DELL Technologies

WHITE PAPER

Efficient Grid Operations

REDUCING SCOPE 2 EMISSIONS WITH VIRTUALIZED SUBSTATIONS

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I. Executive Summary

This white paper discusses the sustainability impact of Dell Technologies virtualized substation solution. The Dell Enterprise Infrastructure Planning Tool (EIPT) is outlined and used to estimate the power consumption of several configurations of the Dell Rugged PowerEdge XR12 server that is used in Dell's implementation of the Virtual Protection Automation and Control (vPAC) industry solution. This paper analyzes configurations most likely to be used for the ABB SSC600 (Smart Substation Control) protection software, to draw a comparison between the consumption of virtualized relays and their traditional counterparts. The results indicate significant reductions in estimated consumption per relay, which can be translated to lowered demand on critical grid infrastructure. The improved efficiency of a virtualized substation decreases the energy intensity of transmission and distribution systems, bolsters energy reliability and security while reducing the scope 2 emissions.

II. Introduction

The global demand to accelerate the clean energy transition and advance decarbonization requires a new, virtualized architecture for electric substation systems. 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.

As more data is generated by increased monitoring and intelligence at the edge, the key to enabling continual analysis and to act upon this large volume of information with minimal latency is higher processing power at the substation. Implementing a 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. The Virtual Protection Automation and Control (vPAC) industry solution provides a reference architecture and approach to deploying a modernized substation architecture to support the demands of the energy transition. With an integrated virtualization architecture, many physical devices, and intelligent electronic devices (IEDs) can be implemented in software.[1] This end-to-end integration enables solution providers to move forward with a digitally progressive and cost- effective approach, enabling multi-vendor OT systems running on a common platform.

In tandem with increased reliability, security, functionality, and operational savings, the digitalized substation presents a range of sustainability benefits: improved energy efficiency, enhanced renewable energy integration, optimized asset management and fault detection, and more precise monitoring and control of equipment. Each of these benefits can be translated to a reduction in power consumption and accompanying greenhouse gas (GHG) emissions.

III. Problem

As global efforts to reduce greenhouse gas emissions intensify, accurate emissions modeling and prediction have become essential in bolstering claims of sustainability advantages. The Dell Technologies Product Carbon Footprint (PCF) Initiative is a program aimed at quantifying and reducing the environmental impact of Dell's products throughout their lifecycle. By meticulously measuring and addressing carbon emissions associated with manufacturing, usage, and end-of-life disposal, Dell is committed to minimizing its products' carbon footprint and advancing sustainability in the technology industry.[2] Life Cycle Assessments (LCAs) and Product Carbon Footprints (PCFs) provide customers with specific insights into those effects and enables more informed purchasing decisions.

This white paper presents the results of a study focused on quantifying the sustainability benefits offered by Dell's vPAC solution, following the standard procedure and tools used to calculate the carbon footprints for other Dell products and solutions.

(1) Delivering energy decarbonization - Dell Technologies Partner Portal. https://www.delltechnologies.com/asset/en-us/solutions/infrastructure-solutions/briefs- summaries/dt-sb-substation-virtualization-solution-overview.pdf.

(2) Advancing Sustainability | Dell USA. https://www.dell.com/en-us/dt/corporate/social-impact/advancing-sustainability.htm.

IV. Methods

A PCF has four parts – manufacturing, transportation, use phase, and end of life. Information from Dell's Enterprise infrastructure Planning Tool (EIPT) is used to calculate the use phase portion, which is typically the largest portion of the 'footprint' for Infrastructure Solutions Group (ISG) products. That information, along with other parameters are put into the Product Attribute to Impact Algorithm (PAIA) to produce a formal PCF.

Table 1. Configuration details for the three sizes of PowerEdge XR12 being assessed in the EIPT tool.

Quote Reference		PowerEdge XR12 Small	PowerEdge XR12 Medium	PowerEdge XR12 Large
Processor (Qty 1)	**Type**	4310T	4314	6312U
	Cores	10	16	24
Memory	**DIMM Size (GB)**	16	16	16
	Qty	2	4	8
	Total Memory Size (GB)	32	64	128
Processor (Qty 1)	**Size**	480 GB	480 GB	480 GB
	Qty	2	2	2
	Size		960 GB	1.92 TB
	Qty		2	2

Each of these three configurations - small, medium, and large – also include one Dell PowerEdge RAID Controller (PERC) H755, two 800W PSUs, one x710 4x10Gbe I/O, and six HP fans. These components are considered when building the models in the EIPT tool.[3]

To assess the sustainability impact of the vPAC solution, as compared to a traditional substation configuration, we must compare the PCFs of both the traditional configurations and the virtualized configurations that are based on ruggedized XR12 servers. To assess the projected power consumption and accompanying carbon footprint of the XR12 and draw this comparison, we used the EIPT and PAIA tools that are described as follows.

DELL'S ENTERPRISE INFRASTRUCTURE PLANNING TOOL (EIPT)

The EIPT is a Dell Technologies tool developed to support Dell customers and Dell Solution Engineers with environmental data regarding data center configurations. EIPT was initially developed to support Dell PowerEdge Servers, Dell Storage, and Networking. As of the writing of this white paper in July of 2023, the EIPT has expanded its catalog to include most of the current product lines. The tool utilizes a drag and drop canvas approach to build configurations and employs a bill of materials for use with other tools, including PowerSizer and the Dell Quoting Tool.

(3) Debuting the Rugged PowerEdge XR11 & XR12 Servers | Dell. https://www.dell.com/en- us/blog/debuting-the-rugged-poweredge-xr11-xr12-servers/

The inclusion of all components allows the customer or Solution Specialist to calculate not only power requirements and energy usage but environmental parameters such as airflow, sound level, overall physical dimensions, and total weight plus other attributes. Derived from total energy usage, the tool calculates estimated annual energy costs and CO_2 emissions using IEA published or user provided factors depending on world region or country.

The EIPT uses the three main formulas below to calculate the Total Power Consumed, Annualized Energy Cost, and Annualized Emission.

1. ***Total Power Consumed (kW) = Sum of All Components (W) / 1000 (W/kW***

   These tools utilize component data sheet power values as well as power characterization measurements, which are provided by engineering, for each component in the system and calculate total power consumption in Watts or kilowatts (kW) depending on the magnitude.

2. ***Annualized Energy Cost = Total Power Cost (kW)* 8760 hours * PUE * Local Utility Rate***

   Each electrical utility (energy provider) has a published light use efficiency (LUE) rate to calculate your total energy cost. This equation illustrates the annualized (yearly) energy cost for a solution. The LUE provides the energy to cost rate and the local currency. Power usage effectiveness (PUE) is an efficiency factor, typically a number from 1.0 to 2.0.

3. ***Annualized Emissions (metric tons) = Total Power Cost (kW) * 8760 hours * PUE * Emission Factor***

   To estimate the annual carbon footprint, the tools multiply the annual energy footprint by the corresponding Emission Factor (EF). The EF has various units of measure, but we normalize the factor to CO_2 (in tons) per kWh of energy for our use.

PRODUCT ATTRIBUTE TO IMPACT ALGORITHM (PAIA)

Dell uses **PAIA** to perform PCF analyses. PAIA is a streamlined LCA tool developed by **MIT's Materials System Laboratory** in concert with Arizona State University, and University of California at Berkeley. The algorithm aims to provide an efficient and cost-effective estimate of the carbon impact of a system by taking into consideration important attributes of the product that can be correlated to specific activities to calculate the overall product carbon footprint, such as screen size, system weight, and annual energy consumption.

The PAIA tool conforms with **IEC 62921** requirements and uses data from participating companies and secondary emission factors from third party sources (such as Ecoinvent). Statistical analysis generates an estimate of the carbon impact at a component level together with the margin of uncertainty. PAIA enables the PCF to be estimated without the need to calculate it from scratch. The results are therefore based on hardware characteristics and may not capture the specifics of the production process. The results of the PCF analysis reflect our understanding at the time of publishing and are not directly comparable with those conducted by other parties or at other times due to differing assumptions.

PAIA's streamlined LCA only estimates the carbon impacts associated with a product's lifecycle and is often expressed as Greenhouse Gas emissions, in the form of CO_2 equivalents (CO_2E). CO_2E is a useful term for describing different greenhouse gases in a common unit. CO_2 only accounts for carbon dioxide while CO_2E accounts for carbon dioxide and all other gases, such as methane, nitrous oxide, and others.

ASSUMPTIONS

Information and Communication Technology (ICT) products typically consist of many different components and have long, complex value chains that are scattered geographically. As a result of this, assessments can be costly and time consuming to produce. Additionally, product portfolios tend to evolve rapidly which means that in-depth studies may be out of date quickly. PAIA's streamlined LCA methodology offers an easy-to-use platform to perform a quantitative evaluation of the carbon footprint of ICT products and reduces the time and cost of doing so.

Utility rates are set by electrical utility companies. While Dell tools include a default value, it is highly recommended that you ask the customer for their utility rate which should be available on their energy bill. The energy bill will reflect the currency of the country or region, and thus the tools can then display the local currency to make the customer presentation more relatable. If needed, the following site may help estimate your customer's utility rate: **OpenEI Utility Rate Database**.

Dell tools will, if not already, default to 0.399 kg CO_2 / kWh which is the average for all Infrastructure Software Group (ISG) units sold in FY23. This calculation was part of the total product carbon footprint for Dell's annual ESG report. The location for each product provided a unique carbon emissions factor, thus the average for all units sold. This is a temporary default until issues with licensing International Energy Agency (IEA) carbon emission factor data are resolved. Once the data is available for use, tools will be updated to default to the global carbon emissions factor and support selection region or country for a more refined carbon emissions factor.

For full detailed accounting of PAIA's intended uses and limitations please refer to the accompanying guidance **document**.[4]

V. Results

The EIPT tool was used to calculate the power consumption and associated emissions for the three different size configurations in Table 1, for four different workloads: maximum power, computational—operating at 30 percent and 100 percent capacity, and transactional. IO intensive workloads focus on data transfer; computational workloads focus on processing power; transactional workloads focus on database operations. In a substation, IO intensive workloads could include data acquisition from multiple sensors and devices, which require high disk and network bandwidth.

(4) Dell Technologies. (2021, March). Understanding the uses and limitations of PAIA, a streamlined LCA methodology [White paper]. https://www.delltechnologies.com/asset/en-us/products/multi-product/industry-market/pcf-lca-whitepaper.pdf

Computational workloads could include running complex algorithms to detect faults or predict equipment failures, which require high CPU and memory resources. Transactional workloads could include frequent database transactions for storing and retrieving data from the substation's database, which require high throughput and low latency.

The reference measurements from the EIPT tool are defined in Table 2 below. These values are used as variable inputs in the calculations for the results found in Table 3. The accompanying CO_2E emissions, found using the PAIA algorithm, are not highlighted in this white paper due to regional variations in both input voltages and sources of generation, but are available upon request.

Table 2.
EIPT program settings used as baseline for consumption and emissions calculations.

EIPT SETTINGS		
Power Usage Effectiveness	2	(50% – Avg)
Product Lifecycle	4	Years
Emission Factor	0.3712	kg/kWh
Local Utility Rate Factor	0.14	$/kWh
Input Voltage	220 V	AC
Temperature	25	°C

Displayed in Table 3 are the results for power consumption for a few workloads on each of the XR12 configurations defined in Table 1. The inclusion of various workloads provides a more comprehensive assessment of the potential consumption predictions for the server. For the comparison to traditional substations, we use the maximum power prediction for the most conservative estimate.

Table 3. Results of power consumption for the PowerEdge XR12 – various configurations and workloads.

Workload		Power Input (W)		
		PowerEdge XR12 Small	PowerEdge XR12 Medium	PowerEdge XR12 Large
Max Power		**195**	**275**	**367**
Transactional	100%	164	232	309
	30%	85	122	157
Computational		166	234	314

Table 4 below depicts the comparison between virtualized relays running the ABB SCC600 workload to traditional protection relays. The ABB REF615 Product Guide, under “Technical Data > Power Supply,” the “burden of auxiliary voltage supply under quiescent operating condition” is estimated to be 16 watts for a nominal workload, and up to 21 watts at maximum consumption.[5] We will use the 16 W value to draw a conservative comparison to virtualized relay consumption in Table 4.

Table 4. Comparison of PowerEdge XR12 consumption results to standard relay consumption.

	vPAC Server Configuration Sizing (n+1 redundancy)			vPAC Server Configuration Sizing (n+2 redundancy)		
	Small	Medium	Large	Small	Medium	Large
Number of compute cores	10	16	24	10	16	24
Maximum power draw (watts)	195	275	367	195	275	367
Cores provisioned for relay workload – Active	4			4		
Clustered servers for redundancy	2			3		
Combined power draw of active cores (watts)	78	69	61	78	69	61
Power draw for virtualized ABB workload (2 servers)	156	138	122	234	206	184
Virtual Relays	30			30		
Power draw equivalent for each virtual relay (watts)	5.2	4.6	4.1	7.8	6.9	6.1
Power draw for a traditional relay (Watts)	16	16	16	16	16	16
Power consumption reduction (relay workload only)	68%	71%	75%	51%	57%	62%

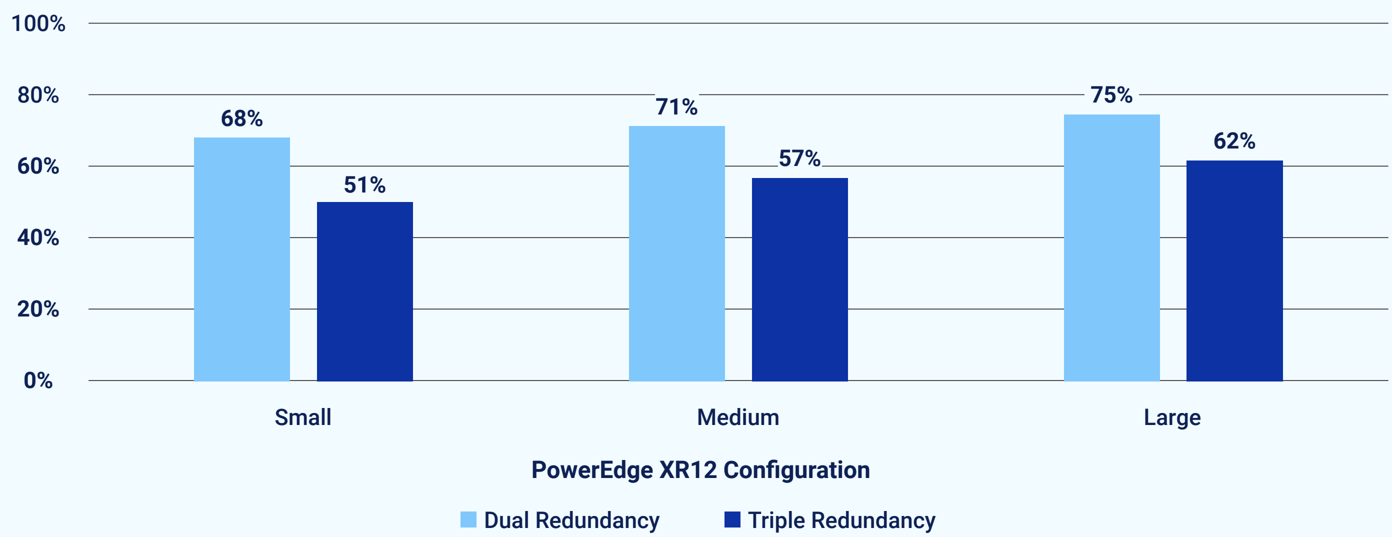
The various configurations and redundancies most likely to be used to run the ABB SSC600 (Smart Substation Control) protection software workloads are described in Table 4 above. The EIPT results for maximum power consumption were used to estimate the power draw per active core. The ABB SSC600 is a smart substation control and protection device that centralizes all protection and control functionality into one single device on distribution substation level for minimal engineering, station- wide visibility, and optimal process management.[6] According to the installation guide, the minimum compute available for the server should be four or more physical CPU cores.[7] For this assessment, the assumption was made that the power draw associated with the ABB workload would be estimated to be the number of servers multiplied by power draw equivalent of the four active cores per server. This value was then divided by 30 to account for the number of relays replaced by the virtual workload, to find the final value of power consumption per virtual relay equivalent. The power draws from the virtual relays are finally compared to the traditional draw of 16 W, and the percentage reduction in power consumption per relay for each configuration is indicated in the final row of Table 4, and Figure 1.

(5) Feeder Protection and Control REF615 Product Guide - ABB Oy .... https://pdf.directindustry.com/pdf/abb-oy-distribution-automation/feeder-protection-control- ref615-product-guide/41044-67923.html

(6) Smart substation control and protection SSC600 - ABB Group. https://new.abb.com/medium-voltage/digital-substations/protection- relays/multiapplication/ssc600

(7) Install and Configure ABB SSC600 SW VM from ESXi - VMware Docs. https://docs.vmware.com/en/VMware-Edge-Compute-Stack/services/utility-substation-vpac- ready-infrastructure/GUID-A0E5F009-6CEE-4753-9D75-A0DCE75BD65A.html

Figure 1. Estimated reduction in power consumption per virtualized relay.

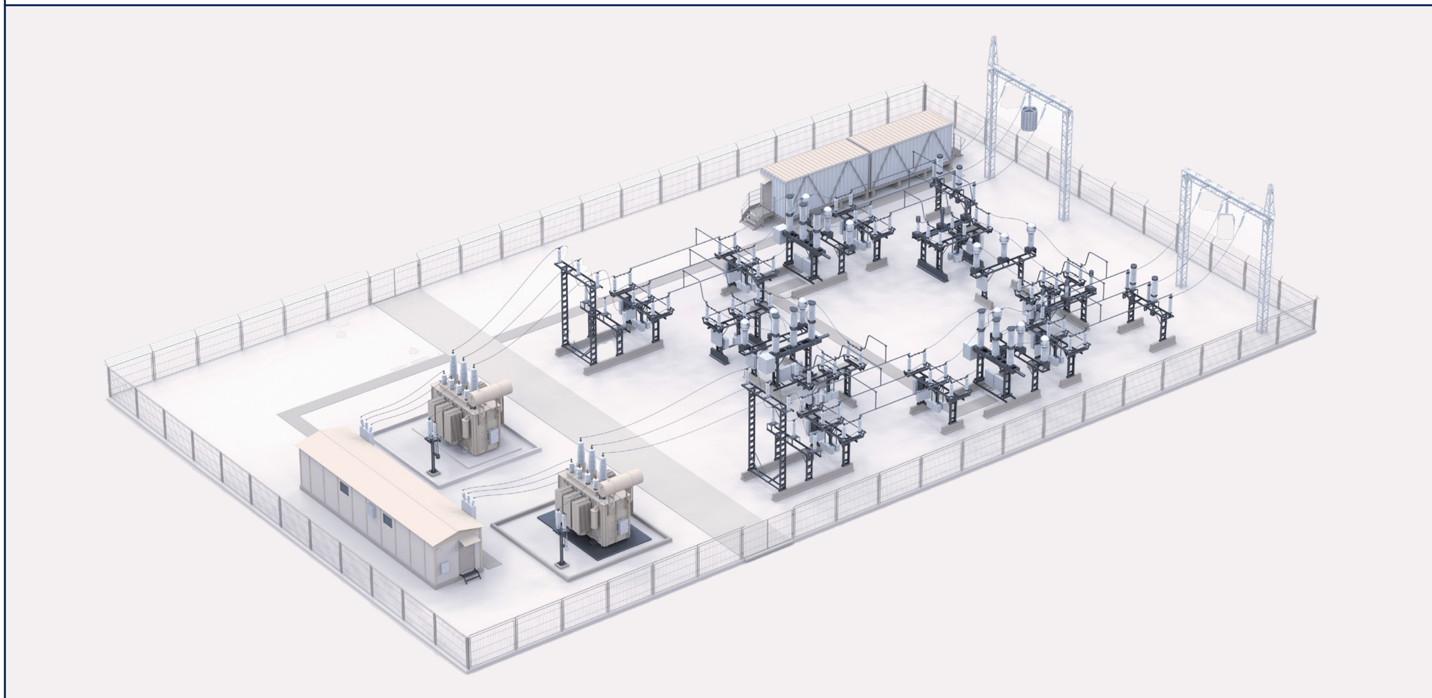


As depicted in both Table 4 and Figure 1 above, the resulting reductions in approximated power consumption per relay equivalent range from 51 percent at a minimum and 75 percent at a maximum, with reductions increasing with XR12 configuration size (number of compute cores) but decreasing with increased redundancy (number of servers). Assuming a standard dual-redundant system for the ABB SSC600 workload, operating on a 'medium'-sized XR12 configuration, the results in direct power-to- power draw per relay are an estimated 70 percent reduction in consumption, which would directly decrease the GHG emissions associated with protection system electrical consumption.

VI. The Traditional Substation

As we begin to transition into a period of substation digitalization, it's worth taking a moment to lay out where the state of substation control has been for the past several decades. As substations in the mid-20th century moved away from physical electromechanical relays as a basis of control, they moved to a system relying on individual digital relays, each tasked with the operation, monitoring, and control of an individual piece of the overall substation system. This hardware centric approach has been the norm for the past several decades, in a time when the energy landscape was less dynamic. This reality is shifting in response to the ongoing energy transition.

Figure 2. Traditional substation architecture.



A hallmark of current protection-relay based substation architectures is the repetitive nature of the individual components. Each substation device (be it a circuit breaker, transformer, switch, sensor, etc.) requires a dedicated individual device that must be monitored and/or controlled. In a moderately sized substation, this results in potentially dozens of repeated devices of the same make and model, performing essentially the same functionality, with little to no consolidation. Additionally, these devices are connected to their paired substation infrastructure using hardwired copper connections. This heavy reliance on hard-wired cabling limits upgrades due to the need for extensive re-wiring to accommodate the new system. This leads to additional outages and costs.

While the current state of the substation comes with many operational limitations, new challenges are appearing in response to the changing energy landscape that must be addressed. Substation operators must contend with the rapidly evolving landscape of distributed generation, driven primarily by renewables such as wind and solar. Changes in grid state and forecasting no longer occur slowly over the course of the day but can change minute by minute. This rise in operational complexity necessitates a change to the control architectures of modern substations, consolidating and automating wherever possible. New emerging threats such as cyber-attacks on critical infrastructure and severe weather events are becoming more common, necessitating a more resilient and secure substation architecture. Although catastrophic grid failures have been rare and localized, existing operational inefficiencies will be exacerbated as the complexity of the grid grows. The legacy substation is simply not equipped to contend with this shift.

In contrast, a digitalized substation allows for the virtualization and consolidation of workloads onto fewer pieces of hardware. Additionally, virtualization of these services can allow utilities to leverage fault-tolerant redundancy modes, bringing a higher level of reliability to the substation than is possible under the current system. The digital communication backbone (primarily optical fiber) allows devices to utilize the same communication infrastructure in the event of upgrades or future control architecture changes. Lastly, this transition to a digital substation allows for seamless future expansion, something critical for the continued integration of distributed renewable generation into the power grid.

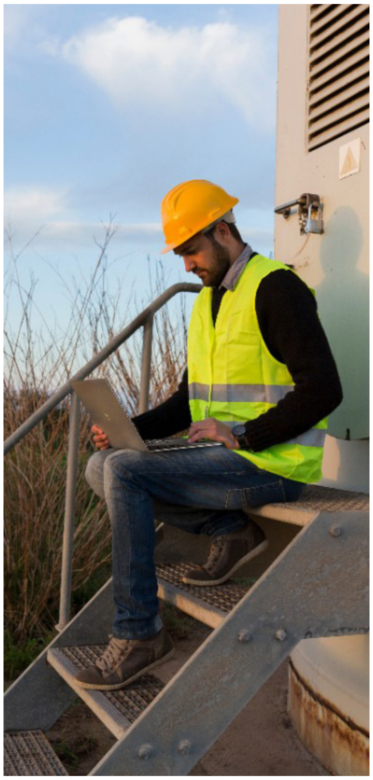
VII. Conclusion: Virtualized vs. Traditional Substation

The vPAC solution with the Dell PowerEdge XR12 provides a modernized substation architecture that supports the demands of the energy transition. The solution enables electric utility companies to move forward with a digitally progressive and cost-effective approach, supporting multi-vendor integration. End-to-end integration improves efficacy 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.

Virtualized systems inherently allow for a greater ability to remotely configure and operate substation systems, reducing the number of necessary on-site tasks. Enhanced redundancy is a key feature of virtualized systems, meaning that a server failure does not propagate into a protection system failure. The virtualization of protection systems will create a basis for further virtualization of other substation systems on the same hardware. ABB SSC600 is a relatively lightweight piece of software, allowing a great deal of additional capacity for further expansion.

In addition to these benefits, the vPAC solution presents a range of sustainability benefits. The improved energy efficiency of the virtualized substation reduces energy consumption and associated carbon emissions, as compared to traditional substation configurations. Virtualization simultaneously supports the integration of a greater volume and variety of sources of generation; a virtualized substation can accommodate more sources of renewable energy, which is essential for decarbonization efforts.

Electricity generation stands as a prominent driver of global carbon emissions. However, the carbon intensity of each unit of power is significantly contingent upon the specific composition of generating fuels within individual countries. For example, one country may derive their electricity from primarily fossil-free sources, such as geothermal and hydroelectric plants, while others rely predominantly on hydrocarbon-dense coal sources for fuel. This regional variation in fuel mix leads to variable sizes of environmental ‘footprints’ incurred by different countries as they flow through the process of generating electricity. When evaluating the carbon footprint associated with a unit of consumed electricity, it is important to recognize that it does not result in a fixed quantity of CO_2E. Instead, it should be viewed as an additional contribution to the ongoing demand on the grid—which is likely to be met through additional hydrocarbon utilization at this point in the energy transition.



The potential to optimize grid operations by utilizing the vPAC platform, incorporating virtualized substations and infusing intelligence into the grid infrastructure, offers an opportunity for substantial integration of fossil-free fuel generation sources. This integration not only reduces the environmental impact stemming from the infrastructure but also curtails the marginal contribution to GHG emissions associated with each unit of electricity consumption.

These benefits further contribute to the cost-effectiveness and sustainability of the vPAC solution with the Dell PowerEdge XR12 server. By reducing required on-site activity, power consumption, and maintenance, the vPAC solution provides a sustainable approach to modernizing substation architecture to accelerate the global energy transition.

Dell Technologies is a founding member of the **vPAC Alliance** comprised of industry leading vendors and utilities. The vPAC Alliance is an independent organization formed to help accelerate the development of a standards-based and secure architecture to support the next generation of substation modernization initiatives.

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