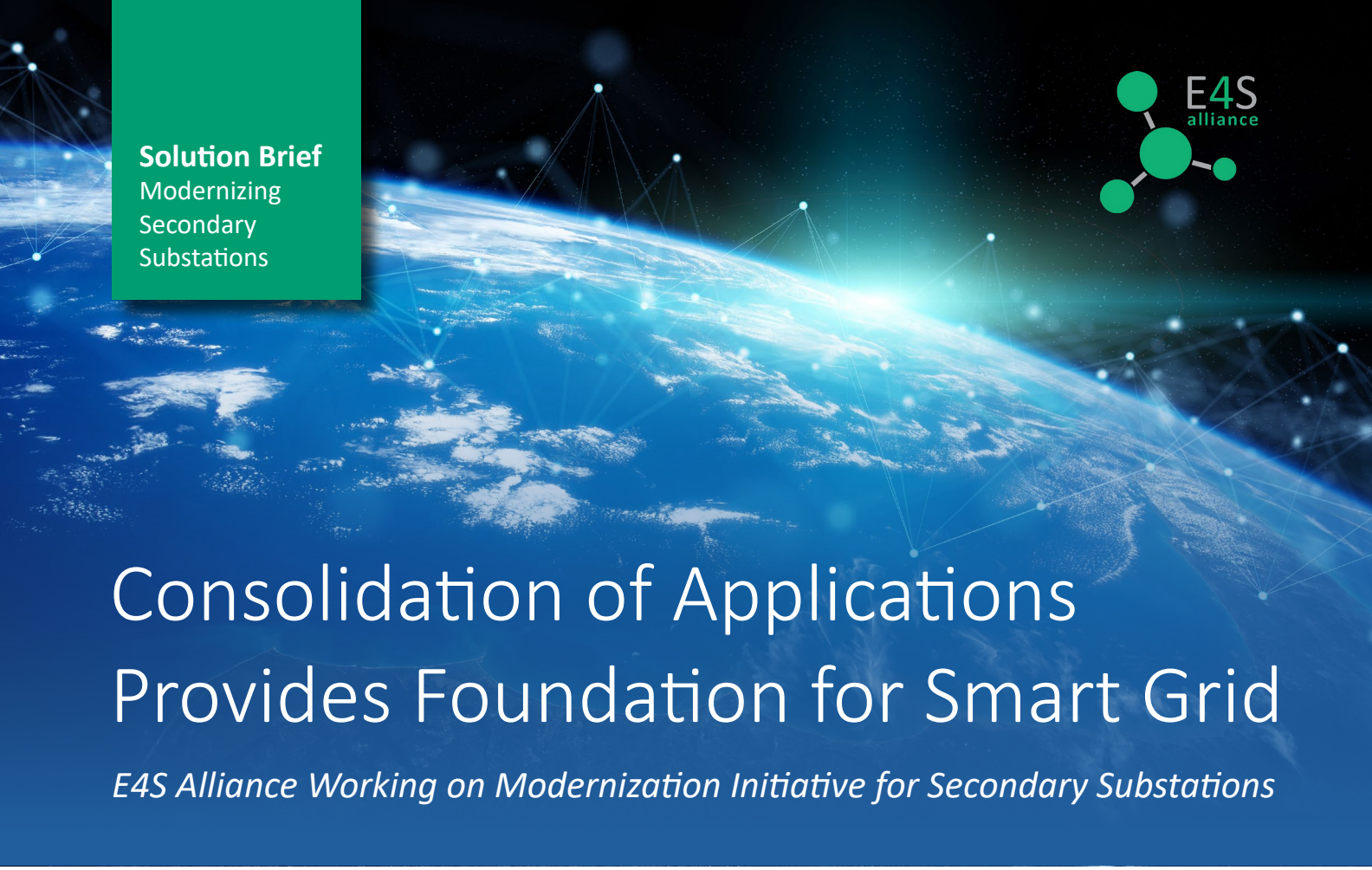


Solution Brief
Modernizing
Secondary
Substations

Consolidation of Applications Provides Foundation for Smart Grid

E4S Alliance Working on Modernization Initiative for Secondary Substations

Utilities in Europe and Asia Pacific use secondary substations at the edge of the grid to manage electricity distribution to customers.

More than 28 million secondary substations are in service worldwide with a varying level operational technologies (OT) for connectivity, monitoring, and automation, and with a large fraction having no OT at all.

But now – with the growth of renewable energy production, battery storage, and electric vehicle demand – secondary substations must address bi-directional flows, the management of load fluctuations, data collection from smart meters, and application deployment strategies.

In substations where OT has been deployed the approach has been to install a collection of fixed-function single-purpose devices. But since space is limited and the environment can be quite challenging, utilities face serious challenges as they attempt to modernize and deploy additional capabilities.

The heart of the secondary substation is the medium-voltage to low-voltage transformer, which delivers single and poly-phase low-voltage electricity to homes and businesses, (ranging from a few hundred to 1000 end-customers).

A key component in each substation is the low-voltage busbar, which handles power distribution to the array of low-voltage cables that fan out across the neighborhood. Utilities monitor the low-voltage busbar to ensure the voltage levels meet regulatory standards and to identify overload conditions. As consumers and businesses connected electric vehicles and distributed generation to the secondary grid, secondary substations need to handle bi-directional power flows which they complicate the interpretation of the voltage data and the operation of the substation.

Developing a New Reference Architecture

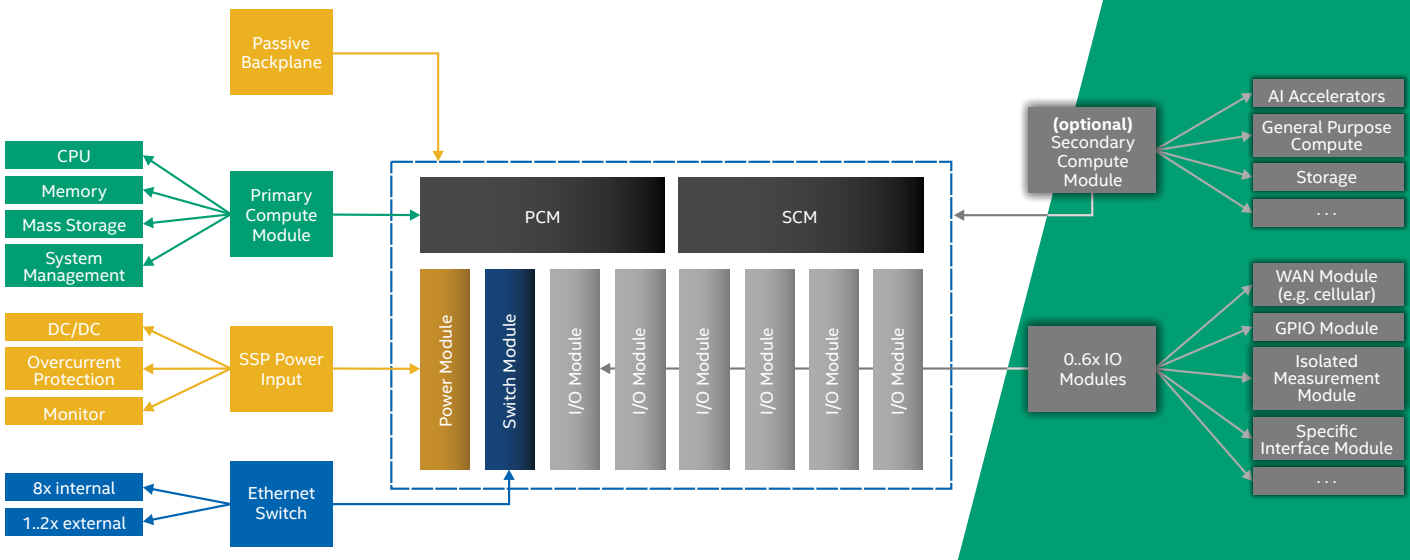
The secondary substation of the future requires a flexible, scalable, and intelligent system that can be managed and upgraded over time to meet the changing needs of the grid. Intel is working with the E4S Alliance (e4salliance.com) on a secondary substation modernization initiative called the Secondary Substation Platform (SSP) Specification (SSP Specification). This initiative includes the development of requirements as well as the prototyping of components and systems to incorporate capabilities, including:

1. Impact of DER on a distribution network
2. Low-voltage busbar monitoring
3. Remote Terminal unit
4. Protection and Control
5. Transfer regulation and monitoring
6. Demand forecasting
7. Intelligent smart meter topology analysis
8. Substation profiling
9. Advanced medium-voltage monitoring and control
10. Low-voltage outage management

The SSP concept, shown in Figure 1, enables reliability, scalability, security, manageability, and resilience by incorporating modern hardware and software practices for consolidating workloads, thus replacing proprietary hardware and siloed applications with a single integrated system.

Containerization will facilitate the standardization of the hardware and software-defined infrastructure for secondary

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

Figure 1: The new reference architecture for secondary substations is standards-based and flexible.

substations. A unified infrastructure will replace the complexity of incompatible solutions from different vendors. The SSP will be based on standardized industrial-grade hardware and applications for control, monitoring, and analysis – all of which can be managed in containerized environments. Standardization will enable utilities to deploy data-driven solutions for control, protection, and monitoring applications.

Workload Consolidation Facilitates Standardization

The E4S Alliance is developing open, interoperable standards for hardware and software. Intel has led the development of a modular E4S Alliance reference design (see Figure 2) with an entirely passive and standardized backplane and chassis for maximum longevity. The chassis connects to power, high-bandwidth communications – including Ethernet and PCI Express – and system management interfaces for networking, computing, sensor, and analytics modules. Standardization will enable hardware and software to be sourced from multiple vendors, enabling utilities to select the best solutions for their needs.

Figure 2: A rendering of a modular E4S platform, based on the E4S Alliance's requirements. The dimensions are 280mm x 150mm x 205mm. Image from Delta Electronics, Inc.

The E4S Alliance has specified a standard size for the entire platform and individual modules to enable each substation to have the optimal configuration.

Intel has built an SSP prototype to validate hardware assumptions for power-on dependability, thermal durability, and adherence to the IEC 61850 standard for substations. As a result, reducing the number of devices and the need for on-site installation will optimize CapEx, OpEx, and utility integration costs.

Pilot Program Provides Proof of Concept

Based on the market cap, Iberdrola, the third-largest electricity service provider globally, is leading the E4S consortium's grid modernization efforts. With about 60% of its total installed capacity of 52.1 million MW coming from renewable energy sources, the company is keenly interested in implementing digital technology to automate load management systems at its 250,000 secondary substations in Spain: refer to https://www.iberdrola.com/about-us/what-we-do/solar-photovoltaic-energy/photovoltaic-plant-cedillo .

Load Management

As part of the initial proof of concept, one application being ported to the virtualized environment is for load management -- to measure the net load on the low-voltage bus. This data can be combined with aggregated meter data, medium-voltage power flow measurements, and a transformer model to have greater visibility into the distributed generation and loads on the substation.

Topology Analysis

Another virtual application developed with Merytronic provides a detailed topology analysis of meter location. Topology analysis at the edge ensures the optimum placement and integration of smart meters at the customers' premises and their association with feeder-level meters at the secondary substations. An accurate mapping between these metering points facilitates data

analysis, load profiling, and supporting the utility response to outage and power quality events.

ZIV Automation is developing a meter data aggregation application for the virtualized platform that can collect the meter data using protocols such as powerline communications and then forward the data to the utility's metering system and make the data available for local processing as specified by the utility.

Together, these applications can provide real-time insights into the behavior at the edge of the network; and they facilitate the development an autonomous system for controlling the flow of electricity to and from the end user.

Outage Management

Landis+Gyr is developing a program to facilitate outage management in the low-voltage grid. The company has considerable expertise in smart grid solutions, including distributed automation sensors, load management technology, scalable meter data management system, and utility grid analytics.

Their outage management application will run on the virtualized SSP platform and periodically analyze data from smart meters, substation meters, and other sensors in the distribution grid to present a timely view of outages to the operations center with greater specificity and insight than is commonly available today.

Transformer Monitoring

The proliferation of distributed energy devices at the edge puts pressure on secondary substations to maintain steady voltage and current. The E4S Alliance pilot is implementing a virtualized application to provide effective control of secondary voltages considering the new resources coming onto the secondary distribution grid. Automated transformer monitoring will help detect and resolve performance issues and ensure temperatures are within normal operating range.

Protection, Automation, and Control

The new reference architecture being developed as part of the E4S Alliance project will result in an IEC 61850-compliant application capable of interfacing to relays, switches, and circuit breakers. The application is also planned to manage the protection, control, and monitoring systems. The IEC 61850 standard provides the building blocks for developing digital substations, including distributed I/O for protection, automated controls, and SCADA reporting.

Conclusion

Modernization of Substation OT systems holds great promise to reduce both OpEx and CapEx costs. From an operational perspective, systems based on the SSP architecture and specification will make it easier to deploy and scale new applications. Security will be improved through better device monitoring, hardware-based security, and security in-depth through the layers of the solution software.

Automated troubleshooting and load management will replace manual processes. Labor-intensive maintenance and upgrades that now require utilities to deploy a truck and crew will be replaced with a system that can, for the most part, be managed, operated, and maintained remotely.

Standardized and compact form factors promise to reduce capital expenses for substation hardware and reduce service costs for operation and maintenance. Virtualization will also reduce the amount of hardware needed in a substation and provide a more economical and scalable solution.

By the second half of 2023, the E4S Alliance plans to test its new SSP technology in one of Iberdrola's substations. The intention is to show how a standard-based, open, interoperable, and secure architecture improves substations' automation, scalability, security, and manageability.

For more information, please visit:

e4salliance.com