The journey toward truly intelligent substations

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DIGITAL SUBSTATION DIGITAL TWIN
INTERNET OF THINGS (IOT)

In line with the so-called fourth industrial revolution, traditional energy network substations are evolving into digital substations, with major breakthroughs that may provide enormous gains for T&D utilities. Asset digitization, situational awareness and decentralized automation are examples of new valued features being incorporated.

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A combination of technology and macroeconomic factors is driving an in-depth transformation of the energy industry. To name a few: the transition toward a new mix of energy sources with greater content from renewable sources; the need to improve power delivery reliability and quality; and pressure to reduce operating expenditures on network assets. The resulting challenges for the electrical grid include integrating distributed energy resources, adjusting supply and demand in real time, enhancing overall equipment performance while minimizing service downtime and blackouts, and so on. In consequence, next-generation electrical grids are becoming more complex and, thus, need to be more and more intelligent to cope with bi-directional flows of energy and information. This can be achieved by adding monitoring and diagnostics devices and smart software tools.

Electrical substations are at the core of this evolution. Being the critical nodes of the energy highways, “it is clear that, in order to make the grid more digital and intelligent, we need to start with making substations not only digital but intelligent, too,” says Javier Lopez, Senior Product Marketing Leader at Grid Solutions. “And this is what Grid Solutions has been doing in recent years.”

1 GE's digital substation journey: first steps

The first stage in the quest for intelligent substations consisted in "digitizing" the equipment. This means being able to interconnect these devices and to exchange data (measurements, binary I/Os, signals) among them by using a common communicating architecture. This was made possible by the arrival, at the beginning of this century, of the IEC 61850 standard dedicated to interoperable communication and data modeling for substation automation systems, based on Ethernet networks. A second development stage brought increasing integration of monitoring systems to provide substation operators and maintenance teams with clearer, more comprehensive and real-time understanding of everything that is happening in the substation: full "situational awareness." Last-generation user interfaces, such as DS Agile aView, provide the necessary graphical support to react adequately to any electrical, safety or security issues.

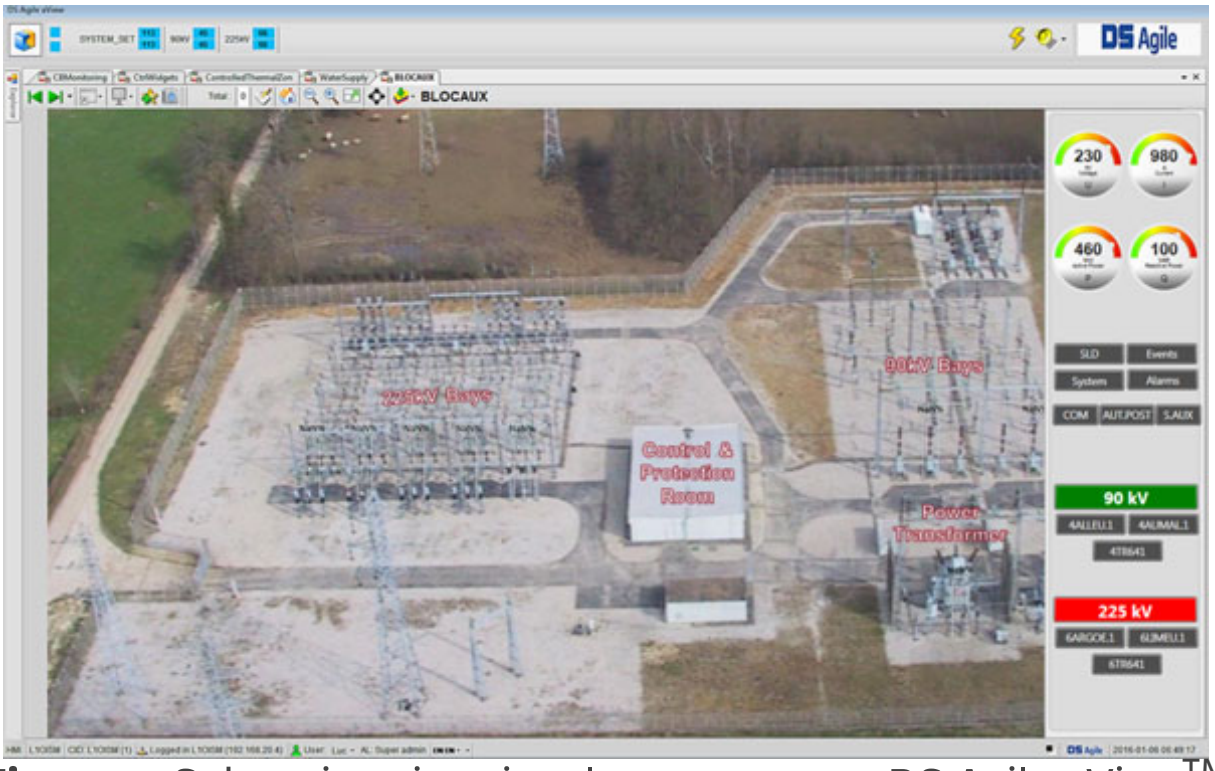


Figure 1. Substation situational awareness on DS Agile aView™

2__Modeling the substation for superior efficiency and performance

Digitizing the substation elements and dashboarding monitoring data was just the beginning of the journey toward truly intelligent digital substations. As Lopez points out, “the value chain starts with collecting and aggregating data with sensors and merging units, and sharing them across Ethernet architectures. But,” he continues, “the greater value resides in our capacity to make intelligent use of those data: applying analytics and modeling techniques, providing diagnostics and taking new operating actions.” Today, GE’s DS Agile digital control system is able to combine the insights from comprehensive situational awareness with statistics and modeling techniques, and to build a faithful replica of the substation. This is close to the GE’s “digital twin” concept, already used in the fields of power turbines and locomotives. A digital twin is a computerized model of a physical asset that can be used for obtaining state estimations, predictions and optimizations by making simulations applying the conditions and challenges the real equipment may face. Below are some of the applications that can be implemented, based on the substation’s digital modeling.

3__Predictive maintenance of assets

“Moving from reactive to predictive actions is a key benefit of GE’s digital twins,” says Lopez. “Similarly, by continuously tracking data from sensors embedded in the substation equipment, historical performance databases can be maintained for each individual device as well as for the whole substation, and

digital models can be built for predicting how they will perform over time." The predictive capabilities of the digital models combined with asset performance management (APM) software tools can help increase asset availability, ease lifecycle management and reduce spare parts inventory levels, costly downtime and operational risks for the users. The benefits for the substation owner can be very significant.

4 __ Dynamic power rating

Digital technologies can be applied to assess the expected performance characteristics of a system, given internal and external parameters and conditions. These are a combination of a digital evaluation of its "state of readiness" (based on sensor readings) and temperature, humidity, and other environmental data that can impact its performance. A use case of this is the DS Agile's smart cooling system for power transformers, which dynamically manages the cooling system of a transformer, taking into account the instantaneous power load, internal status and ambient conditions in order to optimize its overall performance.

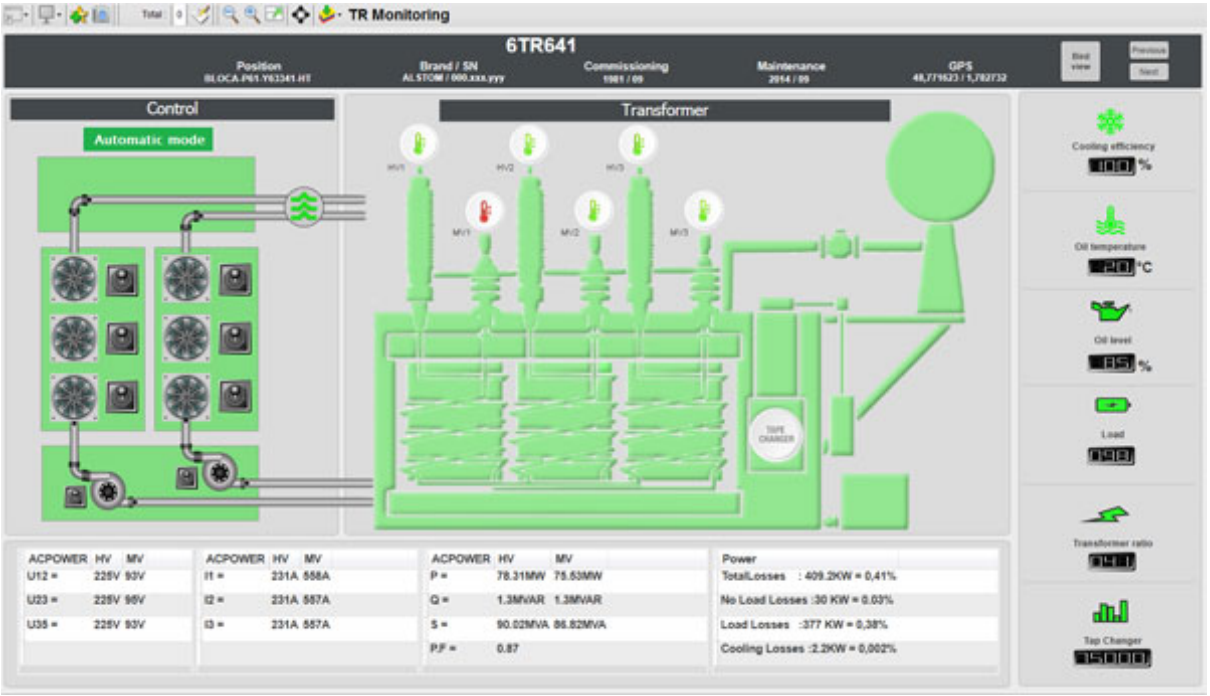


Figure 2. Real-time monitoring of a power transformer with smart cooling system

Another application is dynamic line rating (DLR), which consists of a real-time weather-based dynamic line and transformer rating software tool to adapt loading capacities to the prevailing environmental conditions (wind, rain), based on transmission line models. By calculating the lines' effective power transmission capacity (known as ampacity) under peaks of wind and enabling their ratings to be adjusted in real time, the DLR solution allows utility operators to increase the production of wind power without additional investment in new transmission lines.

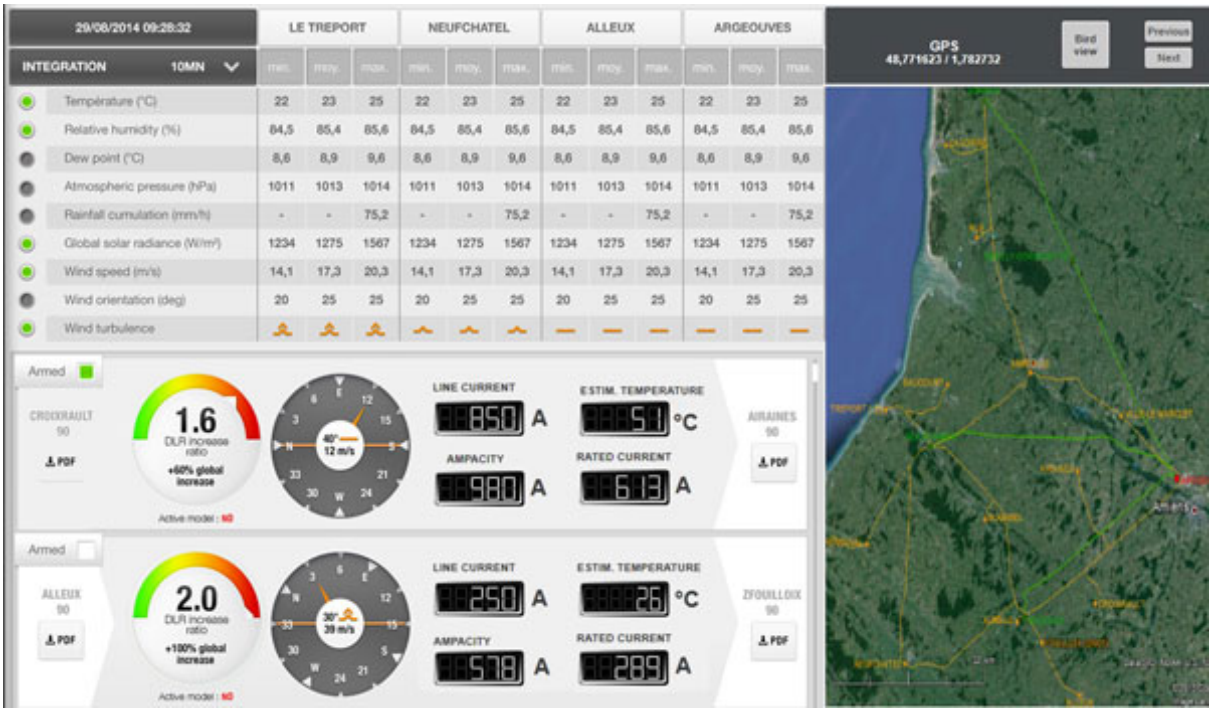


Figure 3. Prototype of DLR graphical dashboard for RTE's Smart Substation project in France

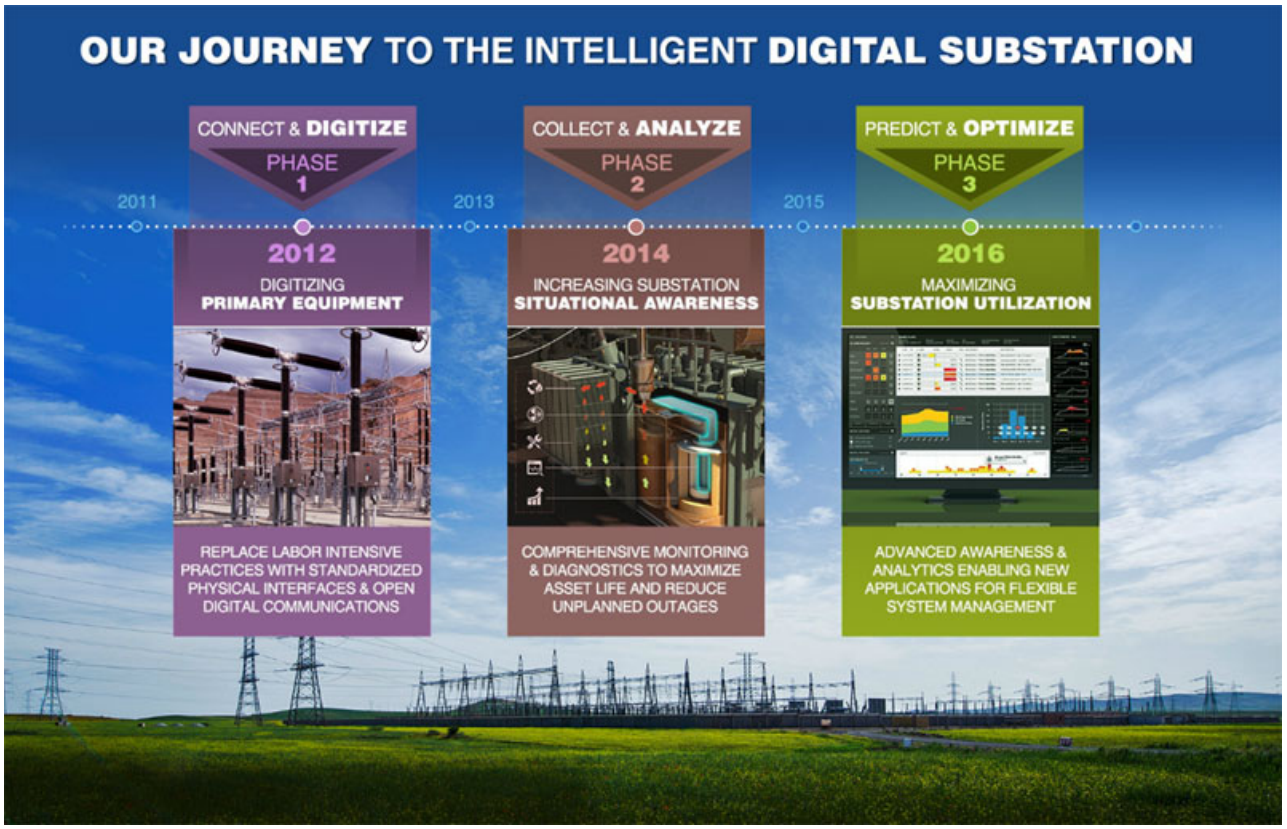
5 Wide-area automation

Digital control systems of modeled neighboring substations can be interconnected to perform automation actions at grid level too. Through inter-substation control and protection data exchange and automation functions, wide-area control units such as the DS Agile WACU offer the possibility of exchanging fast IEC 61850-based GOOSE messages (control signals) between neighboring substations without the need to transit commands via a centralized grid control room. GE's WACU can be programmed to provide smart grid solutions such as:

- fast network self-healing and power restoration from line faults
- load-shedding and islanding of critical grid areas or microgrids following grid instabilities to guarantee security of supply
- management of distributed renewable power source inter-connection
- voltage regulation and power flow optimization at a wide-area level.

6 __ Delivering high-value digital applications and services

As Lopez points out, “digital technologies are bound to transform the entire power sector value chain. At the present stage, the focus is progressively shifting from the hardware into more software applications and high-value digital services. With equipment tending to rapid commoditization, physical assets cannot provide long-lasting differentiation.” He concludes: “What will really give the edge for end users will be the ability to provide higher efficiency and productivity solutions and services by accessing, analyzing and capitalizing on the valuable data from those assets.”



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