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The Power of INFRASTRUCTURE MODERNIZATION

Envisioning an "Intelligent Edge" for Power Sector Digitalization

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Introduction

Global energy production and consumption are shifting from large centralized nuclear and fossil fuels to renewable energy resources. Today's grid is becoming bidirectional as distributed energy resources (DER) are connected to the power grid. Electricity is now flowing from renewable energy sources at customer premises to grid, creating new challenges for grid operators. Utility leaders are being challenged to reimagine grid operations to meet the demands of a modern global energy paradigm.

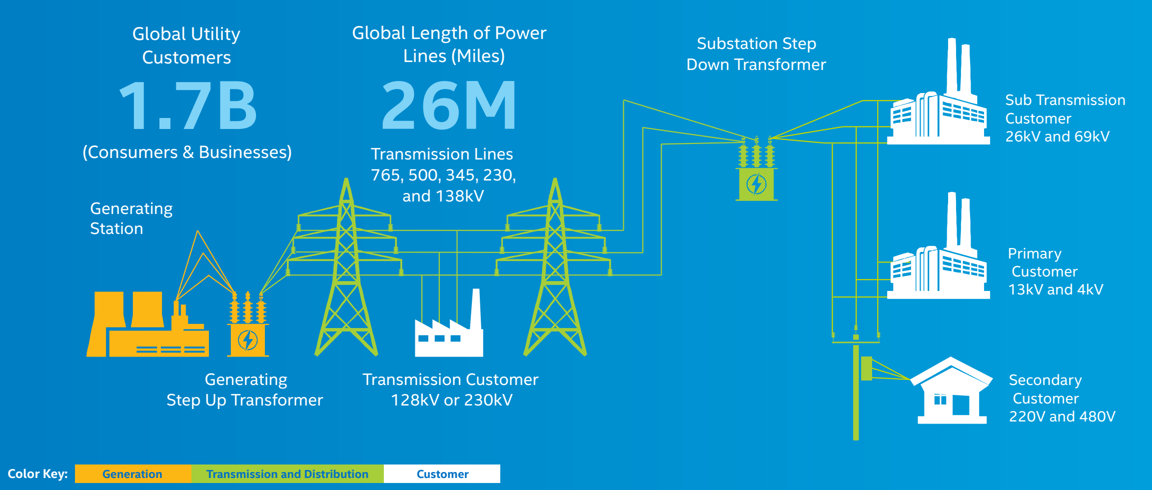
Current systems used to manage and distribute electricity are not sufficient to handle the challenges in the power grid because they were designed to handle the flow of power from utilities to homes and businesses.

Since the first centralized power grids of the 20th century came online, nearly all electricity has flowed from central power plants through a network of transmission and distribution lines. Substations at the nodes ensure the delivery of consistent electricity service to consumers.

Utility substations are now at the crossroads of a two-way flow of electricity and in the crosshairs of change. These distribution nodes have become bottlenecks when effectively integrating

> *"Most of the existing grid architecture is designed for the one-way flow of electricity from large power plants*

ELECTRIC POWER GRID ARCHITECTURE



DER into the grid and enabling bidirectional electricity flows. There is a growing consensus in the electric utility industry that most substations need to be modernized to meet the increasing demands of a global smart grid in response to calls from consumer and regulatory bodies to integrate cleaner and more sustainable energy resources.

A vast majority of primary distribution and secondary distribution substations were built decades ago. Most substations currently in service rely on systems designed to handle the flow of electricity from utilities to homes and businesses. They cannot adequately control the flow of electricity from DER to Grid.

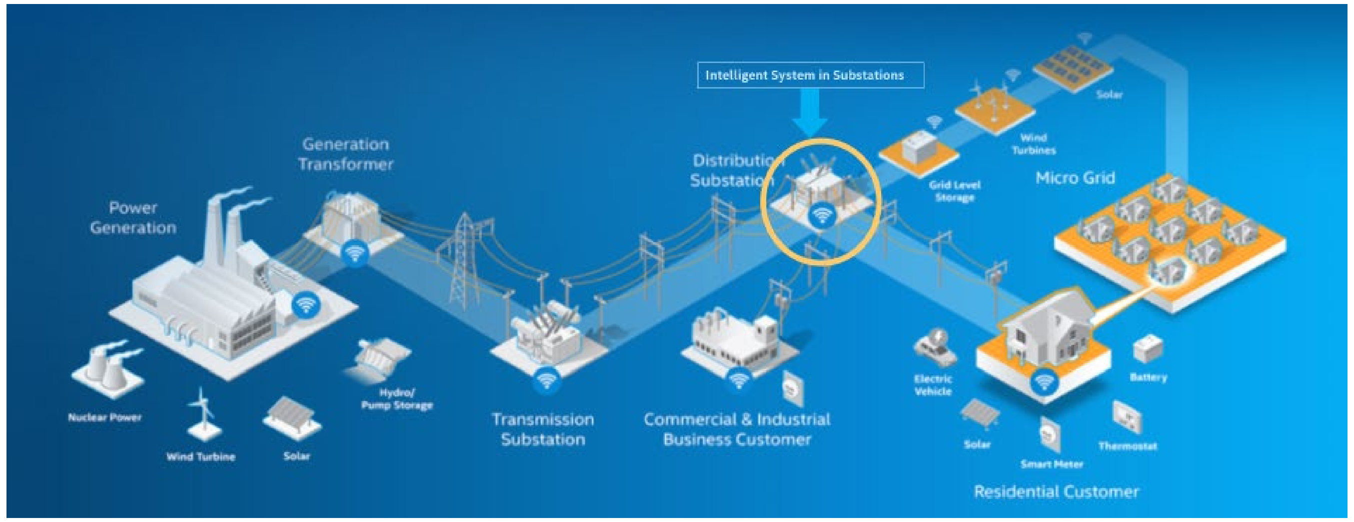
The substation technology currently in service is outdated and inflexible. Hundreds of fixed-function devices – from automation controllers and protection relays to networking and security devices – use proprietary hardware and software that requires on-site intervention for maintenance and upgrades.

These legacy systems were designed to handle distribution from central power generation plants and are not equipped for the automation and data analytics required for building a power grid with distributed energy resources (DER). Moreover, servicing and upgrading fixed feature function devices in substations is expensive and time-consuming. Every time there is a problem or the need for an upgrade, teams of technicians must be sent into the field to handle installation, commissioning, configuration, provisioning, and testing.

Modern substations need standardized systems for building a data driven grid and manage various aspects of grid operational locally along with security and manageability. Modernizing the command and control infrastructure at substations is a massive undertaking but the potential return on investment is significant. According to Anthony Sivesind, Senior Principal Engineer, Salt River Project, implementing software-defined automation and control will reduce the number of devices in a substation by 50% and result in a 76% reduction in operation and maintenance costs*

Utilities are beginning to recognize the need for optimizing and modernizing substations using an intelligent edge. The market for substation modernization is growing at more than 5%** a year as utilities replace legacy hardware and software with standardized infrastructure.

SMART GRID ARCHITECTURE INCLUDES DISTRIBUTED ENERGY RESOURCES AT THE EDGE



* ** Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.
** Marketsandmarkets 2016 and Newton-Evans 2016

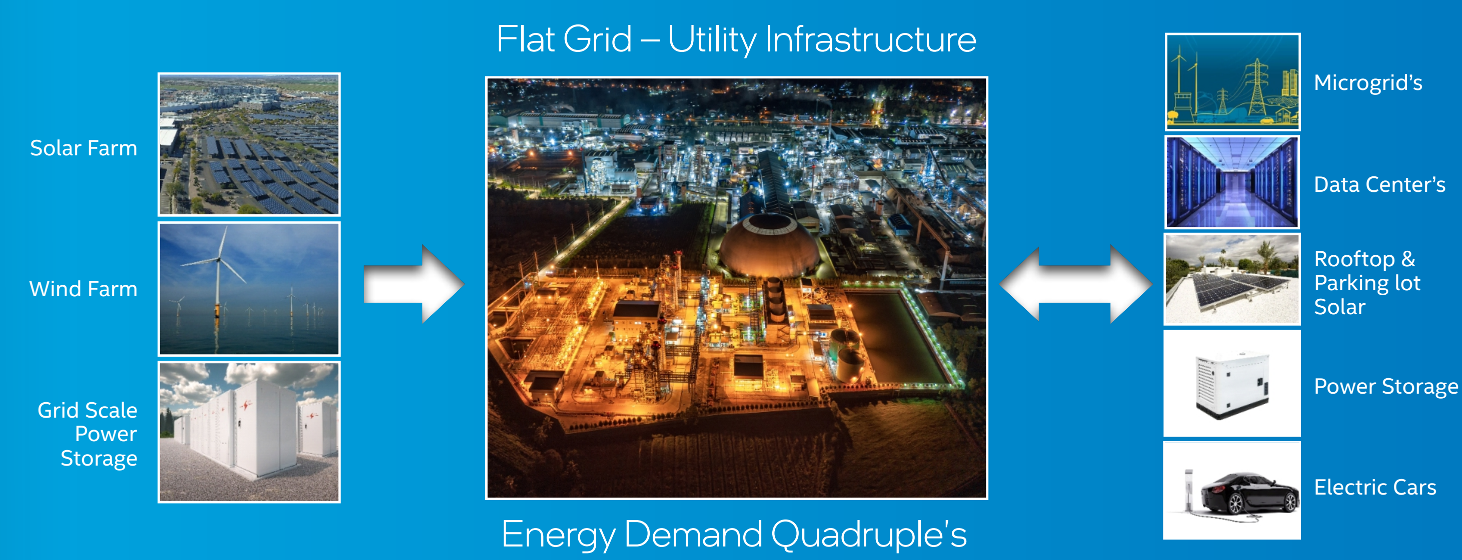
1 RETHINKING THE GRID

Modernization of the grid requires seamlessly integrating DER at the edge of the grid with an Intelligent system in the substations. The process starts with standardized hardware platforms and the implementation of software-defined automation and control systems.

The workload consolidation at substations includes making hardware independent of software and standardizing systems to help facilitate faster and more innovative, efficient solutions. This standardization replaces a waterfall approach of building custom boxes and deploying proprietary software to substations. Workload consolidation enhances a cumbersome legacy process that often takes years to develop and test a new system.

Substation modernization is being supported by Intel-based technology that enables utilities to go beyond traditional supervisory control and data acquisition (SCADA) systems.

> *“The grid of the future will accommodate both traditional power sources and distributed energy resources.*



Today, multiple intelligent electronic devices (IEDs) can communicate with each other and supervise control centers through standardized protocols. The future substation will benefit from controllers that incorporate multiple instrumentations and device control functions into one virtual IED. Virtualized applications and software can be upgraded as needed, giving utility companies the ability to use their existing IEDs as they scale substation infrastructure.

Linking objects in the physical world with automation systems requires distributed SCADA control systems equipped with remote terminal units (RTUs). These microprocessor-controlled electronic devices relay telemetry data to one of the central systems and uses messages from that system to control the physical state of connected objects.

Developing open platforms for substations helps improve reliability, safety, and security. Migrating to rugged servers that meet IEC-61850 requirements will also give utilities more secure systems that can be automated and upgraded from a centralized system. These system enhancements will eliminate the need for sending maintenance crews into the field-helping reduce installation, commissioning, operation, and maintenance costs.

Virtualization has been proven in the data center market for quite long time. Now, virtualization promises to support the development of utility automation and control systems that are more scalable, secure, reliable, and efficient. For example, virtualization of automation and control also means that it will no longer be necessary to install new hardware systems to deploy new applications. The software will be independent of hardware, reducing CapEx and OpEx costs.

“Developing open platforms for substations helps improve reliability, safety, and security.

Modernization will also enable grid operators to exploit powerful computational capacity for advanced monitoring, diagnostics, and more security. Substation automation makes it possible to aggregate and normalize data at the edge, which will help utilities understand the impact of renewables in real-time and unlock the value of data using the machine learning technologies for more profound insight.

Machine learning technologies will become the cornerstone of the digital Grid, facilitating real-time data analysis and automated decision-making at the edge. The resulting insights and operational perspectives will help optimize imbalances in demand and generation caused by variability in the supply and use of energy from DER.

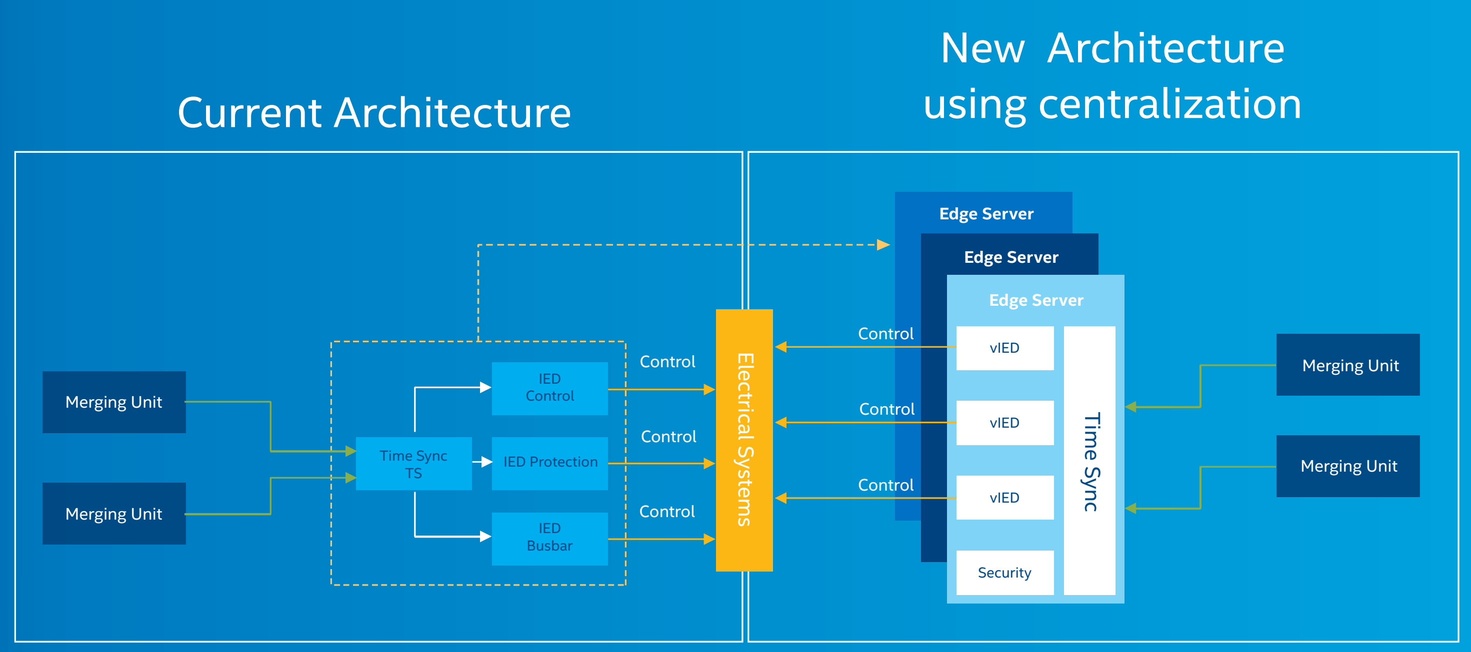
Five essential building blocks for Grid modernization include virtual protection relays (VPRs), micro data centers, secondary substations, wind turbines, and microgrids. The Grid digitalization infrastructure is an Internet of Things (IoT) infrastructure in which equipment and devices are connected to intelligent networks where real-time data analytics can provide actionable insights and automated control.

2 MODERNIZING PROTECTION AND CONTROL WITH VIRTUALIZATION TECHNOLOGY

VPRs will replace aging, often analog, electromechanical, solid-state, and microprocessor devices that are time-consuming and expensive to maintain and upgrade. For instance, virtualization can reduce the number of devices, which reduces trips to substations and reduces O&M costs.

Virtualization of automation and protection and control systems on standardized hardware will facilitate consolidation, protection, and control applications and enable self-diagnostics for optimum up-time, centralized maintenance and upgrades, flexibility, and enhanced security.

Consolidation and normalization of data at the edge will benefit grid operators by exposing deeper system performance insights through enhanced analytics. This deeper understanding will also enable machine learning algorithms to automatically manage grid functions with self-learning control systems for continuous improvement. For utilities, VPRs will help improve safety and reliability and reduce both CapEx and OpEx costs. OEMs will benefit from accelerated time to market, reduced development costs, and increased revenue from software and services.



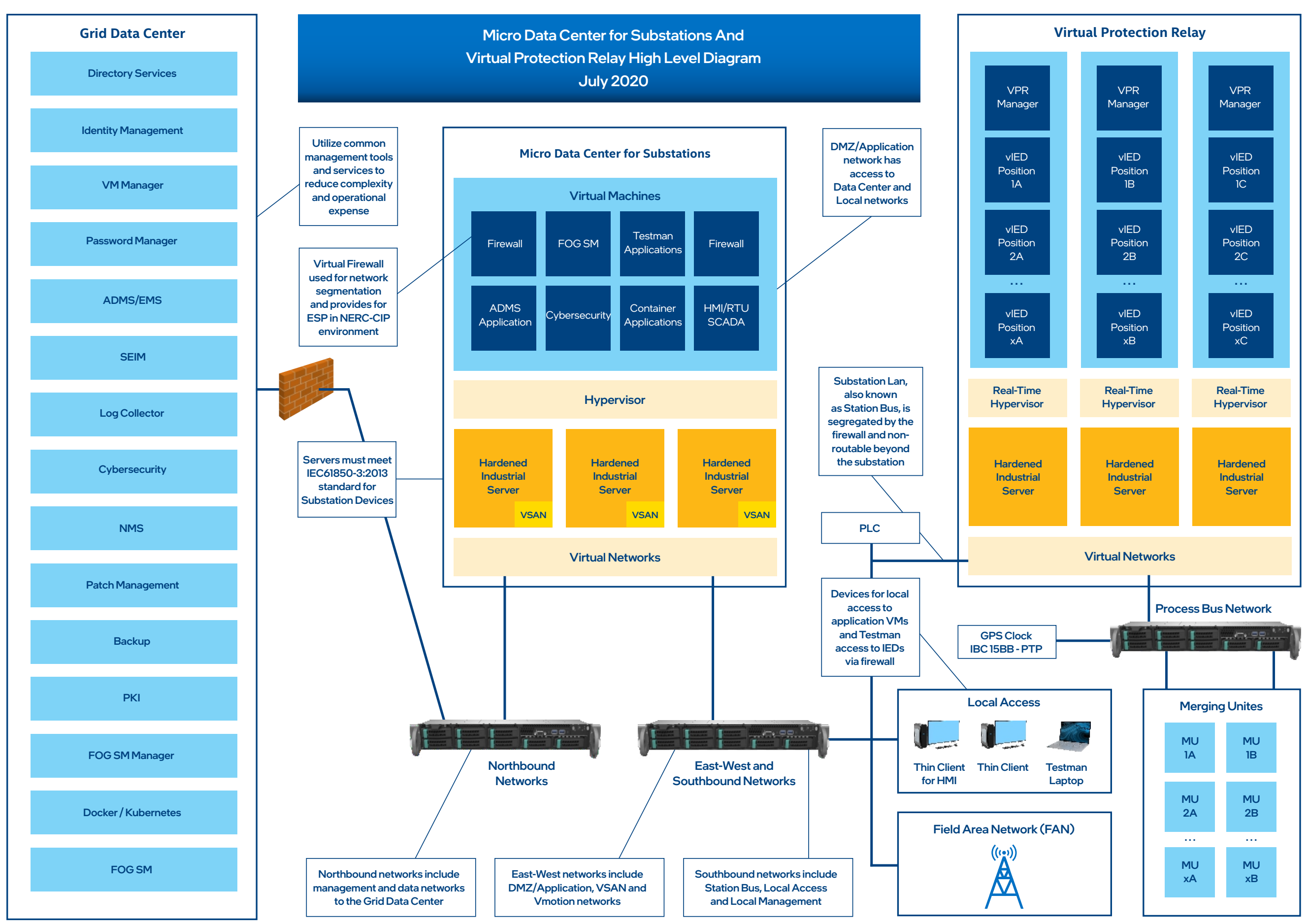
WORKLOADCONSOLIDATION WITH MICRODATA CENTER PLATFORM

More than 70,000 substations across North America currently rely on legacy systems to manage, maintain and operate thousands of devices that are part of an operational technology (OT) and information technology (IT) infrastructure. Substations need to evolve from this outmoded architecture of fixed feature devices – such as IEDs, RTUs, PMU, HMI, Firewall, switches, and routers – to a standardized system at the edge. This reimagined framework will permit the optimization and balancing of feeders in response to the large-scale penetration of DER that introduce instabilities from variations in demand and generation.

A new micro data center architecture is under development that promises to improve reliability, safety, security, and manageability. Modernization of substations includes the integration of various automation workloads into hardened IEC 61850-compliant servers running virtual machines. A micro data center virtualizes the automation and IT applications on the station bus. Introducing virtual networks can separate the traffic between virtual machines to enhance device isolation and security.

The microdata center technology being developed by Intel and its partners will enable the convergence of OT-centric and IT-centric applications into an integrated and scalable infrastructure. Consolidation means that everything from firewalls and routers to security systems and power system applications can be run on as few as two servers. Software-defined infrastructure running on the new virtualized microdata center will help optimize communications and decision-making. An intelligent substation hub will process and analyze data from multiple sources to make local decisions in real-time.

Next Substation Automation and Control Architecture



“ The new microgrid platform enables devices – ranging from routers and switches to SCADA systems and IEDs – to be consolidated in a virtualized environment.

4 MODERNIZING SECONDARY SUBSTATIONS

Utilities in Europe and the Asia Pacific use secondary substations at the edge of the grid to distribute electricity to customers. Secondary substations are responsible for delivering electricity to homes and businesses, ranging from a few hundred to few thousand end users.

More than 28 million secondary substations in service worldwide run an array of legacy hardware devices and applications. Physical constraints in these substations mean limited real estate is available for adding new hardware for every application. Moreover, it is not economical to manually replace or upgrade every device.

Intelligent edge consolidation promises to enable utilities to standardize the hardware in secondary substations. Intel, working with a consortium of industry partners, has developed a prototype with a standardized design specification. The enclosures – hardened for outdoor deployments, extreme temperatures, and humidity – include slots for two compute modules, a power module, and a switch module. Up to six additional I/O modules can be added for application-specific use, and networking is facilitated with an RGMII Ethernet backbone.

Intel's secondary substation prototype is used to validate hardware assumptions for power-on dependability, thermal durability, and compliance with the IEC 61850-3 standard for substations. Reducing both the number of devices and the need for on-site installation will lower CapEx, OpEx, and integration costs for utilities.

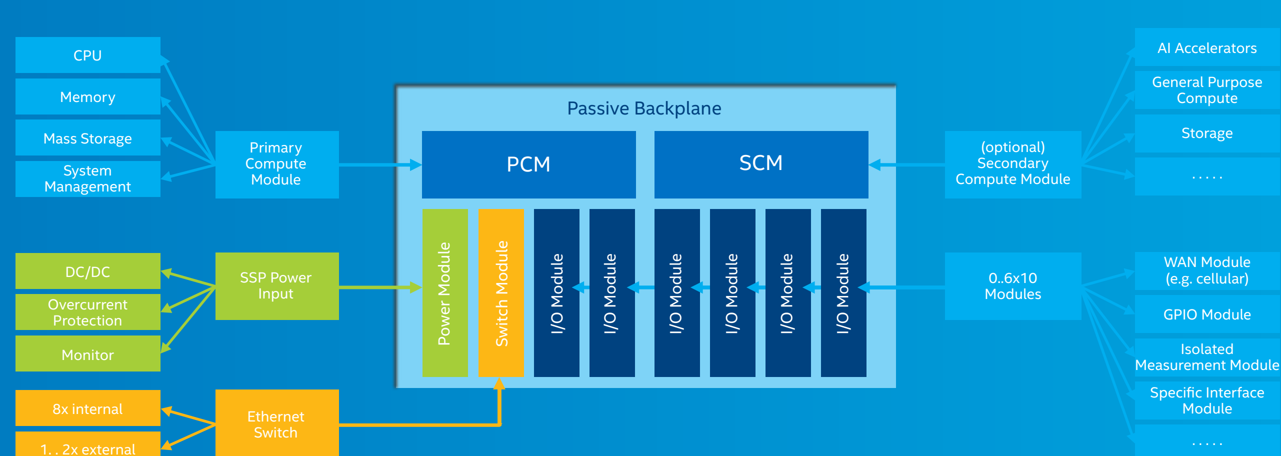
From an operational perspective, the virtualized substations will make it easier to deploy and scale new applications. Security will be enhanced through device monitoring and on-board security features in each device.

The standardized and compact hardware form factors will reduce capital expenses for substation hardware and lower service costs for operation and maintenance. Virtualization will also reduce the O&M costs by enabling the deployment of applications remotely.

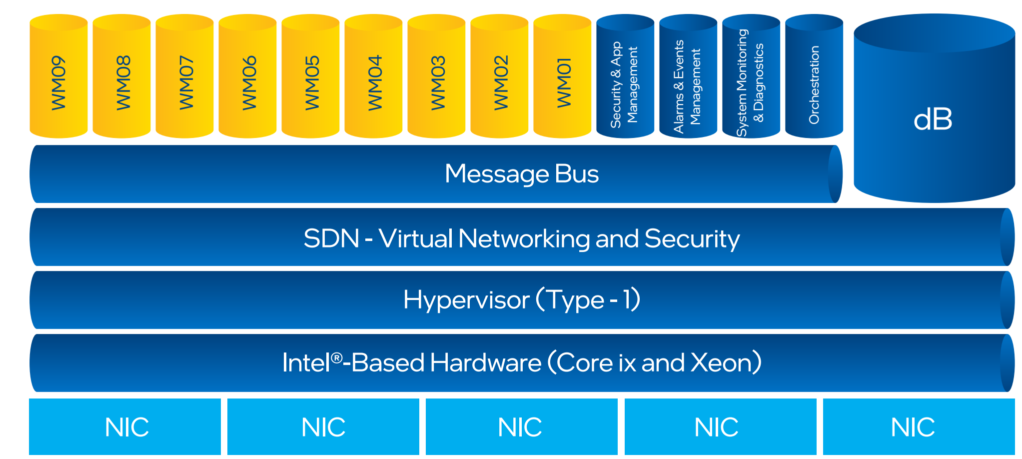
> *"The new reference architecture for secondary substations is standards-based and flexible.*

Electrical Concept

- 2 slots for compute modules (PCM and SCM). PCM is master
- Power Module (PM) and Switch Module (SM) required in all configurations
- Up to 6 I/O Modules for application specific use
- Ethernet (RGMII) backbone via passive backplane



Secondary Substation Digitalization using the Virtualization Technology



5 VIRTUALIZATION TECHNOLOGY IN WIND TURBINES

Workload consolidation in wind turbines is like the virtualization of protection & Control systems in substations. Wind turbine controllers share many similarities with utility substations, including various proprietary fixed-function systems and vendor locks. Servicing individual turbines requires sending crews into the field, where technicians often must work 295-feet in the air.

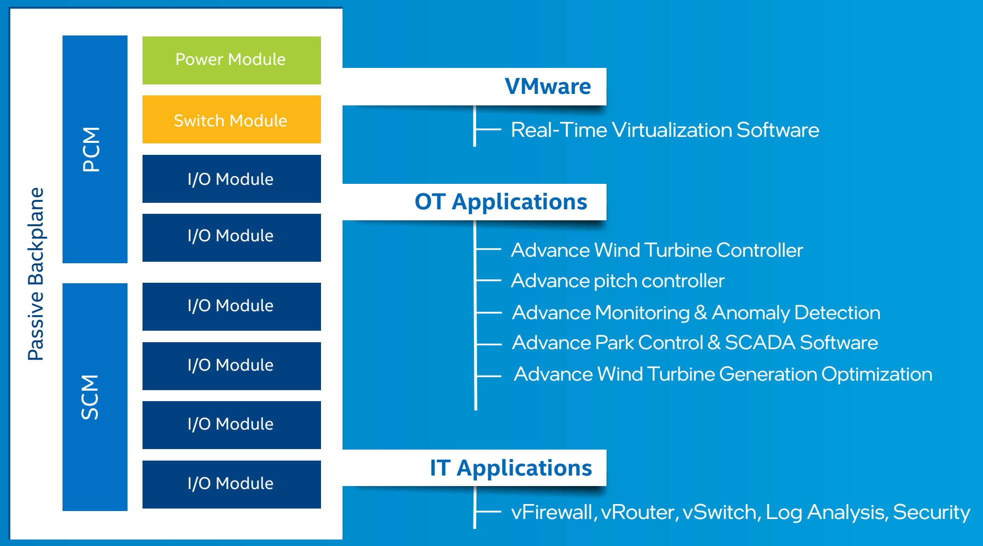
But now, virtualization of turbine control systems promises to improve operation and maintenance, efficiency, and security. Wind turbines have multiple control systems that can run on a cluster of servers in a distributed fashion. The key is to make these systems more secure and flexible by replacing the half dozen or more fixed feature function boxes with virtualized applications running on standardized hardware infrastructure. Everything from turbines pitch controllers to SCADA and analytics systems can run in virtualized environments.

For example, a two-server stack can be used to streamline turbine control systems. The Wind turbine control system will be implemented using an open architecture capable of adding applications as needed. In addition to reducing the operation and maintenance cost, a virtual wind turbine controller facilitates the ability to aggregate system data, normalize it, extract insights, and apply real-time analytics for maximizing performance for generation.

Standardization also will facilitate automation and give wind turbine farm operators the ability to deploy whatever software they prefer, regardless of which OEM supplied the turbines. More flexibility means that operators can customize their wind farms to meet specific performance objectives and integrate their networks into the grid.

“Wind turbine modernization includes virtualization of OT and IT applications.

Wind Turbine Control Digitalization using the Virtualization Technology

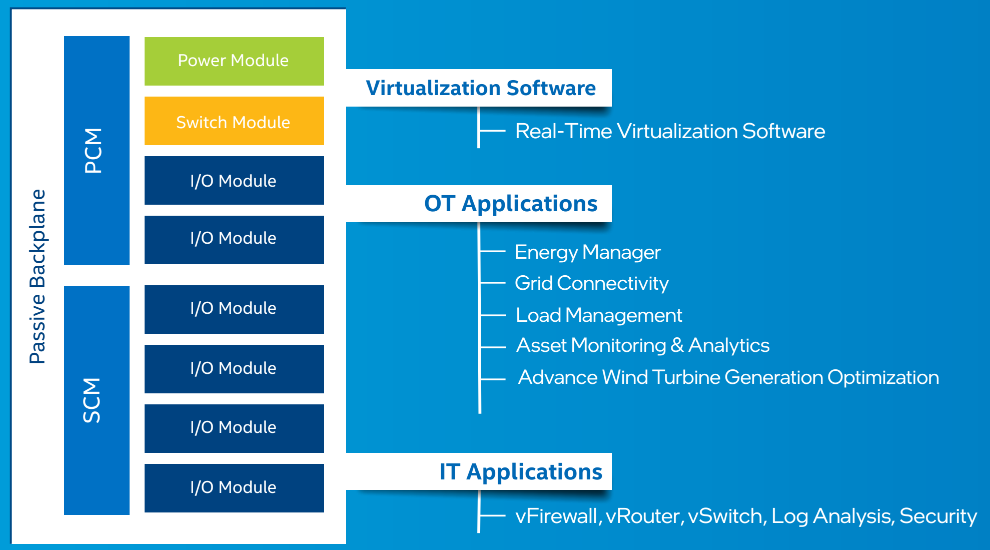


6 STANDARDIZING MICROGRIDS WITH VIRTUALIZATION TECHNOLOGY

The Microgrids include power generation resources – such as solar panels, wind turbines, fuel cells, generators, and storage devices. These islands of power generation can be coupled with the primary grid in microgrids or isolated off-grid applications. Microgrids can lower energy costs, supply resilient power for mission-critical business operations, and provide clean, sustainable energy. Realizing the full potential of microgrids requires a

“Realizing the full potential of microgrids requires a standardized command and control platform that separates hardware and software in a virtualized environment.

Microgrid Control Digitalization using the Virtualization Technology



standardized automation and control platform that separates hardware and software using the virtualization technologies, much like the design of new media for protection & control for substations.

The microgrid platform enables workloads – such as power resource management, grid connectivity, load shaping, and automation and controls – to be consolidated in a virtualized environment.

Standardizing on a virtual platform will enable microgrid operators to benefit from more efficient system management and control strategies. It also will facilitate the ability to adjust based on insights from real-time local and public data. Moreover, standardization will streamline control loops to enable seamless transitions between grid-connected and island modes.

Instead of relying on multiple applications running on incompatible hardware platforms, modernized microgrids will use standardized hardware with virtualization software to consolidate applications running on a multi-tasking platform with various servers. Virtualization will enable the use of separate, isolated environments in which each application has its operating system (OS), resulting in higher reliability and increased resilience against hardware failures.

Workload consolidation facilitates the development of microgrid architecture that reduces the number of devices, enables software-defined networking, and provides the capability for real-time analytics. Reducing the number of devices also helps enhance security by helping reduce the threat footprint for microgrid devices.

Virtualization enables the consolidation of OT and IT applications

Standardization reduces the cost of deployment as well as reducing CapEx and OpEx costs. It also provides an infrastructure that is flexible, scalable, more secure, and facilitates machine learning technologies for analytics.

From a business perspective, workload consolidation accelerates the rate of innovation at the edge. The ability to harness real-time data yields enhanced insights into microgrid operations. In addition to facilitating automation, modernization helps improve efficiency, reduces maintenance costs, and, ultimately, helps maximizes the microgrid's power generation potential.

CONCLUSION

Modernization of the utility infrastructure is being driven by IoT solutions that enable the convergence of IT and OT, harness the power of artificial intelligence, and facilitate the ability to process data at the edge.

Workload consolidation is the key to moving from legacy systems to fully virtualized application environments. Hardware – such as Intel® Xeon® Scalable Processors, Intel® Arria® 10 FPGAs and SoCs , 3D XPoint memory modules, Intel® Movidius™ Vision Processing Unit (VPU) accelerators, and Intel network interface cards – will provide the foundation for virtualization.

The benefits of workload consolidation include improved reliability and reduced total cost of ownership. Virtualization will enable fast time to market and reduce OpEx and CapEx costs.

Smart Grid technology will virtualize everything from distributed automation and control systems and relays to human-machine interfaces and programmable logic controllers. Successful virtualization of the data center marketplace over the past decade underscores the potential for transforming the utility sector.

Grid modernization requires a significant upgrade of existing utility infrastructure and will require collaboration between utilities, regulators, policymakers, and, of course, the private sector. The sustainability of the energy sector depends on grid improvements that reduce carbon emissions, support the electrification of transportation, and facilitate the incorporation of distributed energy resources at the edge.

As the energy sector embraces digital transformation, it will evolve from an analog framework to a new digital standard. Applying virtualization technologies to automation and control systems will require collaboration and innovation. The result will be an intelligent ecosystem that typifies a Smart Grid.

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