WHITE PAPER

Digital Substations Are a Catalyst to Achieving Net Zero

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The United Kingdom's target of achieving net zero carbon emissions by 2050 will require sweeping changes to the engineering and operational approaches of electrical transmission and distribution companies. The Future Energy Scenarios 2020 report from National Grid, a U.K. electricity system operator, outlines the journey towards zero carbon emissions by focusing on investments required within each of the verticals: renewables, network upgrades, substations, energy storage, and electric vehicles. Net zero depends on moving away from traditional one-way power systems to distributed systems.

Electricity demand is expected to almost double to 96 gigawatts (GW) by 2050. To deliver sufficient supply to meet the increasing demand, the electric grid will include an increased number of distributed energy resources, such as solar photovoltaics, batteries, wind farms, tidal sources and microgrids. This will significantly change the demography of the electric grid and the way it operates, increasing in complexity, and driving transmission and distribution operators to adopt an operating model that facilitates multidirectional power flows.

As the electric grid becomes more distributed, demanding, localised and dynamic, grid operators will need to transform their systems using digital solutions. They will rely upon the availability of dynamic data, demand patterns and greater intervention at a distribution level to run a reliable, efficient and safe grid.

Moving Beyond Traditional Substations

Substations have a critical role to play on the grid as it connects the various conventional and renewable sources of generation with consumers. Traditional substations can require large plots of land and thousands of costly point-to-point copper signaling wires to connect primary systems with secondary systems. Building them demands labour-intensive construction, outage planning and a complex commissioning schedule. Traditional approaches require costly periodic testing and maintenance throughout the substation's life cycle. The equipment does not generate dynamic information such as demand patterns or consumer behaviour, which can hinder the utility's ability to carry out predictive maintenance.

To address the inefficiencies associated with traditional design, almost all U.K. transmission and distribution operators have developed strategies to convert existing analogue substation systems to digital. The next decade will witness phenomenal growth in asset replacement, as well as investment in new capacities, innovative techniques and data management. The adoption of digital substation solutions will replace thousands of copper control cables with fibre-optic communication alternatives. It will also supersede conventional copper-wound measuring equipment such as current transformers and voltage transformers with optical sensors, and congested junction boxes/marshalling kiosks will give way to slim merging units and faster Ethernet switches.

Standard Advantages

Since its release in 2003, the IEC 61850 standard has been directing the approach to digital transformation, and it has become a key reference point for digital substations, covering all aspects of substation design. Nearly all major electric utilities around the world have embraced it or are in the process of adopting it. The standard provides interoperability between various manufacturers, similar to if an individual suddenly were able to understand the dialects of every language and efficiently communicate, collaborate and undertake complex tasks.

The standard also sets out a road map to digital transformation, enhances security, and has evolved to become a way of life for utility automation. Digital substations based on IEC 61850 offer many benefits in comparison to their traditional analogue alternatives. These include:

- **Reduced cabling:** Copper protection and control cables are reduced by up to 70%. On an average substation, that would result in a reduction of more than 20 tons in materials. This will significantly reduce capital and transportation costs, as well as manufacturing efforts, both reducing the carbon footprint.
- **Compact construction:** The digital solution eradicates the requirement for conventional relays and protection equipment, resulting in an up to 50% reduction in the number of control panels. Further space savings can also be achieved through optimised engineering design using the digital assets. The net result is a more compact substation control building, reducing the overall footprint of the substation, limiting civil construction activities and generating further cost savings.
- **Enhanced cybersecurity:** Utilities were hesitant initially to implement digital substation solutions based on IEC 61850 because of potential security vulnerability. IEC 61850 was primarily created to provide interoperability and seamless connectivity between various devices inside the substation; it was not developed to provide enhanced security as a mainstream function. As a result, solutions could be compliant with IEC 61850 and yet be vulnerable to malicious communication messages — known as "fake GOOSE" (or Generic Object Oriented Substation Event protocol) — generated by hackers that could cause widespread blackouts across the grid. To address this, communication messages for digital substations have been combined with the IEC 61351 protocol to protect against such attacks. The IEC 61351 standard enables a "check for villains" approach for compromised messages and provides an extremely crucial hackproof architecture.
- **Asset management:** One of the biggest benefits of digital substations is the ability to provide data in real time to utilities' operating companies. Collecting asset data is a less rigorous exercise than it used to be. The flexibility enabled by the IEC 61850 protocol to work with third-party devices has greatly reduced the time and cost to make rich data available to inform decision-making. This results in an enhanced life cycle, increased system availability and more reliable operations. It can be used to optimise strategies for planned investment and operational and maintenance expenditures.
- **Reduced commissioning time:** As a result of standardisation and the ability to carry out some design and commissioning remotely, digital substations require less on-site commissioning time. This reduces outage time and improves system reliability.
- **Increased personal safety:** A significant advantage of digital substations is the reduced risk of contact with live infrastructure, owing to the replacement of copper cables with fibre-optic cables. Digital current and voltage transformers are significantly lighter and smaller than traditional builds. As a result, personal safety in handling and installation is also improved. Equipment blast risk due to open circuits during commissioning and substation maintenance is effectively eliminated.

Over the years, the IEC 61850 standard has received some criticism. The standard is complex, lengthy and demanding. Since its release, the standard has evolved to address various bugs and security issues. Manufacturers have adopted it into their designs, accepting the basic syntax while adding nonstandard features, which can create communication issues and complicate some aspects of compatibility. And yet, the bottom line remains that the benefits clearly outweigh perceived disadvantages.

Conclusion

The path to achieving net zero passes through digital transformation of energy networks. Regardless of what shape the energy market takes, a decarbonised economy and digital technology will be two significant contributors. Integrating various technologies and finding solutions to propel the U.K. towards a truly net zero economy strongly supports the digitalisation of energy networks, providing utilities with valuable data that enables them to respond swiftly to challenges, adopt changes and invest in the right direction.

Testing Hypotheses

To better serve its utility clients on digital substation projects, Burns & McDonnell built an Integration & Automation Lab in 2007. It serves as a testing facility for clients interested in the interoperability of software, two-way communications equipment and other automation devices associated with delivery of digital substations. The state-of-the-art facility can simulate various substation configurations based upon equipment that many utilities currently deploy, enabling testing between multiple vendors and vintages of equipment. The laboratory demonstrates how advanced information technologies can be integrated with power delivery equipment as the industry embraces highly automated systems.

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