Cisco Smart Grid:
Substation Automation Solutions for Utility Operations

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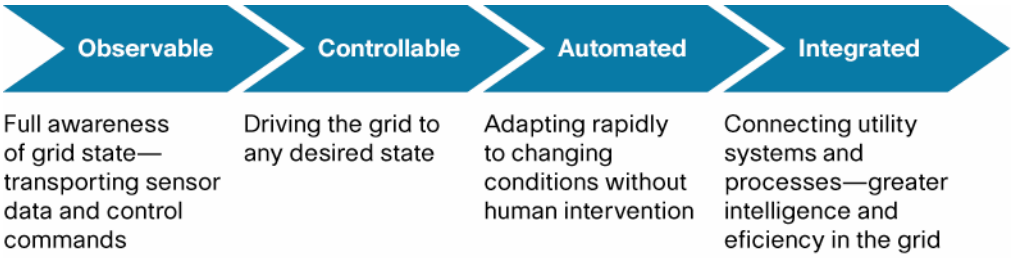
Introduction

Smart Grid promises to deliver a next generation power grid that allows utilities to manage the generation and consumption of power more efficiently. The US Department of Energy defines smart grid as "the electricity delivery system from point of generation to point of consumption integrated with communications and information technology for enhanced grid operations, customer services, and environmental benefits."

While the definition of Smart Grid is subject to interpretation, it is clear that building an intelligent communications network is a foundation to building a Smart Grid. Utilities are investing in communications networks to improve their situational awareness of grid assets in order to control, automate, and integrate systems. Value is created when utilities 'smooth out' peak load demand, forego use of costly spinning reserves, and alleviate the need for long-term capital investments in new generation plants and other capital investments such as re-conductoring for capacity improvement. Figure 1 elaborates on these key elements of a Smart Grid. It is these four characteristics combined that make a grid smart and the smart elements reside in the layer of digital superstructure that utilities add to the traditional and modern grid analog infrastructure that provide the platform for advanced grid functionality.

Figure 1. Elements of a Smart Grid



A Brief Introduction to Cisco

As the worldwide leader in communications networking, Cisco builds network infrastructure for global enterprises, governments, and service providers worldwide. Over the past 25 years, Cisco has helped several industries transition from proprietary networks to standards based communications. In the late 1980s and early '90s, Cisco developed solutions to transport proprietary protocols such as IBM SNA over IP networks. These helped companies migrate to IP at their own pace without having to forklift upgrade their entire communications networks.

Starting in the late 1990s, Cisco began offering IP Telephony solutions which transported voice communications over IP networks. Some enterprises were skeptical of IP telephony due to concerns over latency and reliability of packet switched networks. Today, IP telephony is the predominant form of voice communications in enterprises. Voice, video, and data communications have converged on to a common IP network which has helped enterprises drive down operational expense and reduce overhead from maintaining separate networks.

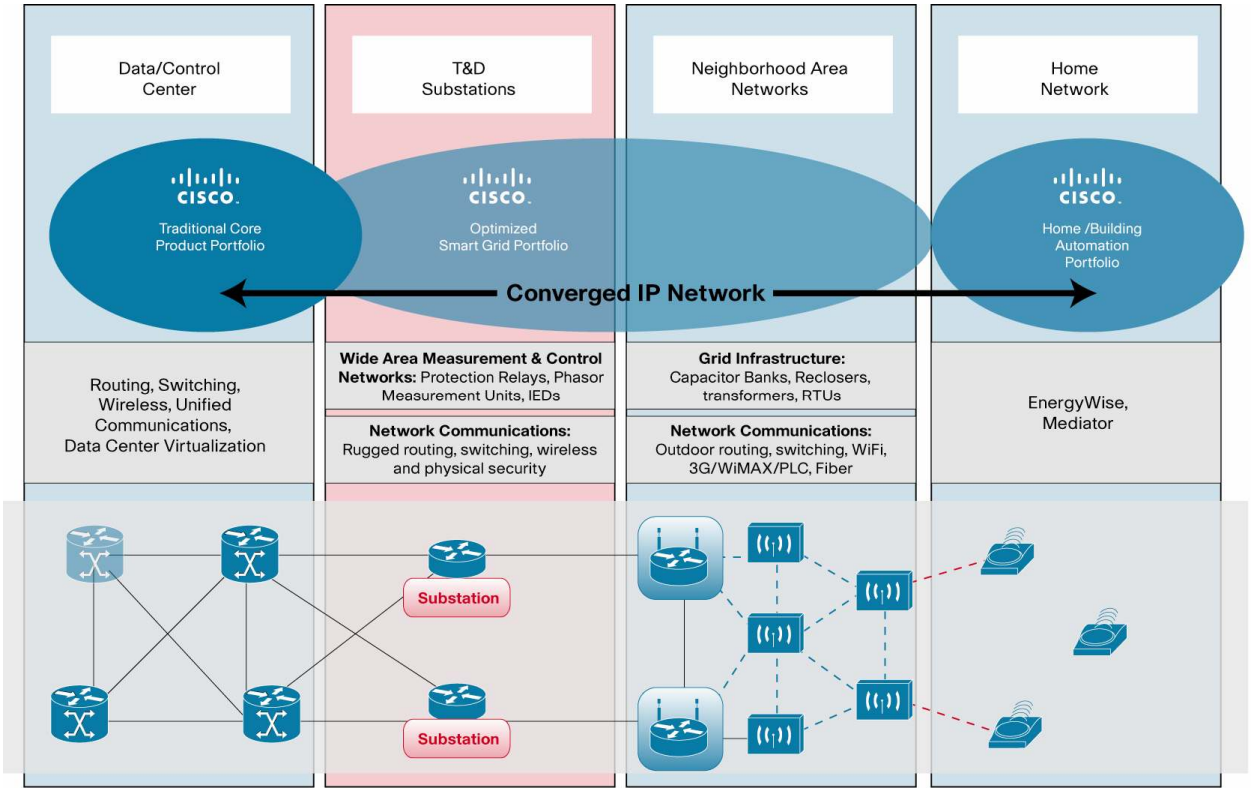
Cisco embraced IP standards, and invested in security, quality of service, and network segmentation as an integral part of a multi-service network. IP networks have become the standard for mission critical communications in

enterprise, military, banking, and service provider networks. Today, networks based on Cisco scale to support millions of end points while securing millions of business and financial transactions daily. Many of these enterprise customers include Investor Owned Utilities, public municipalities, and Energy Cooperatives.

Cisco's Role in Smart Grid

It is clear that building an intelligent communications network is a foundation to building a Smart Grid. Cisco sees its role in Smart Grid as providing best in class communications network from the generation of electrons to consumption in home, business, or industry. Our vision is to provide an end to end IP communications network which is manageable, scalable, and secure. Figure 2 shows a visual representation of an end to end network communications fabric. Cisco is committed to helping utilities build out an intelligent communications network for decades to come.

Figure 2. End-to-End Communications Network for Smart Grid



Substation Automation: A Key Enabler to Smart Grid

Cisco believes substation automation is one of the key first steps to achieving a smarter grid. As shown in Figure 1 above, the grid must be observable and measureable before it can be controlled and automated. Substation automation, which has been underway in the utility industry for many years since the advent of the microprocessor relay, helps utilities add sophisticated protection and control functions while also providing greater visibility into the performance and health of grid infrastructure. Extending a secure, scalable communications infrastructure to substations enables important applications. These applications help utilities control and automate the grid. Condition-based and predictive maintenance programs benefit from improved observability of asset health and accumulated stress, enabling proactive maintenance that can avoid costly unplanned outages.

T&D Operations 'Care Abouts'

This paper is intended for the utility's Transmission & Distribution (T&D) substation engineering and operations teams within an electric utility. Grid operations teams are responsible for the management and maintenance of the power grid. The purpose of this paper is to share with T&D Operations what Cisco's vision and value proposition are for substation automation.

Grid Reliability

The operations groups are responsible for the day to day management and reliability of the power grid. The challenges of maintaining variable energy supply in the wake of growing and uneven energy demands is no easy task. The key task is to keep the lights on, as measured by operational effectiveness metrics and system performance indices like SAIDI and SAIFI, some of which must be reported to regulatory bodies.

To manage outages, utilities deploy protection relays that provide for fault location identification, and restoration. Protection relays and phasor measurement units that are now being deployed on transmission systems on a regional basis, are highly dependent on deterministic communications to ensure precise timing and fast network convergence to mitigate voltage or phase imbalance.

As such, it is common for utilities to deploy their own dark fiber between sites for peer to peer protection communications. Likewise, with the advent of IEC 61850 standards, station bus communications have already begun migrating to ethernet for intra-substation protection which facilitates interoperability, scalable network design, and OPEX reduction.

Worker & Public Safety

The most important responsibility of any operations group is to ensure worker and public safety. Grid operators implement strict policies and procedures to ensure trained and qualified personnel manage and monitor grid infrastructure such as transformers, circuit breakers, capacitor banks, and protection relay devices. When outages occur, utility operators must, in additionl to their other outage and fault management tasks, identify energized lines, especially ones that are down and may be a public safety hazard. Utilities must go to great lengths to mitigate the risk of injury or death to utility operators and the general public.

As a result, utility operators must have adequate communication networks in place to expand their situational awareness of grid conditions at all times. Remote workers must have data and voice communications to report the conditions to control centers and the first responders if necessary. Substation technicians at remote sites must also have redundant, survivable communication paths while performing grid maintenance in the event worker safety becomes compromised. Minimizing time spent in substations to alleviate potential for human error is one way utilities reduce risk to worker safety and grid reliability.

Industry Compliance

In addition to ensuring a safe and reliable power infrastructure, grid operators are tasked with adopting new industry standards and regulations. Industry standards such the North American Electric Reliability Corporation (NERC) / Critical Infrastructure Protection (CIP) require utilities to have a cyber and physical security plan in place to secure facilities handling the transmission and distribution of bulk power across the grid. While NERC/CIP's jurisdiction is primarily in North America, utilities worldwide are implementing similar measures to ensure the grid infrastructure is protected from physical and cyber attacks.

Utilities face several challenges with implementing a NERC/CIP plan. First, utilities are subject to hefty fines exceeding $1 million per day if they are deemed out of compliance. Second, the regulations are subject to interpretation which creates the need for utilities to go to extreme measures to demonstrate compliance. And finally, utilities are bracing for further changes to NERC/CIP which could expand the scope and definition of what is deemed a critical cyber asset.

Operational Expenses

A fourth 'care about' for T&D operations teams is managing and reducing operational expense. Operations engineers are constantly looking for ways to automate their networks and processes and drive efficiencies in managing and automating the network. For example, sending the right crew to the right location in a timely fashion and avoiding callbacks for nested outage causes, is just one example of how utilities can reduce truck rolls and the cost of maintaining the grid.

Many utilities cover broad service territories which serve customers in both metropolitan and rural areas. It is common for power substations to be dispersed over hundreds of miles or kilometers of territory and so field service teams look for ways to reduce 'windshield time' driving to remote substations. In addition, empowering the remote worker with secure communications to control centers and enterprise databases improves worker efficiency and minimizes time spent in substations.

Another area utilities look to reduce cost is by reducing leased line communication circuits running into the substation. Some substations are over 50 years old and have accumulated multiple dial up modems and WAN circuits for a variety of applications. In some cases, utilities are discovering they're paying for duplicate or unused leased lines.

Substation upgrades can be an expensive proposition for utilities and may take weeks of on-site work to accomplish . Re-cabling or trenching fiber lines adds to the expense of substation upgrades. As a result, substation engineering conduct significant planning and testing of substation gear in advance to ensure that network designs are secure, redundant, and replicable.

Benefits of Communication Standards in Substations

Substation automation is one of the first steps utilities are taking to improve grid reliability, enhance security, and reduce costs of managing the grid. Adopting industry standards such as IEC 61850 can help drive down OPEX by converging on a common communications protocol. The adoption of IEC 61850 standards will vary from utility to utility and region to region. Therefore, it is important that communications providers provide a migration path from SCADA to IEC 61850 to maximize the useful life of existing assets.

Adopting a communications standard such as IEC 61850 provides several benefits. First, it allows communications interoperability among devices, and no longer locks a utility into a particular vendor's solution. Second, a standards based network enables a more scalable, replicable substation design which can streamline the test, setup, and reconfiguration of substation networks. A third benefit is that with devices now addressable on an IP network, grid operations improve their visibility and remote engineering access to the network, thereby reducing windshield time traveling to substations for onsite troubleshooting. And finally, as Distributed Energy Resources (DER) continue to scale, substation automation provides valuable instrumentation to manage and control variable energy supplies.

In summary, automating substations with networking devices such as routers and switches enables utilities to manage, control, and automate remote grid assets more efficiently, thereby converging network functions and streamlining grid operations.

Cisco's Substation Automation Solutions

Cisco's vision is to deliver an end to end IP communications platform from the power generation to consumption in homes and businesses. The intelligence is derived from the integration and management of potentially millions of end points to provide greater visibility, control, and dynamic flow of electrons across the grid.

Cisco has recently announced The Cisco Connected Grid portfolio of products & solutions designed specifically for a Smart Grid network. These products include the Cisco 2010 Connected Grid Router (CGR 2010) and the Cisco 2520 Connected Grid Switch (CGS 2520). These platforms are optimized for use in power substations and meet substation compliance standards including IEEE 1613 and IEC 61850-3. The Cisco Connected Grid portfolio are

designed for high availability, integrated security management, and network scalability. Figure 3 shows the Cisco Connected Grid portfolio for substation networks.

Figure 3. Cisco Connected Grid Portfolio, CGS 2520 Switches and the CGR 2010 Router

In addition to the Connected Grid Router and Switch portfolio, Cisco offers a breadth of IP video surveillance and access control products and solutions to securely manage substation perimeters. In addition these offerings can be used for remote video inspection of substation equipment.

Many utilities deploy dedicated fiber between substations to facilitate protection and control. Cisco offers a portfolio of optical network solutions such as the ONS family which carry protection relay communications over high speed, low latency, fiber networks. These products include a variety of transport technologies including SONET, DWDM, and packet over SONET.

Cisco's substation automation solution encompasses not only communications within a substation, but also products and solutions to network other substations, control centers, data centers, and ISOs. For example, Cisco offers the Nexus family of data center products and edge routing platforms including the ASR 1000 Series. These highly scalable platforms aggregate, store, and manage the proliferation of data from the grid.

Table 1 describes how Cisco's portfolio of substation automation solutions help grid operations address challenges of grid reliability, worker & public safety, industry compliance, and OPEX reduction.

Table 1. Cisco's Substation Automation Offering

Grid Operator Care Abouts	Cisco Value Proposition	Utility Benefits
Grid Reliability		
High Availability	• Hot-Standby Router Protocol & Virtual Router Redundancy Protocol support • Advanced Routing to route around WAN or network link failures • Dual redundant, power supplies on Cisco Connected Grid routers & switches • Performance Routing (PfR) improves application performance and availability by selecting the best path for each application based upon advanced criteria such as, reachability, delay, loss, jitter, and Mean Opinion Score (MOS). • Bidirectional Fowarding Detection provides a low-overhead, sub second capabilities of detecting failures in the forwarding path between two routers allowing for minimal disruptions from failover scenarios. • Flexible, scalable & secure network architectures based on 25 years of networking experience	• Minimize network down time when communications are disrupted • Survivable grid communications if WAN link(s) fail • Cisco is a trusted partner for providing secure, scalable communication architectures
Protection & Control Communications	• Protection & Control support (GOOSE and SCADA support) • Tunneling of SCADA protocols such as DNP-3 and MODBUS over an IP network • Fast Convergence Protocols for Ring or Hub-and-Spoke Deployments • Optical products & solutions for Teleprotection schemes • Standards based Precision Timing Protocol support in hardware (IEEE 1588)	• Dedicated and reliable communications for grid control • Migrate to new substation protocols w/out leaving stranded assets

Grid Operator Care Abouts	Cisco Value Proposition	Utility Benefits
Distributed Energy Resource (DER) integration	• Network integration of sensors to report the variability of renewable resources to control centers • Network platform capable of supporting distributed analytics and control for VOLT/VAR monitoring for DER sites	• Improved monitoring & control of DER • Monitoring End point management of SNMP enabled devices
Worker & Public Safety		
Improving situational awareness for worker & public safety	• Physical security and access control solutions for substation monitoring • Pan, Tilt, Zoom and video analytics for identification and detection of movements and objects in substation premise. • IP Interoperability & Collaboration System (IPICS) to conference with any endpoint device including first responder radios in the event of an emergency	• Situational awareness of substation grounds from control center • Ensuring only qualified personel have access to substation premise • Fast notification to first responders from any network device
Industry Compliance		
NERC/CIP compliance	• Cisco high resolution IP video cameras, storage, and access control for NERC/CIP compliance • Advanced Network Security for NERC/CIP compliance: • Network Access Control • Intrusion Prevention System • Intrustion Detection System • Zone Based Firewalls • TACACs+ authentication server • Access Control Lists • IP SEC encryption • Advanced VPN designs • CiscoWorks LAN Management Solution • Cisco Network Design Services for achieving NERC/CIP compliance	• Compliance with NERC/CIP audits • Ability to generate logs for NERC/CIP audits
Compliance with environmental specifications	• IEEE 1613 and IEC 61850-3 compliant solutions for substation environments • No moving parts or fans in substation products • -40°to +85℃ operating temperature (100 hour type tests @ 85℃)	• Robust network communications for 15 year service life • Investment protection from reliable product design for substation surge, immunity, and wide temperature ranges •
Grid Loss Reduction (SAIDI, SAIFI)	• Standards-based network designs to scale support for millions of end points • Integration of sensor data on to an IP network for condition based maintenance programs	• Improved customer satisfaction from fewer outages • More efficient grid using existing assets • Forego capital costs of new generation sites
Migrating to communication standards (IEC-61850)	• Worldwide leader in helping industries migrate from legacy, proprietary networks to a scalable, secure IP network. • Breadth of network and design services to ensure scalable communications across thousands of locations and millions of end points.	• Trusted partner with experience in technology transitions • Best in class service and support offerings for utilities across the globe
Managing OPEX		
Reducing Windshield Time	• Remote engineering access to substation networks through secure, scalable networks • IP video cameras used for remote training instruction and remote support • Remote equipment inspection using Pan, Tilt, Zoom (PTZ) cameras • Reliable configuration management tools to support remote upgrades	• Cost savings from minimizing windshield time traveling to substations for troubleshooting • Cost savings from remote monitoring & maintenance of substation assets • Condition based maintenance programs to proactively maintain grid before costly equipment failures
Managing network silos	• Network convergence to reduce costs of separate, physical networks • Integrating voice, video, and data applications in substations on to a common IP network • Migration path to converge onto a common network while maintaining segregation of operational and non-operational data • SCADA tunneling (e.g., MODBUS and DNP-3 over IP networks	• OPEX reduction from converging services on to a single network infrastructure • Flexible upgrade from SCADA to IEC61850 without stranding assets

Grid Operator Care Abouts	Cisco Value Proposition	Utility Benefits
Workforce Training	• Real-time video training using remote video surveillance and Telepresence solutions	• Addresses knowledge gap between aging workforce & new industry professionals
Ease of Management	• HMI support of CGS 2520 via MODBUS memory map. • GUI-Based management tools to provision substation networks on site or remotely • SNMP management to support integration with standards based DMS systems • Connected Grid swap drive on the CGS 2520 supporting ease of product replacement • Smart Port templates to ease pre-configuration of networks prior to deployment • Dual redundant hot swap power supplies for ease of serviceability	• Cost reduction from managing multiple systems • Proven and reliable network management tools • Monitoring End point management of SNMP enabled devices • Substation engineer or contractor doesn't require networking background to replace network switch

Partner Strategy

Cisco recognizes the need for building sustainable partnerships with industry providers that have served the electric utility for decades in order to achieve a smarter grid. Cisco is partnering with leading substation integrators, power equipment manufacturers, and suppliers from around the globe to design, validate, and implement substation network solutions.

For more information about Cisco's products, services, and partner ecosystem, please contact your local representative or visit http://www.cisco.com/go/smartgrid.

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