station to be remotely controlled, even if both substation control computers are shut down.

KHR gained numerous advantages by basing the new secondary part of the substation on the IEC 61850 standard. The standard defines the SCD-file⁴. It contains all relevant information, from the topology of the primary equipment down to the complete data flow of the secondary equipment. The availability of this information supports later extensions, replacements or upgrades of the substation automation system or parts thereof, and so supports long-term reusability. Besides this, it also ensures data consistency of the complete system for current engineering. Since IEC 61850 also specifies the horizontal and vertical communication on the bus, the system can be built using IEC 61850 compliant products from different suppliers.

Furthermore, to reduce the copper wiring between bays, KHR decided to implement horizontal, bay-to-bay communication with the GOOSE protocol. All communication relating to the interlocking between bays is exchanged via GOOSE messaging between IEDs using the IEC 61850 bus.

Project phases

All projects start with a design phase, with focus being on interfaces to existing equipment and the additional functionality to be introduced to the system. The design phase must clarify how new parts are to be commissioned without jeopardizing the commercial operation of the substation. At Sils, ABB's engineers had to understand the functionality of the current system in detail in order to design the new system appropriately. In future, this phase will be supported by the availability of the SCD files.

The next project phase is implementation and production. The IEC 61850 standard also defines the engineering processes. It is therefore essential to use a system engineering tool that fully supports IEC 61850, keeping data and data flow consistent across the entire substation and correctly documenting changes in the SCD file.

In the Sils project, special attention was given to the factory testing phase – the last project phase before the new equipment was delivered to site. This served

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to shorten the subsequent commissioning phase compared to on-site testing. Various simulators were used to test in-

Footnote

4 SCD: substation configuration description.

4 Installed breakers waiting to be connected



interactions with existing equipment. Testing was split into two phases: individual tests for each bay, and a test for the entire system. IEDs of each typical bay type were connected at station level and the functionality of the complete system was tested in ABB's test field. To test the bay interlocking, GOOSE messages from all devices that were not physically present in the test field were simulated.

The commissioning phase is probably the most challenging phase of a retrofit project. An entire substation cannot be shut down for commissioning. The outage times of individual feeders need to be kept to an absolute minimum and must be planned and approved by the grid operator (in this case, Swiss-grid) months in advance. At Sils, commissioning had to be executed step-wise, feeder by feeder, following a detailed schedule.

Bay-by-bay commissioning involves complete systems being delivered to site. The complete bay level system, including the station level components, is installed on site with only the AIS (air-insulated switchgear) interfaces being omitted → 4. This omission permits extensive testing (including complete IEC 61850 communication) of the installation without affecting commercial operation. Once this is complete, all that remains to be done is swapping the connection to the primary equipment from the old to the new IEDs. This approach shortens commissioning time and ensures that the outage time of the bay can run to plan.

An additional advantage of bay-to-bay commissioning is that when the complete system is connected to the IEC 61850 bus, whether it is already connected to the AIS or not, all GOOSE messages are already working for bay-to-bay interlocking. No configuration changes are needed at system level or in the already commissioned bay-level systems.

As an alternative to having all IEDs sending GOOSE messages via the bus, IEDs can also be simulated.

During the transition phase (which can be a period of several months) the substation must operate with equipment that is going to be replaced and equipment that has already been replaced running side by side. In planning this phase, special attention must be given to system-wide functions, such as busbar protection. In the Sils project, the switch

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over to new busbar protection was performed at the end of commissioning, with the old system continuing to operate throughout the transition.

Integration of the 220 kV substation to the control system

Following the successful retrofit of the 380 kV substation, the 220 kV part was integrated with the newly delivered substation control system. On the 220 kV level, the complete bay level was still up to date and there was no need for replacement. The existing IEDs were equipped with new IEC 61850 communication interfaces. These enable communication with the new MicroSCADA Pro control system via IEC 61850 and ensure that both the 380 kV and 220 kV switch yards can be operated and monitored from the central control system. Furthermore, the MicroSCADA Pro system was extended to a hot standby system, in which the complete control and monitor-

ing functionality runs on one computer, and while a second computer, running the same application in parallel, is ready to take over the complete operation immediately in case of faulty operation of the first computer.

A successful project

The Retrofit of KHR's Substation was performed successfully and the renewed system is up and running. Thanks to close and constructive collaboration between ABB and KHR, and the extensive respective experience of both partners, the complex project was completed with minimal inconvenience.

The project demonstrated the aptness of the IEC 61850 standard for retrofit projects. The standard enabled the straightforward combination of ABB and third-party protection IEDs and thus fulfilled the requirement of the customer. The use of GOOSE messages for bay-to-bay interlocking considerably reduced the need for copper wiring. The complete substation is now documented in an SCD-file in a standardized way, which is an advantage for future maintenance and extension projects. The 220 kV part of the project was integrated using ABB's 61850 SPA/IEC 61850 gateway to ensure that the complete 380/220 kV substation can be monitored and operated from new MicroSCADA Pro central control system.

As a result of exemplary teamwork and the high-quality project execution, the secondary part of KHR's 380 kV Sils Substation is now equipped with state-of-the-art technology and ready for another 10 to 15 years of operation.

Marcel Lenzin

ABB Power Systems
Baden, Switzerland
marcel.lenzin@ch.abb.com