Delivering energy transition and decarbonization with virtualized substations

The convergence of energy transition, decarbonization and grid modernization

Our team of industry experts is committed to accelerating the energy transition and advancing decarbonization of the grid through partnerships with electric utilities and market leading vendors. The following solution brief specifically addresses our co-delivered Virtual Protection, Automation, and Control (vPAC) industry solution, which provides a reference architecture and structured approach to deploying a modernized substation to support the demands of the dynamic power system.

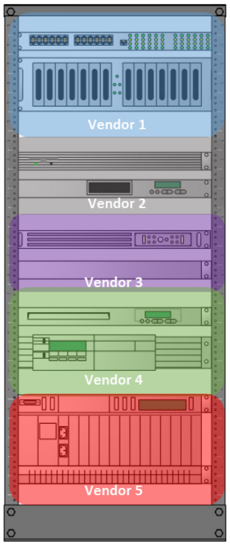
Utility virtualized protection, automation and control (vPAC) – why is it needed?

The global demand to deliver the energy transition to greener energy sources, coupled with decarbonization efforts, requires a new, virtualized architecture model for electric substation systems. The present substation protection, automation, and control systems are comprised of proprietary and fit-for-purpose hardware components which are expensive to upgrade and difficult to scale. The challenges driven by these inflexible solutions are reflected in long deployment times and higher costs for construction, operations, and maintenance.

Continued fundamental changes in how the grid is planned, designed, built, and operated are necessary to enable the energy transition and meet new distribution models. The growth of distributed energy resources (DERs) like solar, wind, electric vehicles (EVs), and batteries are making electricity demand more variable; yet existing customer expectations for reliability and resilience do not change. Therefore, the operation of the power system must rely on data from across the connected grid to rapidly and accurately forecast the generation and distribution of these intermittent energy sources, to meet demand and maintain reliability, as well as optimize the rate structure. New wholistic control, modeling, and management systems will require supporting digital platforms and tools to better detect anomalies, balance supply and demand in real-time, and maintain reliability by detecting and remediating cyber-attacks.

Figure 1. Present limitations and benefits of the digital vPAC solution.

Current Substation Architecture



- Fixed function components
- Proprietary hw/sw
- Multi vendor
- Bare metal
- Hard wired – copper
- Inflexible
- High maintenance costs
- On-site configuration and maintenance
- Expensive and disruptive refresh/ replacement process

Virtualized Substation Architecture

- Consolidation onto a standardized multi-workload platform
- Workload vendor agnostic
- Smaller physical footprint, less hardware and cabling
- Software-defined architecture
- Automated remote operations
- Faster deployment
- Reduced M&O costs

Utility companies are leveraging new technologies to meet their business objectives. Their goals include delivery of reliable and resilient digital platforms and systems to support regulatory and stakeholder requirements and to meet customer expectations. The many benefits of the transition to virtualization include improved safety, reliability, and intelligence within the substation. Nearly every industry group and authority, including the International Energy Agency (IEA), views grid modernization as the main enabler of addressing the world's climate change needs; and grid modernization starts with substation modernization. Substations are intelligence and information hubs for a utility and are thus the critical cornerstone for all aspects of the smart grid, including increasing and managing the use of renewables, DERs, EV charging, and energy storage for intermittent renewables. Without substation modernization and upgrades, the vision for the smart grid cannot be realized.

As part of the overall grid modernization efforts, this solution brief addresses specifically how to update substation architectures using hardware virtualization to support multiple workloads on a common server platform.

Limitations of the traditional electric substation, opportunities with the digital vPAC

Over the years, the underlying design and architecture of the grid has not evolved at the same pace as digital technology. The legacy architectures of electrical substations consist of custom hardware and software components, fixed-function devices and complex copper cabling connections – which result in higher operations and maintenance costs. To facilitate the growth of new energy sources, more data-driven processes, and evolving cybersecurity and compliance policies, the substation architecture that served us well for generations is undergoing and needs to continue to undergo significant changes. A more flexible, agile architecture is required to support new digital applications that enable advanced management in operations, remote support capabilities, faster application upgrades, real-time data analytics, and higher levels of cybersecurity – without sacrificing safety and reliability. Moving toward a more standardized enterprise-grade infrastructure at the substation, while retaining the same capabilities and management tools as the enterprise-grade grid operations center, is a natural starting point for the evolution of the traditional electric grid.

The vPAC Digital Substation Solution

Utilities recognize the need for optimizing and modernizing substations by building more intelligence at the edge. As more data is generated by an increased number of sensors, the key to enable our ability to continually analyze and act upon this large volume of information with minimal latency is higher processing power at the edge (substation). The journey to modern substation architecture begins with leveraging standardized, IEC-61850-3 compliant commercial-off-the-shelf (COTS) ruggedized server hardware for the substations and implementing software-defined automation and control systems. Multiple substation workloads can be virtualized and consolidated onto a single platform, making management of these workloads easier.

The following solution specifically addresses our co-delivered Virtual Protection, Automation and Control (vPAC) industry solution, which provides a reference architecture and approach to deploying a modernized substation architecture to support the demands of the energy transition.

Capgemini leading, strategic partner for energy and utility transformation

Working with energy organizations around the world to chart a course toward the future, Capgemini helps energy and utility clients take a comprehensive and holistic approach to transformation, focusing not just on building a strong technological foundation and on scaling impactful use cases, but also transforming the business itself as it relates to energy transition, low-carbon tech revolution, and consumer behaviors. This solution combines Capgemini's extensive domain expertise and business consulting services with Dell Technologies Intel based industry validated server platforms to help utility clients enable the multidirectional flow needed to seamlessly manage supply and demand across the grid, including large and small loads, and a variety of generation sources.

Dell Technologies vPAC IEC-compliant server

The Dell PowerEdge XR12 server is part of the growing Dell Technologies PowerEdge XR server portfolio. The PowerEdge XR servers, by design, are intended to operate in extreme and rugged environments, often referred to as the edge. The PowerEdge XR12 is a ruggedized, 2U server designed to optimize computing outside of the datacenter with reliability, security, and performance. It is well suited to operate at low and high temperatures in harsh or space-constrained environments and can handle the demanding processing workloads and applications typically used in the electric utilities, telecom and defense industries. The PowerEdge XR12 server with its built-in cyber-resilient architecture, is Dell Technologies response to the requirements of customers who need smaller footprints, higher performance and reliability, and lower latency for their edge computing environments. It is designed to be configurable to support electric utility business models – and their demanding applications – as well as advanced analytics. It provides powerful, high-density single socket performance in a reduced-depth form factor, which is ideal for substation application workloads. The XR12 system offers the flexibility to support both front and rear I/O port access, which makes it adaptable to the orientation required by different substation facility layouts. The XR12 is also designed to support global energy industry standards and has been tested and validated by an independent organization to be fully compliant with IEC 61850-3.

Figure 2: vPAC system with Dell XR12 rugged server

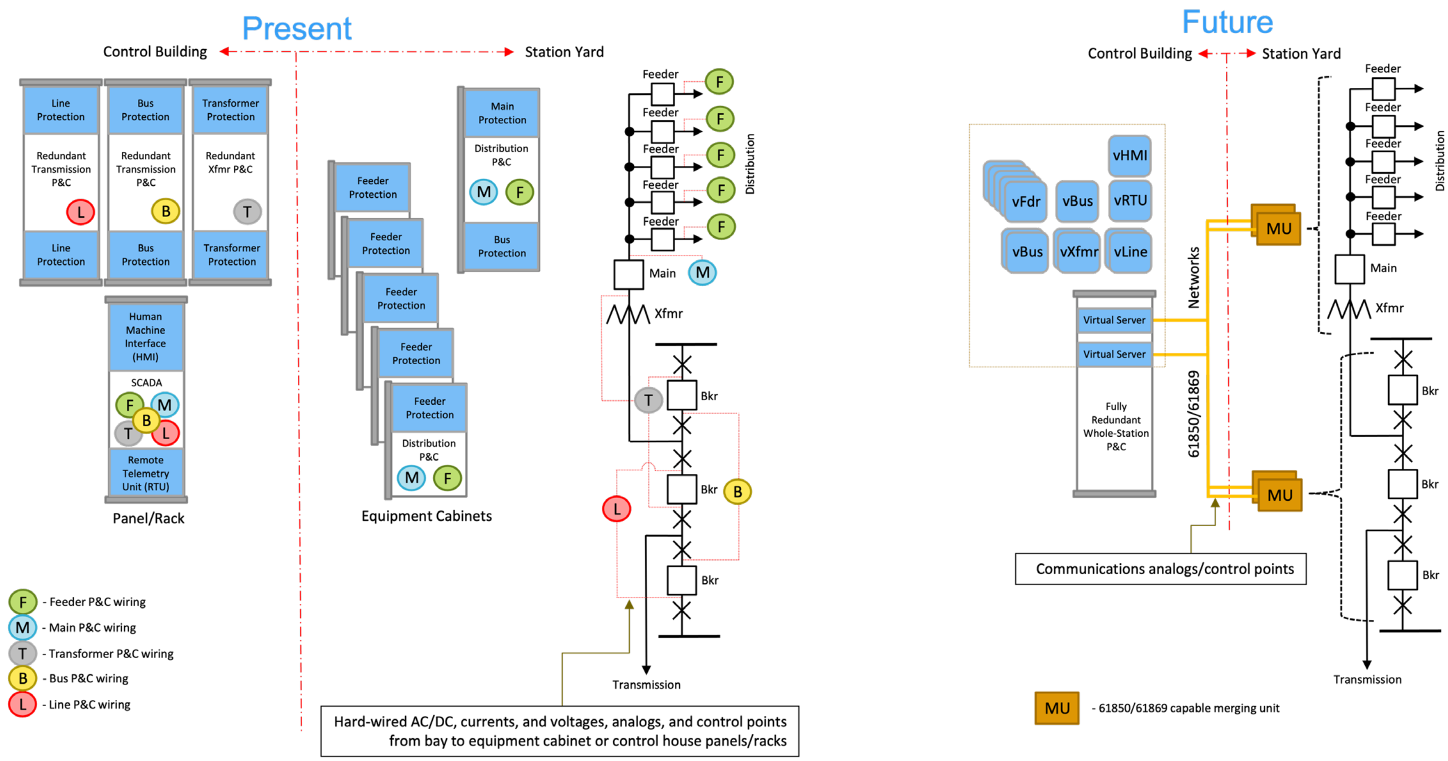
Intel® industry leadership for hardware-based virtualization support

The ability to integrate and consolidate workloads of different classes and criticalities to a common hardware platform architecture is a foundational tenet of the Industry 4.0 movement – which includes applications such as digital substations, advanced robotics, manufacturing automation, and more. To achieve this requires a true systems-view – to define set of extensions to not just the base Silicon architecture, but also to the firmware and the infrastructure software (virtualization system and operating systems) that allow for software applications to have the quality and class of resource access they need for communications, storage, and computing.

Intel has led the industry with hardware-based virtualization support (Vt-x), fine-grained control over the CPU cache utilization for applications (CAT), virtualization extensions for the PCI-express bus (SRIOV), and time-sensitive networking (TSN) support. Together, these capabilities enable the low-latency and consistent performance for critical workloads such as grid protection and control functions. In addition, deep-learning acceleration and most recently hardware-aware algorithm design for analytics give the same platform the ability to add local edge analytics to the system for improving the automation of grid functions to optimize the grid to increase resilience, as well as to use analytics to guide or automate responses if a grid protection event is detected.

These technologies are only useful if the systems of hardware and software in the substation can be trusted. Intel is an industry leader in hardware-based cybersecurity with innovations in our Software Guard Extensions (SGX) suite of security features and we work with the infrastructure and application developer software communities to enable end-to-end security for the critical applications that will be deployed in the digital substation.

Figure 3. vPAC digital substation: high-level architecture



VMware virtualization: from IT infrastructure to OT-hardened substation platform

Virtualization is accomplished via a software layer called hypervisor installed directly on the physical server. The hypervisor abstracts the physical hardware using virtual drivers that emulate the central processing unit (CPU), memory, networking, storage, and other physical devices. Virtual Machines (VMs) are supported by virtual hardware which enables multiple operating systems to run simultaneously on the same physical hardware. VMware vSphere virtualization software has become the de facto hypervisor to operate today's modern applications. This software-defined architecture for the substation (see figure 3) enables more flexibility and security while automating administrative tasks and applications deployment.

Real-time capabilities are needed to address the requirements of power management or protection software running in substations. VMware recently partnered in a co-innovation project with Intel and Dell Technologies to improve their virtualization capabilities, now allowing electric utility software found in power substations to run within deterministic, low-latency tolerances. Working together, these companies have co-developed a virtualized solution to achieve better consolidation, interoperability, and resiliency for power substations as compared to today's legacy hardware solutions.

VMware and its partners are jointly working on validating vPAC applications on Dell XR-12 servers that are certified compliant to IEC 61850-3, making them suitable for harsh substation environments. These servers run VMware Edge Compute Stack, which consists of:

- VMware vSphere, the industry-leading type-1 hypervisor. It is now capable of real-time operation to support strict, low-latency execution of real-time workloads as required by vPAC applications.
- VMware Tanzu Kubernetes Grid (TKG), VMware's multi-cloud Kubernetes (K8s) distribution for running modern applications and micro-services. TKG delivers full lifecycle management of K8s clusters and is integrated with vSphere.
- VMware vSAN, software defined storage delivering hyperconverged infrastructure (HCI) at the edge. HCI enables multiple servers to pool their storage resources and make them available to all workloads running within.

Figure 4. ABB SSC6000 vPAC Digital Substation solution

vPAC

- Full scalability of hardware and software
- Multi-vendor integration on the same hardware platform
- Remote asset and apps management through VM centralized asset management tools
- Compatible with open-source and commercial vendors for the VM layer
- Allow EPCs and utilities to utilize the same components worldwide and customize only the apps needed in the VMs/containers

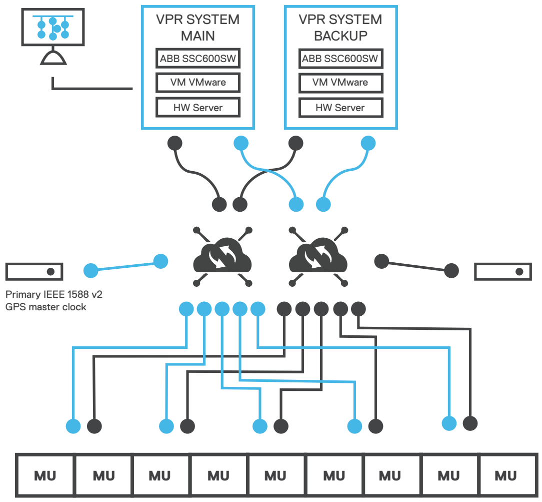


ABB SSC600 as Virtual Machine
Centralized 61850-based platform running on virtual machines with Intel® Xeon® Gold CPU up to 24 cores up to 150 bays

In partnership with:

Dell Technologies, vmware, ABB, intel XEON GOLD

ABB vPAC Solution and Systems

ABB is a leading global technology company that energizes the transformation of society and industry to achieve a more productive, sustainable future. ABB has joined this partnership to leverage their research and development capabilities in virtual protection, automation, and control functions in the electric substation. In collaboration with Dell, VMware, and Intel, they have tested and validated their SSC600 Smart Substation Control and Protection portfolio. ABB Ability™ Smart Substation Control and Protection for electrical systems SSC600 centralizes all protection and control functionality into one single software with minimal engineering, station-wide visibility, and optimal process management. Combining SSC600 with merging units creates an IEC 61850-compliant centralized protection and control solution. The modular software can be flexibly modified for the entire lifetime of the digital substation and allows SSC600 to change with the evolving grid.

Key benefits of vPAC Digital Substation

Traditional substation protection, automation, and control (PAC) systems have been reliable, but there are considerable challenges with their continued use in energy transition and transformation due to the limitations of proprietary hardware, such as deployment times and costs, lack of flexibility, maintenance, and operations costs. Implementing virtualization software on a common Intel-based server into the electric substation enables traditional PAC hardware components to be converted into software appliances. This enables the immediate deployment of multiple vendor applications and workloads on common hardware, such as the IEC 61850-3 industry-compliant Dell PowerEdge XR12 server. This virtualized platform provides the flexibility required to quickly respond to new PAC challenges in the face of a volatile, evolving grid. In addition, the PowerEdge XR12 server improves safety through the reduction of the number of physical devices, the reduction of onsite visits, and the minimization of complex cabling requirements for today's substations.

With an integrated virtualization architecture, many physical devices, and intelligent electronic devices (IEDs) can be converted to software appliances (see figure 4). This enables electric service providers to move forward with a digitally progressive and cost-effective approach, supporting multi-vendor integration solutions. Hardware platforms will no longer have to be changed every time an application changes. Instead, added flexibility will increase the ability to quickly respond to new PAC, management, monitoring, and security challenges in the ever-changing grid.

Primary benefits of this new substation architecture

- **Improve remote operations capability** by leveraging built-in remote management capabilities provided by Dell OpenManage™ enterprise systems management console and Integrated Dell Remote Access Controller (iDRAC).
- **Improve resiliency** with proactive failure detection and alarms, highly available and fault tolerant applications, live migration, automatic load balancing, restart due to infrastructure failures, redundancy in storage, and minimizing service disruptions.
- **Enhance security** with Dell PowerEdge Servers providing a cyber-resilient architecture, including supply chain assurances and a secured component verification (SCV) option.
- **Lower total cost of ownership** with VMware automation handling much of the functionality that would otherwise drive up the cost of implementing a complex, interconnected legacy microprocessor-based solution. Reduce CAPEX due to a smaller hardware footprint with hardware consolidation, and reduce OPEX due to labor reductions and lower maintenance overheads.
- **Streamline NERC-CIP compliance** with increased access to data, while consolidating the number of physical networks.

- **Progress sustainability goals** by enabling a greater percentage of renewable generation.
- **Decrease reliance** on proprietary solutions and enable choices of best of breed solutions.

Further benefits provided by the vPAC platform solution

- **Reduce number** of different hardware components
- **Conversion of individual, fixed-function IEDs** into a software-defined substation system
- **Improve safety and reduce costs** with fewer on-site maintenance visits
- **Reduce amount of copper cable** in the substation
- **Deploy or upgrade new, innovative algorithms** into the substation within minutes, without on-site intervention

The industry leading technology partners for vPAC are also co-engineering enhanced digital solutions and architectures to fully support grid modernization efforts for energy transition of electric utilities. As electric utilities transform their operating models to be more flexible, secure, and cloud-capable, our team is working together and with other industry-leading independent software vendors (ISV) to support these grid modernization initiatives. Together, we deliver digital solutions that enable grid modernization transformation from the connected remote field worker to digital substation protection, automation, and control, to integrated grid management and operations. This end-to-end integration improves results across the entire grid and results in increased reliability, security, safety, and manageability, while reducing risk, continued maintenance and operations support, and total cost of ownership.

The entire solution set portfolio can be delivered as-a-Service (aaS) to better align costs to business needs with flexible payment options to accommodate budget cycles. For electric Utilities with cloud-like strategic modernization plans, Capgemini consulting services with the Dell Technologies APEX models, provides usage-based flexible consumption models, which simplify and predicts budgeting, billing, and technology lifecycle management. This combination allows utility companies to consume best of breed consulting services and Dell Technologies innovation as-a-Service, unlocking the flexibility Utilities need to adapt and deliver the grid of the future.

CASE STUDY

A large Great Britain-based distributed network operator (DNO)

Long Term Objective: Implement a more sustainable operating model to support movement to net-zero emissions

Approach: Launched a five-year program beginning in May of 2021 to get to net-zero by 2030 by increasing the resilience of their operation, releasing capacity for more low-carbon generation, and enabling scalable deployment of smart functionality. Specifically, they plan to achieve these objectives by enhancing their substations by making them digital, inoperable, and future proof while enabling secure communication between them.

Phase 1. Trial design and procurement phase (completed)

The approach of creating a more digital or smart substation required the deployment of industrial servers to facilitate multiple software workloads. They choose Dell Technologies ruggedized PowerEdge XR-12 IEC 61850-3 compliant server and initiated an in-house test program to validate its viability for their substations. The validation steps included various functionality and performance tests. As well as understanding its remote management capabilities. After completion of the test scenarios, they approved the XR-12 server platform to support their substation modernization project.

Phase 2. Network trial and site preparation and PNDC (in progress)

The new smart substation will require more rapid deployment of new functionality from applications. This requires that the substation servers be virtualized or abstracted from the underlying hardware. Following successful server testing they developed two specific virtualized server configurations using VMware's hypervisor software. A single node configuration and a dual node configuration that incorporated VMware's vSAN software defined storage to provide a highly resilient configuration. A combination of these configurations was deployed to support testing at both grid and distributed energy resource (DER) sites in their network. Additionally, specific legacy substation functions that have been 'software defined' by both ABB and GE Digital will be deployed and tested on these servers' configurations at the Power Network Demonstration Center (PNDC), a research, test, and demonstration environment in Scotland. pndc.co.uk

Phase 3. Network testing (future)

Following a validated hardware and software platform, the project will introduce more functionality from additional software vendors to include network local active network management (ANM) for DERS and 5G site-to-site communications.

Next steps, how to get started today

The industry leading technology partners for vPAC have formed a coalition to assist the electric utilities in qualifying the essential steps as they digitally transform to better support their customers in a more sustainable energy world. Capgemini, Intel, Dell Technologies, VMware, and ABB bring a wealth of industry knowledge and experience to all aspects of the energy transition. We are identifying Utility collaboration partners to pilot the vPAC substation platform and assist in refining and enhancing the solution. We are prepared to engage in a collaboration-based project to deploy a pilot vPAC substation platform with specific testing scenarios to quantify performance metrics and application workload validations. This program includes end-to-end defined methodologies and recommendations for all hardware, software, and services to ensure successful program outcomes and reporting.

Our team of industry experts are committed to accelerating energy transition and advancing decarbonization of electric utilities through partnerships with energy providers and market leading vendors. To become a collaboration partner please contact a Dell Technologies Solutions Expert.

DELL Technologies

Dell Technologies (NYSE:DELL) helps organizations and individuals build their digital future and transform how they work, live and play. The company provides customers with the industry's broadest and most innovative technology and services portfolio for the data era. To learn more, go to **DellTechnologies.com**.

intel

Intel (Nasdaq: INTC) is an industry leader, creating world-changing technology that enables global progress and enriches lives. Inspired by Moore's Law, we continuously work to advance the design and manufacturing of semiconductors to help address our customers' greatest challenges. By embedding intelligence in the cloud, network, edge, and every kind of computing device, we unleash the potential of data to transform business and society for the better. To learn more about Intel's innovations, go to **newsroom.intel.com** and **intel.com**.

Capgemini

Capgemini is a global leader in partnering with companies to transform and manage their business by harnessing the power of technology. The Group is guided everyday by its purpose of unleashing human energy through technology for an inclusive and sustainable future. It is a responsible and diverse organization of 340,000 team members in more than 50 countries. With its strong 55-year heritage and deep industry expertise, Capgemini is trusted by its clients to address the entire breadth of their business needs, from strategy and design to operations, fueled by the fast evolving and innovative world of cloud, data, AI, connectivity, software, digital engineering and platforms. The Group reported in 2021 global revenues of €18 billion, go to **capgemini.com**.

vmware

VMware, Inc. is an industry leading company providing virtualization and software-defined infrastructure solutions enabling businesses to transform the way they build, deliver, and consume computing resources. They empower organizations to innovate by streamlining and modernizing physical operations into on-demand service(s) by pooling together assets and automating processes. VMware products allow customers to manage resources across private networks, as well as within hybrid and public clouds. At the heart of everything they do lies the responsibility and the opportunity to build a sustainable, equitable, and more secure future for all. Visit **vmware.com**.

ABB

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