Power Utility Substation

Market Description
The ability to provide reliable electrical power for residential and commercial use depends on an expansive infrastructure comprised of power generation facilities, transmission cables, substations, and local transformers. This infrastructure is instrumental in moving power from the generation facilities to the consumer.

Electrical Power Generation
Years ago, power generation took place in large facilities utilizing several different power generation technologies. Power generation plants were often located along major rivers to harness the power of flowing water to rotate water turbines to generate electricity. Where major rivers weren’t present, power plants used coal or natural gas to create steam to rotate steam turbines to generate electricity. Advancements in nuclear technology created power plants that used nuclear material to create steam to rotate steam turbines.

Recent developments in renewable energy sources with less impact on the environment have created a diverse array of energy producing sources including wind farms, solar farms, and even residential solar systems. While this diversity of power generation sources helps to reduce our dependency on the large power generation facilities, it has greatly impacted the power distribution infrastructure.

Electrical Power Distribution
While we have grown accustomed to stable power being available 365 days per year, 24 hours a day, the right technology is required to meet that expectation. With all the different power generation sources available today, power line balancing has become a real challenge. Power generation sources need to be coordinated so that enough power is produced to meet demand, but that a surplus is not produced. Newer power generation technologies like wind and solar provide variable amounts of power based on environmental conditions. For example, abundant energy is produced by renewable energy sources on sunny or windy days, but not as much is produced on cloudy, still days, or at night. The output from traditional predictable power generation sources now must be adjusted based on the power generated from renewable energy sources.

Once the power is in the power system, “on the grid”, the challenge becomes getting it from the generation source to the consumer. Power generation produces very high voltage power that can be transmitted over long distances. Tall power towers with high tension wires are used for this purpose. Since so much power is carried by these cables, it’s important to control the
amount of power each cable carries to avoid a cable failure. Balancing the power over multiple cables to spread out the power load is essential.

Electrical Power Substations
Power substations are facilities between the power generation sources and the consumer. Substations are used to transform electrical power and balance the distribution of power to multiple locations. Substations transform the power from transmission voltages to usable voltages. Usable voltages vary depending on the application. Metal foundries, for example, require high voltages to power large metal processing furnaces. Manufacturing companies require moderate voltages to power manufacturing equipment. Residential consumers require relatively low voltage. Substations provide these voltage reductions and multiply the number of power lines to provide connections for massive numbers of customers.

Some customers require higher levels of power stability. For critical service providers like hospitals, the reliability of power is paramount. In the event of a power failure, substations can switch to an alternate power source to ensure the hospital continues to receive uninterrupted power. This requires simultaneous switching at several substations, to disconnect one power source and connect a different one.
Power substations are also used to balance the power supplied to the power grid from various power generation sources. When renewable power sources such as solar and wind are very productive, generation from variable sources like hydro, coal, and nuclear are reduced. Accomplishing this involves coordinated switching at many substations so that consumers continue to receive stable uninterrupted power. Therefore, communication between substations must be instantaneous. Communication networks of various types are used for this purpose, with IP networks gaining in popularity due to their ability to provide redundant communication paths, very fast communication speeds, alerts and notifications, and a high level of security.

**Market Needs**
The power utility industry requires networking equipment that can operate in extreme environments, provide the latest technology, and provide the reliability, event notification, and security the industry requires. Several standards have been developed specifically for the power utility industry including IEC 61850 and IEEE 1613. These standards provide the guidelines for equipment operating environments, communication standards, and security. The US government has also developed regulations to provide more uniform guidelines for the implementation of equipment and communications networks in the power utility industry. These NERC/CIP regulations are designed to increase the interoperability, reliability and security of the US power infrastructure.

**Market Products**
As needs change quickly, power utility companies are migrating towards IP networks for their communication needs. The combination of IP networks and fiber-optic technology is providing the ability to widen the communication network and monitor equipment between the substations and consumers. This ability increases the reliability of the power grid by monitoring equipment and providing predictive failure analysis.

Equipment must be able to withstand the harsh substation environment, including extreme temperatures, high levels of electromagnetic interference, power fluctuations, and in some instances vibration. The ability to communicate using fiber-optic cabling ensures immunity to electromagnetic interference and provides the communication distances required to interconnect substations and other remotely located equipment.

Utility companies require standards such as IEEE 1588 (Precision Time Protocol) and IEC 62439 (Media Redundancy Protocol). PTP provides a very accurate timestamp on communications to ensure precise sequencing of events and accurate reporting and assessment of past events. One of the elements of the NERC/CIP regulations is the ability to provide accurate records of events. MRP is standard technology used to provide redundant network connections between mission critical equipment. Since power utilities use equipment from a wide variety of vendors, non-proprietary network redundancy is essential.
Product Application

While the quantity and types of equipment may vary from one substation to the next, the same basic networking equipment elements are required. Some of the equipment may vary based on the power control equipment in the substation. Older equipment may have serial based data communications, whereas newer equipment will likely have a network connection.

For serial based communication equipment, a serial device server is typically chosen. Serial device servers are connected to the power control equipment using a serial cable. The serial device servers can be configured to match the serial communication protocol of the power control device. The network connection on the serial device server can be connected to a switch or server. Many utilities prefer this network connection to be a fiber-optic connection since communication can be disrupted by electromagnetic interference.

Security for these devices is also critical, so serial device servers with encryption capabilities are preferred. The encryption is needed on both the serial communication and the network communication. Some serial device servers, like Transition Networks’ SDS Series, also have the capability of communicating with more than one server simultaneously, providing redundancy in the event of a server malfunction. Serial device servers are used to automate legacy power equipment with serial interfaces. Newer equipment is being designed with network ports allowing direct connection to the local network for communication.

While some copper network connections may exist, the majority of the network connections within the substation utilize fiber-optic cabling to minimize the impact of electromagnetic interference. Where collections of copper connections exist, hardened switches with IEC 61850 certifications are used to aggregate the connections and provide a fiber-optic uplink to servers or main network switches. The networks are designed with redundancy that ensures reliable communication even when network segments have failures. Switches that support IEC 62439 Media Redundancy Protocol and ITU-T G.8032 redundancy, like the Transition Networks’ INDURA, are preferred since these redundancy technologies are based on standards supported by various equipment vendors.
Substation networks continue to grow in size and complexity. Physical security is one major factor for this growth. Security cameras, intrusion detection equipment, and access control are all being connected to the network. Video surveillance is used to monitor substation operation and provide security monitoring. Intrusion detection equipment provides further protection by alerting security personnel when unauthorized access occurs. Physical access control equipment provides the ability to monitor and record authorized access and unauthorized access attempts. Reporting a log of these events is one element of the NERC/CIP regulations.

All of this equipment and the data it provides need to be connected to data recording servers within the substation, other substations, and control facilities. Aggregation switches that are IEC 61850 certified are used for this purpose. These switches contain management features that allow the network traffic to be prioritized in the order of importance. The network can be divided into several virtual LANs (VLANs) to separate network traffic. Critical network communication for power control equipment can be prioritized to ensure it has the highest priority for network transmission. Less time sensitive traffic, like recording an event, can be prioritized lower to provide network bandwidth for critical information. The use of IEE 1588 (Precision Time Protocol) ensures that all network communication is accurately time stamped so that communications and events can be sequenced and recorded correctly regardless of their priority. Managed switches contain the management features to optimize the local substation network and security features required for communications outside the substation perimeter.
To better secure the electrical power infrastructure from malicious activity, NERC/CIP regulations call for all external substation network communication to be transmitted through a stateful firewall. Layer 3 routers, integrated with a firewall, provide the secure access required. The router/firewall provides a separation between the local substation network and external wide area networks (WANs). This ensures that access to the equipment within the substation is restricted to authorized communication through the firewall.

**Summary**

Power utilities companies and the power grid they share contain a complex collection of power control and communication equipment. The products used in these applications is mission critical equipment that needs to operate reliably in extended temperatures and be tolerant of vibration, electro-magnetic interference and power fluctuations. Data communications are crucial to the reliable operation of the power grid and need to be protected by restricting access to only authorized personnel, encrypting sensitive data, and providing redundant network communication paths to ensure communication delivery. These requirements are documented in standards like IEC 61850 and NERC/CIP regulations. Using equipment from vendors supporting these standards and regulations will ensure the integrity and security of the power grid.