Enabling digital substations

The smarter grid needs a smarter substation, and it has to be digital

STEFAN MEIER – The concept of a digital substation has long been an insubstantial thing – an ideal vision of all-knowing substations networked into an intelligent grid. But the concept is now a lot more practical so the specifics of what makes a substation "digital," and why that is such a desirable thing, can be discussed.

Digital signaling offers excellent reliability and capacity, and has been in use in power infrastructure for decades. Most existing electricity grids employ digital fiber-optic networks for the reliable and efficient transport of operation and supervision data from automation systems in substations – and even power line networks carry tele-protection signals these days. But only now are the advantages of standardized digital messaging starting to extend into the deeper substation environment.

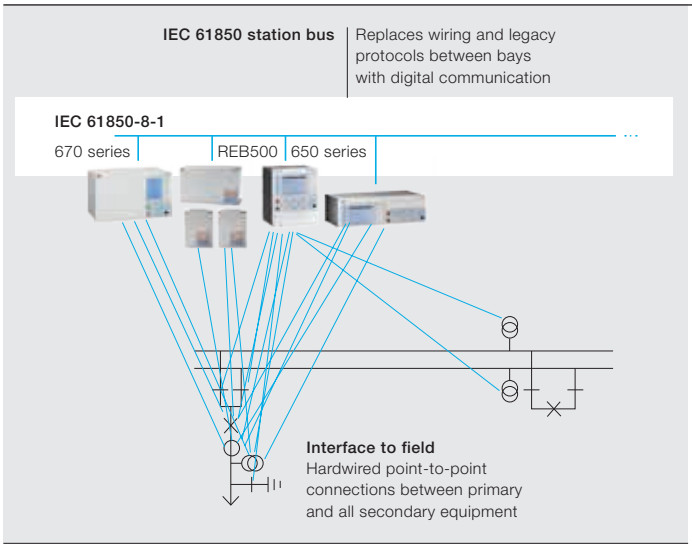
IEC 61850

Without standards, the adoption of digital messaging for intrasubstation communication was piecemeal and fragmented, with mutually incompatible signaling creating an assortment of messaging within vertical silos. ABB has long championed industry adoption of IEC 61850, a standard with which the company has been intimately involved since its inception. "Communication networks and systems for power utility automation," as the IEC document is properly known, is a comprehensive standard broken down into components that, for example, specify how the functionality of substation devices should be described – how they should communicate with each other, what they should communicate and how fast that communication should be. All of this is critical to realizing the benefits of a truly digital substation.

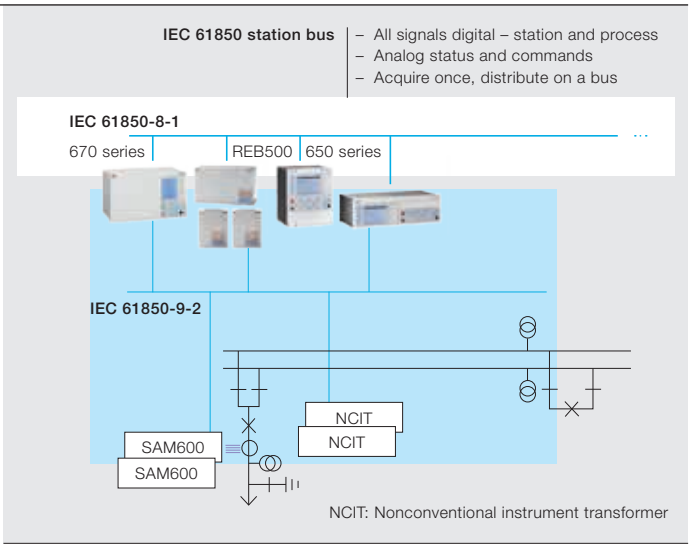
At the station level, things are generally digital, even in relatively old installations. SCADA (supervisory control and data acquisition) systems usually demand

Title picture
Technology is now available to allow substations to be completely digital – right down to the current transformers. The advantages of having a digital substation are manifold.

1 Digital substation and IEC 61850



1a Today



1b Tomorrow

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digital information and ABB has been selling fiber-optic “backbones” for more than two decades.

Between the station level and the bays, fibers can carry digital data – conforming to IEC 61850 – but to become a true digital substation the standard has to extend even further.

Deep digital

The world beyond the bays is still predominately analog. The conventional primary equipment, like current and voltage transformers, is connected back to intelligent electronic devices (IEDs) using parallel copper wires carrying analog voltage signals ➔ 1a. The IEDs receiving that data perform first-level analysis and often provide the gateway into a digital world.

But there is little advantage in keeping the data in analog form for so long and to properly earn the title of “digital substation” the transition to digital must take place as soon as the data is gathered ➔ 1b.

Through permanent system supervision, digital equipment reduces the need for manual intervention and the adoption of the all-digital process bus allows sensitive equipment to be relocated into the bays. The digital equipment that has to be located out in the yard must be easy to fit, and every bit as robust and reliable as the analog equipment it is replacing or interfacing to ➔ 2.

FOCS

Robustness and reliability requirements apply to new technologies such as ABB’s fiber-optic current sensor (FOCS) too. A FOCS [1] can directly monitor current running through a high-voltage line without having to involve a current transformer (CT) to step down the current to a measurable value. Eliminating the CT also eliminates the risk of open CT circuits, in which life-threatening voltages can occur, and so increases safety.

A FOCS exploits the phase shift in polarized light introduced by an electromagnetic field (the Faraday effect). The shift is in direct proportion to the current flowing in the high-voltage line, around which the fiber carrying the light is wrapped. The measurement is digitized right at the source and transmitted as a digital signal, via the process bus, to the protection and control IEDs, as well as the revenue meters.

Such an optical CT takes up a lot less space than its analog equivalent. It can even be integrated into a disconnecting circuit breaker (as ABB did in 2013) to combine the functions of circuit breaker, current transformer and disconnector in one device – halving the size of a new substation.

The FOCS is one of a range of nonconventional instrument transformers (NCITs) that can make things entirely digital. NCITs have to be every bit as reliable as the equipment being replaced – and they

2 New equipment destined for use out in the yard is exposed to the elements so has to be very robust.

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are: Over the past decade ABB has supplied more than 300 NCITs (combined current and voltage sensors fitted into gas-insulated switchgear) for use in Queensland, Australia, and the utility has yet to see a single failure in the primary sensor. Extensive use of NCITs makes a substation simpler, cheaper, smaller and more efficient.

Not everything can be digital – analog data will continue to arrive from conventional current and voltage transformers, for example. But there is no reason for wholesale replacement when a standalone merging unit can perform the transition to digital right beside the existing instrument transformer. Fiber optics can then replace the copper cables connecting the primary equipment to the protection and control IEDs.

ABB has long championed industry adoption of IEC 61850, a standard with which the company has been intimately involved since its inception.

Process bus

As a conductor, every bit of copper in a substation is a potential risk. For example, where current is incorrectly disconnected, such as with an open secondary current transformer, arcing may occur as dangerously high voltages build and a copper line can suddenly carry high voltage, putting workers and equipment at risk. Less copper brings greater safety.

The digital substation dispenses with copper by using the digital process bus, which might use fiber optics or a wireless network, such as ABB's Tropos technology. Just the removal of copper can, in some circumstances, justify the switch to digital. Going digital can cut the quantity of copper in a substation by 80 percent – a substantial cost saving and, more importantly, a significant safety enhancement.

The process bus also adds flexibility: Digital devices can speak directly to each other →3. For this, IEC 61850 defines the GOOSE (generic object-orientated substation events) protocol for fast transmission of binary data. Part 9-2 of the standard describes the transmission of sampled values over Ethernet. These principles ensure the timely delivery of high-priority data via otherwise unpredictable Ethernet links. ABB's ASF range of Ethernet switches fully supports this critical aspect of substation messaging.

3 IEC 61850 makes the fully digital substation a reality.

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Installations

ABB has been heavily involved in IEC 61850 since its inception. The standard is essential to ensure that utilities can mix and match equipment from different suppliers, but, through compliance testing, it also provides a benchmark against which manufacturers can be measured.

ABB deployed the first commercial IEC 61850-9-2 installation in 2011 at the Loganlea substation, for Powerlink Queensland. The use of ABB's IEC 61850-9-2-compliant merging units and IEDs, not to mention NCITs, makes the deployment a landmark in the evolution of substation design.

That project was part of an upgrade of an existing station, an upgrade that saw it move into an IEC 61850 future, adopting digital standards for effective future-proofing. ABB created a retrofit solution based on specifications from Powerlink that can be applied to another five Powerlink substations when they are ready for refitting.

Two of those stations, Millmerran and Bulli Creek, were already upgraded in 2013 and 2014, respectively. The refurbished substations have a MicroSCADA Pro SYS600 system and RTU560 gateway that manage Relion 670 protection and control IEDs, with REB500 busbar protection. These all communicate over IEC 61850-9-2 to the merging units and over IEC 61850 to the station-level devices.

A fully digital substation is smaller, more reliable, has a reduced life-cycle cost and is simpler to maintain and extend than an analog one. It offers increased safety and is more efficient than its analog equivalent.

Not every substation needs to be catapulted into a wholesale digital world – it depends on the substation size and type, and whether it is a new station or a retrofit of the secondary system. Different approaches and solutions are required. ABB's extensive IEC 61850 experience and portfolio of NCITs, merging units, protection and control IEDs as well as station automation solutions eases utilities into the digital world. Flexible solutions allow utilities to set their own pace on their way toward the digital substation.

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Reference

[1] S. Light measures current – A fiber-optic current sensor integrated into a high-voltage circuit breaker. Available: http://www05.abb.com/global/scot/scot271.nsf/veritydisplay/0d948cedb40451cec1257ca900532dd0/$file/12-17%201m411_EN_72dpi.pdf