Substations go fully digital but stay compatible

Find new ways to combine and improve things

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DIGITAL SUBSTATION DIT
PROTECTION & CONTROL

The fully digital substation replaces the kilometres of copper hardwiring and proprietary devices of conventional installations with a software-based solution that builds interoperability today and tomorrow.

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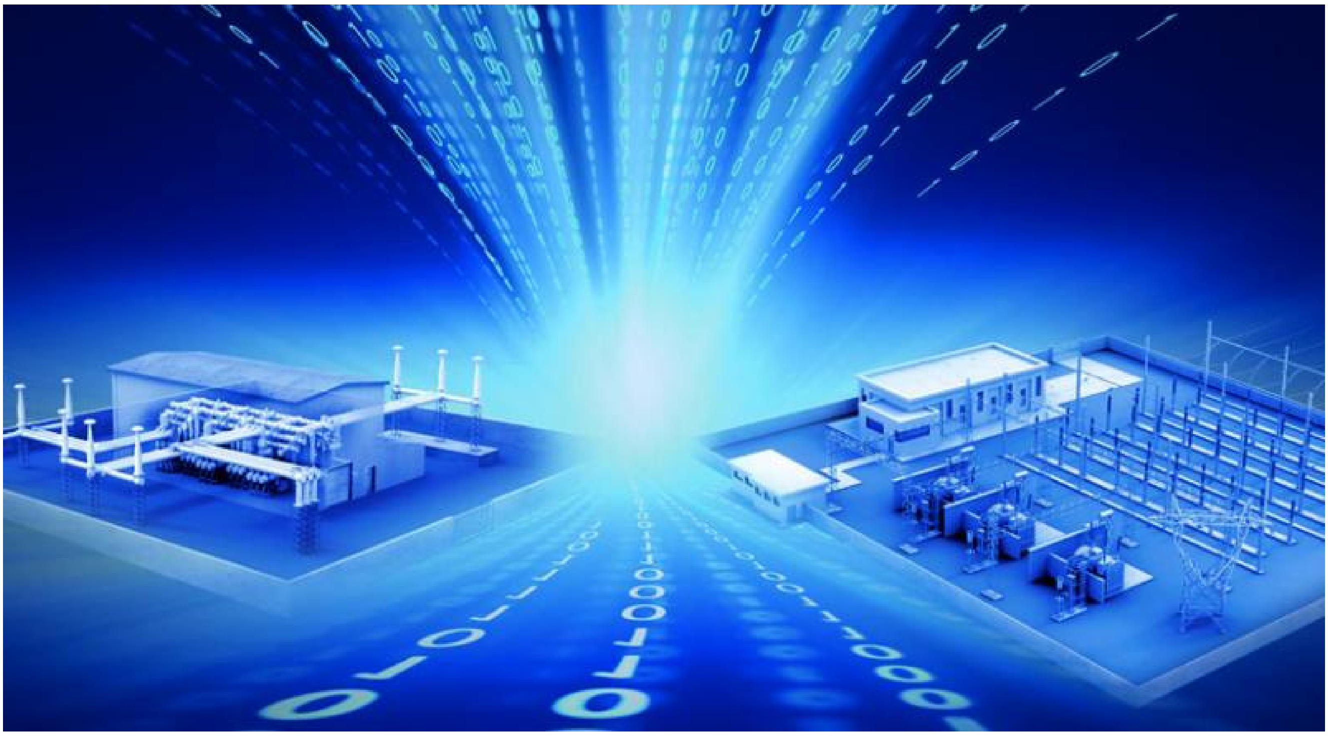


When asked to define innovation, most people think about inventing completely new products. In the modern economy it is much more than that. Innovation can derive from seeing new ways to combine and improve things that exist already – joining computers to telephone networks to produce the Internet, for example – or new ways to organise the manufacturing and distribution of products, such as just-in-time manufacturing. And the cycle of innovation is getting much shorter, as innovations in one domain become quickly accessible elsewhere, client expectations become greater, and regulations and standards get stricter. Substation solutions and components are the perfect illustration of all these trends.

Alstom's digital control system has been the most successful on the market for the past 10 years, but it is already being superseded by a new solution – the company's cutting-edge DS Agile system for substation automation. This enables valuable features like wide-area control, the IEC 61850 process bus and integrated condition monitoring, together with a new range of ruggedized substation-grade grid routers and switches from Cisco. Enhanced communication and cyber security functionality are designed in (see sidebar "Cyber security").

Cyber security
In order to offer new applications, the digital substation is integrating more information technology, new standards and new protocols such as Ethernet. Integrated cyber assets need to be protected from cyber threats, which are growing rapidly and have become highly sophisticated. In 2010 the discovery of the Stuxnet worm publicly illustrated the vulnerability of industrial control systems to cyber attacks. As Jean-Pierre Mennella, Software Solutions Cyber Security Manager, explains: “The main challenge is to adapt cyber security solutions to the specific environment and constraints of the digital substation. Alstom’s approach is to ensure that both architecture and components are designed with cyber security foremost in our thinking.” Alstom is involved in standards definition (for example IEC 61850 and IEC 62351) and in energy sector cyber security activities such as the European Commission’s Directorate- General for Energy M/490 Mandate Smart Grid Information Security Working Group. Alstom is also collaborating with leadingedge partners such as Cisco to offer and develop new, secure digital substation solutions.

1 __Interoperability

DS Agile reconciles the multiple requirements of users, first by offering the most advanced solution available today without the need to replace every piece of equipment and software along the whole energy chain; and second by ensuring that future upgrades can be integrated smoothly. As Simon Richards, Digital Substation Marketing Coordinator at Alstom, explains, “Many utilities that wanted to take advantage of fully digital solutions hesitated because of the complexity of reconciling different protocols and the effort needed to make proprietary systems communicate.

Today, the IEC 61850 standard we use in DS Agile and all our intelligent electronic devices (IEDs) and sensors means there are no issues with proprietary approaches, and this facilitates interoperability between different equipment and suppliers."
The IEC 61850 to which Richards refers is a comprehensive standard for Ethernet based communication in substations, linking components together and with the operator interface. It is also designed to deliver functionality not supported in legacy communications protocols.

« DS Agile reconciles the multiple requirements of users. »

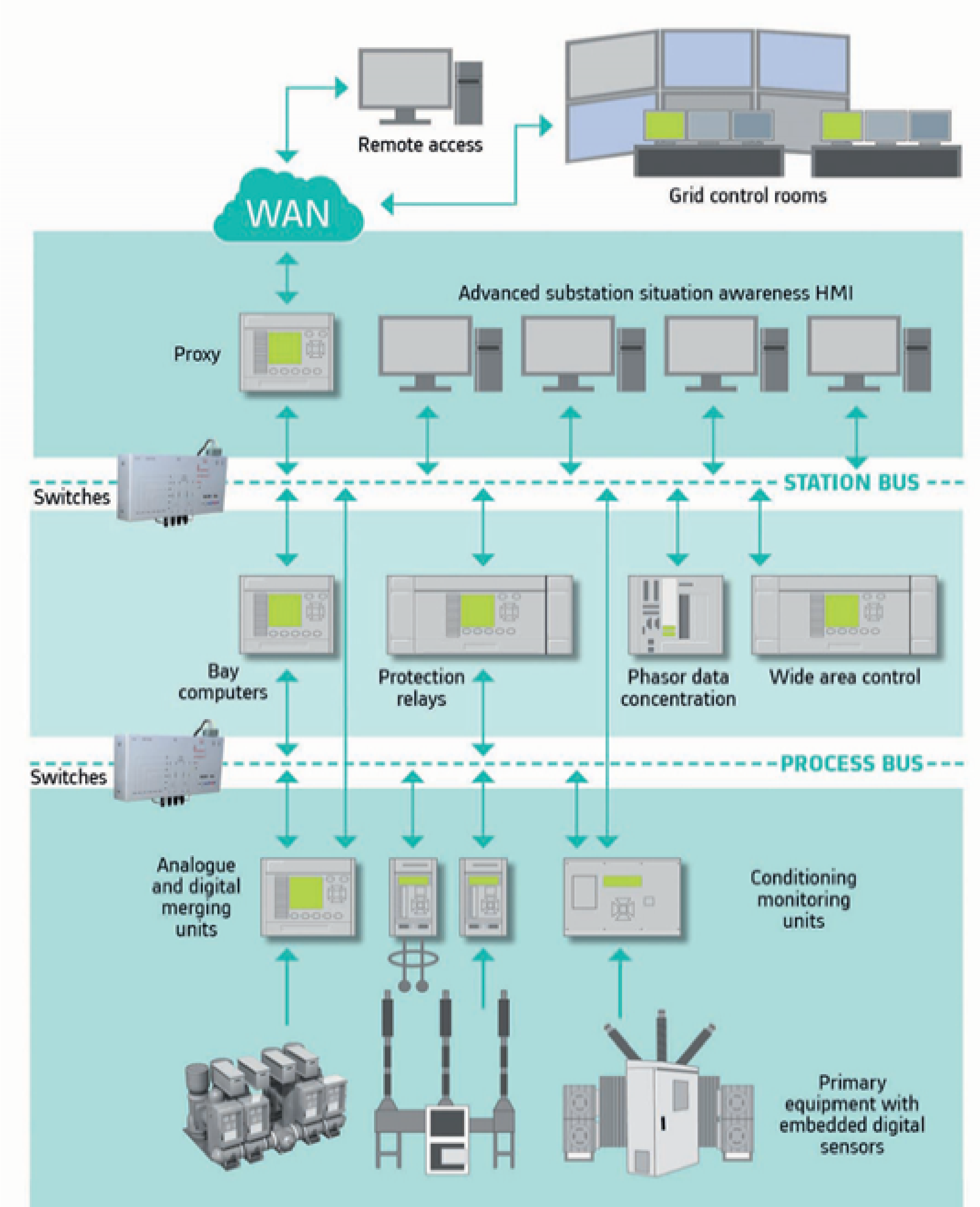
IEC 61850 allows for the full digitalisation of the signals in a substation, which is necessary for the large amount of data that has to be processed and communicated for the real-time management of smarter power grids. Apart from interoperability of devices from different suppliers, IEC 61850 enables the solution to be engineered as a centralized scheme or as a decentralised scheme with dispersed logic. Since it is constantly being revised and updated, this standard ensures that any investment in bay solution designs will be repaid by repeated deployments well into the future, thereby avoiding stranded assets. Other savings are generated by the possibility to tune scheme responses with a software-based design change, avoiding the need for rewiring.

2__Three-level architecture

The digital substation architecture consists of 3 levels.

- The first is the process level, interfacing with the primary equipment in the switchyard.

- Second is the protection and control level, including IEDs traditionally called “secondary equipment” (protection, measurement devices, bay controller, recorders, etc.).
- Third, the station control level handles communication within the substation and control system, coordination with the substation operational functions and station-level support.



Real-time operational measurements and other data are polled from sensors embedded within the primary system and communicated to the devices that must act on those measurements via a process bus. Smart devices and systems within the substation can immediately process this data. By subscribing as clients to this data flow over an Ethernet process bus, the information from the power system is distributed and communicated much more efficiently to the bay level than in conventional hardwired schemes. **The DS Agile architecture can be set up as a self-healing ring or as an IEC 62439 parallel redundancy protocol (PRP) redundant star**, with numerous advantages as summarized by Richards' colleague, Denis Chatrefou, Digital Substation R&D Coordinator. "The extensive self-diagnosis capability of digital devices maximises the up-time of the substation. Any degradation in the performance of an asset is pinpointed in real time. Inherent redundancy in the system can be employed to self-heal the operation, which permits troubleshooting without the need for any primary system outage."

A typical DS Agile digital control system (DCS) incorporates a range of IEDs, such as protection relays, measurement devices and monitoring equipment, as well as bay controllers, Ethernet switches and gateways.

The network can be local to the substation or can interconnect several dispersed substations, and can be linked to the grid control room. The process bus is the link by which the primary equipment information travels back to the substation's relay room.

In a fully digital architecture, control commands (switchgear operator commands, protection trips) are also routed to the primary devices via the process bus, in the opposite direction. In a digital substation, thanks to IEC 61850, the IEDs interact with the field via the process bus, and with other peer devices in the bay, other bays, and the digital control system via the station bus. In the digital substation, the station bus is much more than a traditional SCADA bus. It permits many devices to exchange data, supports peer-to-peer device communication, and links to wide-area control units (WACUs) for wide-area communication between substations or between voltage levels.

Wide-area applications

The BRIC economies (Brazil, Russia, India, China) are building or planning large power plants far from their main population and industrial centres, and wide-area networks are developing in other markets too, with several countries in Europe planning large offshore wind farms, for instance. This is placing an increasing strain on transmission corridors, and operators may find themselves working ever closer to the limits of the networks.

To ensure system stability over these long distances and to prevent the propagation of disturbances requires real-time monitoring and the timely implementation of countermeasures. Phasor measurement units (PMU) (1) are at the heart of wide-area monitoring, protection and control. They collect highly time-synchronised data on system parameters such as voltage, current and frequency, which they then report to the PDC (phasor data concentrator) for visualisation, data storage and, most importantly, for running a variety of on-line and off-line applications in systems analysis and control. This enables operators to optimize the scheduling of transmission capacity, to respond to contingencies, and to preserve stability after disturbances.

The Alstom P847 PMU exceeds the requirements of IEEE C37.118 Level 1 with enhanced performance under off-nominal and dynamic system conditions by means of an advanced frequency-tracking algorithm.

(1) More on our article "**Synchrophasor solutions**" .

3 __Even the instrument transformers are digital

Digital instrument transformers eliminate the inaccuracy of conventional instrument transformers caused by reliance upon an iron core that has to be magnetised, but not over-fluxed, and by the connection of analogue secondary circuits. In conventional current transformers, it is a challenge to achieve the accuracy at low signal levels and the dynamic range to satisfy both measurement and protection duties. Instead of the iron core, the translation from primary to secondary measurement can use optical, Rogowski or capacitive technology, with the optimum choice for AIS (air-insulated substations) and GIS (gas-insulated substations) driven by the respective digital device size, which in turn permits size optimization of the switchgear. But whatever the technology, **Alstom's COSI range of non-conventional instrument transformers (NCITs) offer similar benefits, including greater accuracy, repeatability and safety than conventional instrument transformers.**

In addition, NCITs feature a high measurement bandwidth for fundamental frequency, harmonics, inter-harmonics, sub-harmonics, and quali-metering (metering of power quality). Another significant benefit is that the NCITs are compact and light in weight. According to Chatrefou, improved safety is a key advantage of the design. "Insulating secondary equipment from high voltages by using fibre optics means higher safety for substation personnel. Removal of wired cross-site current transformer circuits reduces the risk of lethal injury due to inadvertent opening of the circuit. And avoiding oil in instrument transformers reduces explosion risks too." Environmental protection and natural resource usage are also improved by eliminating oil in instrument transformers and by employing fibre optics instead of copper. This has direct economic benefits too, given the 400 % rise in the price of copper in the last 10 years.

Likewise, with a footprint 15 to 25 % smaller than conventional substations, there are cost savings on real estate, foundations, structures and construction, and planning permission can be easier.

4 __In the field

Prototyping and trials have long since been completed. The fact that the information acquisition, processing and output is performed in real time through a digital architecture means that extensive testing can be done virtually, in the factory, without the same need for the extensive (and expensive) testing required on site for hardwired systems. Alstom's digital substation will now prove its merits in the field, in differential protection applications for Energinet's transmission system in Denmark, and for FSK in Russia. For Energinet, the protected circuits are hybrids, consisting of 400 kV lines and sub-sea cabled sections. The operational demands are such that auto-reclosing is required for faults on the overhead lines, but not for faults within the underground cable sections. Alstom MiCOM differential protection is used for fast and precise detection of faults within the cables. The main reason for selecting NCITs was their low mass and slim-line construction, allowing them to be mounted on the same structures as the cable bushings. In the 110/220 kV substation in Russia, the primary GIS equipment is supplied by a third party vendor, equipped with conventional instrument transformers. The analogue data is digitised at source using MU Agile analogue merging units, and connected cross-site to relays and bay controllers by an IEC 61850 process bus. A full range of Alstom MiCOM transmission relays protect the substation, as inherent components of the DS Agile digital control system. Trip and operational control of switchgear is secured using DS Agile SCU switchgear control units with PRP redundancy, completing the full digital acquisition and command chain.

Alstom remains a pioneer in digital substation development and a driving force in the elaboration of the IEC 61850 standard that underlies today's designs. After more than 15 years of advanced research and projects worldwide, Alstom's digital substations are now delivering the full potential of this technology.

Performance evaluation for digital substations

A state-of-the-art testing platform has been developed by Alstom in Villeurbanne, France, in order to evaluate the performance of protection for fully digital substations. The platform was developed to check all substation functionalities, with a focus on measurement accuracy of relays and circuit-breaker trip delays. Various protection relays, digital configurations and many substation single-line diagram arrangements can be analysed, as well as the interoperability of IEDs (intelligent electronic devices) from different vendors. For each type of protection connected to the process bus, the platform can be used to explore all characteristics in order to check for correct operation and the results can then be compared to conventional hardwired solutions. The platform generates IED inputs –

conventional or digital (IEC 61850-9-2 compliant) – and also monitors IED outputs, whether analogue trip or digital trip (GOOSE). It can also be used for customer factory acceptance tests and for final testing before dispatch to a project or a demonstration. The testing platform serves to prove and optimise the solution. Customers who have already benefitted from the platform include Endesa (Spain), which tested its prototype architecture, and Energinet (Denmark), which attended the factory acceptance test for its MiCOM P546 and COSI-CT system.

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