

Making the Smart Grid Work

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In order to bring down the cost of supplying power and reduce the carbon footprint of the power industry worldwide, many governments and industries have been moving the transmission and distribution of electricity to a new “smart grid” model. This model is expected to produce a real-time responsive electric system from power generation to end consumers.

The system design is intended to be quite different from the existing grid. From the consumer side, smart controls will report to the transmission and distribution system in real-time about usage and demand. The distribution grid will respond instantaneously to demand changes from both residential and industrial consumers, producing only enough electricity as is required on a real-time basis. The intent is to eliminate distribution power brown-outs as well as overproduction of electricity.

The consumer side will at first be largely industrial and commercial users such as process and discrete manufacturing plants and large commercial buildings. Eventually, most residential consumers will be retrofitted with “demand response” controls.

But the problem is that the electrical grid is by and large “stupid.” That is, exactly as with industrial automation in the 1970s and 1980s, there are islands in the grid...substations, control systems, auxiliary generation equipment, load balancing systems, that are not fully interconnected in real-time to the rest of the grid.

What has been missing is the same thing that plagued automation systems in manufacturing—a common set of communication protocols and tools. In the final analysis, it isn't going to be Internet-enabled thermostats and billing meters that will assure the smart grid's success, it's the rapid modernization and interoperation of the transmission and distribution system itself.

The IEC 61850 Trend

More than 70% of the transmission infrastructure in the electric utilities in North America, Australia and Western Europe are over 25 years old. In India, China, the rest of Asia, South America, and Eastern Europe, the transmission infrastructure is either inadequate for today's usage and tomorrow's growth, or there is no infrastructure at all.

Because today's transmission and distribution grid grew piecemeal, it is a hodge-podge of different communication protocols and islands of control. Engineers with a lot of experience have been managing these conditions of legacy systems, with multiple and proprietary protocols, but these engineers are becoming unavailable.

Although we have a temporary reprieve in some cases due to the economic recession of 2009, we will continue to see a drain of talent but most of all experience, as older engineers and technicians leave the utility space by retiring. They've been able to keep the grid running because of their experiential learning rather than engineering design. The call for a Smart Grid is really a call for a more reliable and more automatic system for transmission and distribution of electricity.

In addition, the generation of electricity is becoming quite different. Multiple sources of in-feeds to the grid are being developed, including wind, solar, tidal, and cogeneration. The existing grid infrastructure was never intended to cope with these varying multiple sources that are less reliable than a string of conventional or nuclear power generation plants. But the emerging need for renewable energy sources, and Distributed Energy Resources, will make it necessary for the grid to be able to handle variable feeds from wind turbines, solar power plants, tidal power generators,

from large customers pushing excess power back into the grid, and from small cogeneration plants that may or may not be regularly online.

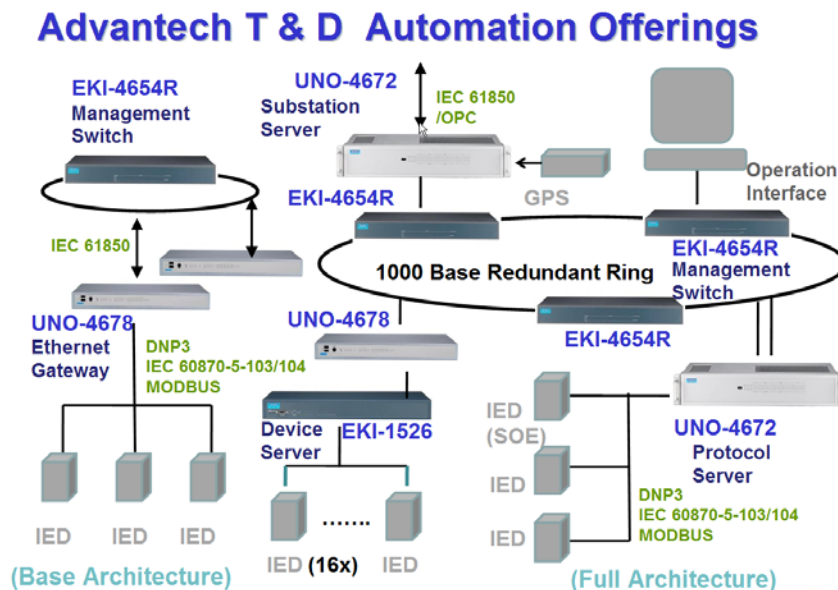
This situation has led to the development of a global standard, IEC 61850, for communications between substations, internal communications within substations, and communications between various parts of the grid and the central control system for that portion of the grid.

The key benefits expected to derive from IEC 61850 are exceptional interconnectivity, using one worldwide protocol, along with easy interoperability between systems and devices from different vendors. A single common standard should also provide simple, easy to learn design and configuration tools and practices, as well as reliability and cost savings through higher availability of LAN and fiber optic networks.

All About IEC 61850

At the heart of IEC 61850 is standard Ethernet communications—the most common means of electronic communications in use today around the world. The IEC 61850 standard came out of work done at EPRI (Electric Power Research Institute) to create a Utility Communication Architecture, with defined protocols, data models and abstract services definitions, and from the work of the IEC 60870-5 committee, which created a communications profile for sending basic tele-control messages between two systems that was based on permanent directly connected data circuits.

IEC 61850-enabled IEDs (Intelligent Electronic Devices) get digitalized power grid condition data via an Ethernet process bus and field communication interfaces (also called merge units). These can be varied from Modbus, DNP3, UCA/MMS, RS232 and Ethernet-enabled PLCs and devices with proprietary protocols. Even dialup modem access is provided for.



Field communication interfaces consist of data gateways, protocol translators, communication servers and controllers for legacy SCADA protocols like DNP3. The IEDs communicate with each other by using the substation bus (a standard Ethernet LAN configuration) through a set of redundant Ethernet switches. Legacy devices use a 61850 wrapper around the legacy data protocol transmissions.

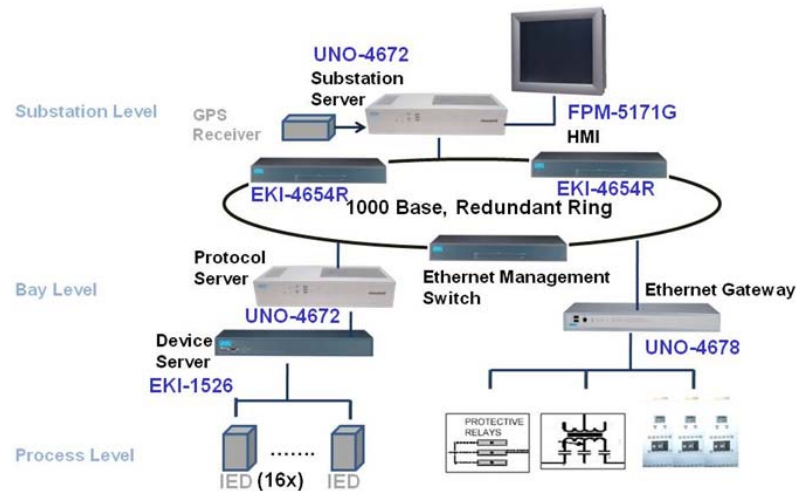
The core of IEC 61850 is an object model that describes the information available from the different primary equipment, and from the automation functions normally performed at the

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substation level. A specification details the communications between the IEDs of the substation automation system and maps the services to specific protocols via a configuration language. It is a true object oriented approach to substation automation. It is backward compatible with previous attempts at global standardized communications, like the UCA GOOSE, and contains its own GOOSE (Generic Object Oriented Substation Event model) and GSSE (Generic Substation Status Event model) capability to produce accurate event logging and alarm generation and manipulation.

So What Does 61850 Look Like?

In a typical application, shown in the Figure below with Advantech products,



IEDs connect to a Device Server. The Device Server connects to the process bus (the 100 Mbps Ethernet Substation LAN, based on IEC 61850) through a Protocol Server. At the same time, relays and other field devices also connect to the 61850 Ethernet LAN through a Data Gateway. The LAN is composed of smart managed switches in a redundant architecture for both availability and security of data.

Sitting on the LAN are a variety of Data Servers, such as a Modbus server, an MMS server, a conventional Ethernet data server and possibly 3rd party servers. These use conventional protocols such as DDE/.NET and DDE/OPC to serve data to the various applications in the substation control system, and through either the Internet, or an Intranet, or combination of them, provide data to what could be called a “remote monitoring and diagnostic” layer in the system structure.

Because IEC 61850 is a standard set of protocols that runs over Ethernet, it is possible to use COTS (Commercial Off The Shelf) products to provide the device servers, data servers, protocol servers and data gateways necessary to construct the substation automation architecture.

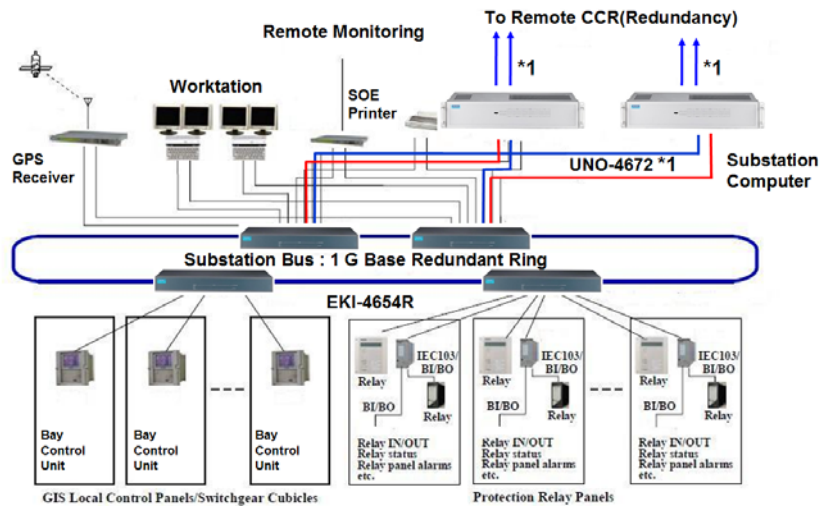
However, the stresses of industrial uses for these devices preclude the use of basic “commercial” embedded computers, managed Ethernet switches, and other devices, in favor of industrially-hardened purpose-designed and purpose-built versions that can handle the industrial environment and provide high duty factor and high availability for many years.

It is for just this reason that IEC 61850 provides specifications for environmental performance for temperature, vibration, shock, static load, electromagnetic immunity, emissions and other parameters, including software parameters regarding data transmission.

The designer and user should select devices and components for the system that have been designed specifically to meet the requirements of IEC 61850-3. In the application above, for example, the Control System Integrator selected the Advantech EKI-4654R Ethernet Managed Switch because it provides up to 24 Fast Ethernet Ports, two 1000BaseT SFP ports, and operates on a redundant X-Ring architecture providing very rapid recovery from faults and very low packet loss rates, as well as a long-range redundant power supply.

These features are generally not found in “commercial grade” managed Ethernet switches. The EKI-1526 serial device servers in the example are similarly designed to be able to operate in rugged service and provide connectivity between serial devices such as IEDs and a TCP/IP network.

In the application, the Control System Integrator took advantage of the availability of industrial grade embedded computing platforms such as the Advantech UNO-4678 to serve as protocol converters & gateways and UNO-4672 to simplify system configuration(integration of gateway, GPS and substation server into one station computer) in the system. These devices are low power, high computing capability fanless box PCs running Windows and capable of handling complex tasks while conforming to the physical requirements of IEC 61850-3. These devices have extended temperature, vibration, shock and EMI immunity, and have more inboard diagnostics than typical commercial grade single board computers.



Note that since the heart of the system is a redundant Ethernet LAN, it is easy to add a HMI(Human Machine Interface, in this case an Advantech industrial monitor FPM-5171G) for local monitoring, alarm management and diagnostics while the data moves to the central control facility via TCP/IP. At the central facility, IEC61850 makes it possible to begin to design systems that integrate both the substation controls and the generation and distribution control systems, which are more conventional DCS style systems. IEC 61850 may make it possible to have one standard, one system architecture, for the entire world.

Making the Smart Grid Work

The governments of many nations have seen the advantages of having a smart grid. They have provided funding of various levels to see it accomplished. But in order to produce a smart grid, we need to have a secure, interconnected and interoperable grid. IEC 61850 is the standard that will provide that interconnectivity, interoperability and security.

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