INDUSTRY ACTIVITIES IN SUBSTATION PROTOCOL STANDARDIZATION

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ABSTRACT

The need for information in the deregulated, competitive utility environment places even greater emphasis on the communication protocol. Historically, suppliers have developed their own protocols that best suited their products. The systems suppliers and integrators who tried to integrate these products had a difficult time making these products talk to each other. Worse yet, even the same protocol had different versions that caused incompatibility between two systems or devices. With the greater emphasis on the communication protocol today, there is greater emphasis on standardization of communication protocols. The most focused industry activity today in protocol standardization is in the substation integration and automation area. Specifically, these efforts address a standard intelligent electronic device (IED) protocol, as well as a standard substation local area network (LAN) technology. The efforts also include a standard protocol to bring the substation information out of the substation and into the utility enterprise.

INTRODUCTION

Electric utility deregulation, economic pressures forcing downsizing, and the marketplace pressures of potential takeovers have forced utilities to examine their operational and organizational practices. Utilities are realizing that they must shift their focus to customer service. Customer service requirements all point to one key element, information – the right amount of information to the right person or computer within the right amount of time. The flow of information requires data communication over extended networks of systems and users. In fact, utilities are becoming among the largest users of data and, are the largest users of real-time information.

The communication protocol is needed for data communications and the subsequent flow of information. Communications and protocols enable automation to be implemented. The success of the automation applications is very dependent on the selected devices, the communications media and the communication protocol. Standard industry protocols for different application areas (e.g., control center, substation, wide area network, customer site) allow the electric utility the flexibility to choose the best products from suppliers for their system, without the constraint of unique protocols and unique devices.

PROTOCOL FUNDAMENTALS

The communication protocol allows two devices to communicate with each other. Each device must have the same protocol implemented, and the same version of the protocol. Any differences in the implementation of the protocol in either device will result in communication errors.

If both devices are from the same supplier, as well as the communication protocol, there is little risk that the devices would not be able to communicate with each other. This is typical of the situation where the supplier has developed a unique protocol to allow all the capabilities of the two devices to be utilized. In other words, by using the supplier's unique protocol, the utility guarantees the maximum return on their investment in the devices. They are able to use all the device's functionality. However, because of the unique protocol, the utility is constrained to one supplier for support and purchase of future devices.

If both devices are from the same supplier, but the protocol is an industry standard protocol supported by the device supplier, there is little risk that the devices would not be able to communicate with each other. The device supplier has designed their devices to operate with this industry standard protocol, and with the same version in each device. The utility is not constrained to one supplier for future device purchases, and will be able to realize lower device prices due to competition. Industry standard protocols typically have much more overhead than a supplier unique protocol, and therefore require a higher speed channel for the same efficiency or information throughput. There is some risk that device functionality may be not be totally realized by using an industry standard protocol. Were the devices designed before the industry standard protocol was available? If so, there may be device functionality not supported by the protocol. If the devices were designed after the industry standard protocol was available, the supplier should have designed the devices in conjunction with the protocol functional capabilities.

With the advent of open system concepts, which ideally allow devices from different suppliers to communicate with each other (interoperate with each other), it should be possible for a device from one supplier to talk to a device from another supplier, using an industry standard protocol. In this scenario, it is critical for factory testing to verify that the functions of one device are supported by the protocol and by the other device, and vice versa. Since the devices are from different suppliers, there is risk that each device may have capabilities not supported by the other device. There is also risk that the protocol implementations of the industry standard protocol by the two suppliers in each device may have differences. These differences would need to be found and corrected during factory testing.

Having an industry standard protocol, where the device suppliers have designed their devices so all device functionality and capabilities is possible with this protocol, provides the utility the flexibility to choose the best devices for each application. With multiple sources for the devices the competitive purchase process results in lower prices for the utility. Higher speed communication channels are more prevalent today to make up for the increased overhead of industry standard protocols.

EPRI UCA PROTOCOL PROFILE

During the late 1980s, the Electric Power Research Institute (EPRI) commissioned a study into the communications requirements of the electric utility industry. That study, released in 1991, performed a needs assessment, looked at the then available open systems networking protocols, and made recommendations regarding the best fit between available protocols and the industry's communications needs. The results of the study were the Utility Communication Architecture (UCA1). The study recommended that the framework underlying the UCA be the OSI basic reference model and that the protocols chosen be ISO standards, wherever possible. The UCA is a subset of the ISO/OSI standards chosen to be an internally consistent set of protocols that conceptually provide all communications services that would be required in the electric utility business and operations environment. Such a suite of protocols, which is chosen to provide a vertical set of communications services, is called a profile. UCA1 included two profiles, one using the full seven layer OSI model, and one Enhanced Performance Architecture (EPA) three layer profile for simpler, less complex devices or IEDs.

UCA2 was developed by EPRI as an update of version 1 incorporating definition work done by an industry group and several utility demonstration projects. Like version 1, UCA does not define one communication profile, but rather provides for a selection of standards to create a profile for specific applications. In all cases, the profile includes the Manufacturing Message Specification (MMS) protocol standard at the application level as a messaging service. UCA2 provides increased functionality going beyond most proprietary and some de facto standard protocols.

Although UCA2 has been announced and documentation has been released, work still continues in a number of committees to define the object models (software modules associated with components such as breakers or switches) needed to support interoperability of devices. This work has been completed for basic power system devices, and is known as GOMSFE (Generic Object Models for Substation and Feeder Equipment).

UCA devices are self-describing. The self-describing supplier-independent device object models, when combined with the supporting profiles, provide a seamless view of real-time data throughout the utility enterprise. Using standard commercial off-the-shelf PC and/or workstation packages (e.g., MMS browsers), individual users anywhere in the UCA enterprise can, subject to security and access controls, directly access real-time data from substation devices, or customer interface – and beyond.

An IEEE Standards Coordinating Committee (SCC) of the IEEE, called SCC 36, oversees and coordinates the further evolution of UCA specifications into IEEE Technical Reports. The committee's scope includes data communication standards for electric, gas and water utilities. Relevant IEEE standards committees manage progress of the various parts of UCA, and SCC 36 assures consistent and productive overall direction. SCC 36 organized an IEEE review of the existing UCA documents and determined how they can be adopted and/or revised as IEEE Technical Reports (TRs), resulting in the publication of IEEE TR1550 in December 1999. SCC 36 issued a solicitation for members to numerous bodies that are developing standards related to utility data communications, including for example, the American Gas Association, the American Water Works Association, and within the IEEE (the Power Engineering Society, the Industry Applications Society, and the Communications Society). EPRI continues its active role in UCA development. It will support standardization committee activities, including IEEE, and will continue to identify new utility requirements and solutions in data communications.

The UCA2 MMS and GOMSFE work is being integrated into IEC 61850. This substation automation communications standard is bringing European and North American standards developers together to produce one worldwide standard.

UTILITY SUBSTATION COMMUNICATION INITIATIVE

The EPRI UCA/Substation Automation Project began over five years ago to produce industry consensus regarding substation integrated control, protection and data acquisition, and to allow interoperability of substation devices from different manufacturers. In mid-1996 the Utility Substation Communication Initiative had its first meeting as a continuation of the EPRI UCA/Substation Automation Project. Approximately 25 utilities and 15 suppliers are participating, having formed supplier/utility teams to define the supplier IED functionality, and to implement a standard IED protocol (UCA2 profile) and LAN protocol (Ethernet). Initiative meetings are held three times each year, including UCA interoperability demonstrations of supplier IEDs at every other meeting. New IED products with this functionality are now commercially available, and compiled in a UCA products list maintained by the Initiative (available from ftp.sisconet.com/epri/subdemo/products.zip). The utilities provide demonstration sites for the implementation of the new IED products to demonstrate interoperability between IED equipment from different suppliers. The widespread consensus and collective buying power of many utilities caused the suppliers to redefine their products toward industry standards. The supplier/utility teams are working together in two ways: redefinition of the supplier products, and utilities providing actual substation demonstration sites for the implementation and testing of the new products.

DNP USER GROUP

Since 1993 vendor and utility membership in the DNP User Group has steadily grown to its current worldwide membership of more than 300. The ongoing management of the protocol is directly in the hands of the utilities and vendors who use it. The DNP User Group acts the focal point for this ongoing evolution, bringing the DNP3 community together to collectively manage and evolve the protocol.

A primary reason for DNP3's success has been its stability, coupled with interoperability and enhancements to ensure compatibility with existing implementations. Acceptance of the conformance testing process now means users have a high expectation that devices from different suppliers will work correctly out-of-the-box. The DNP Technical Committee responds to market needs while ensuring that extensions to DNP3 do not make existing implementations obsolete. Both suppliers and utilities benefit from this commitment to compatibility and continuity.

There is an updated DNP web site (www.dnp.org) and a new DNP membership structure. The goal of the new web site is to provide new features to enhance the site's usefulness for both visitors and members. In addition to the Basic Membership level, a new Premium Membership level providing additional membership services will be offered.

CHOOSING THE BEST PROTOCOL

How do you choose the best protocol for your application? There are a number of questions to be answered. First, what area of your system are you concerned with? Is it the protocol from a SCADA master station to the SCADA RTUs? Is it a protocol from substation IEDs to an RTU or a Programmable Logic Controller (PLC)? Is it a local area network in the substation? This is the first question to be answered.

Second, what is the timing of your installation? Is it in the next six months, or is it in the next eighteen to twenty-four months? Or, is it even longer term, in the next three to five years? In some of the application areas technology is changing quickly, and the timing of your installation has a great impact on your choice of protocol. For example, if you are implementing new IEDs in the substation, and need them to be in service in six months, your protocol choices will be DNP3, Modbus and Modbus Plus. These protocols are used extensively in IEDs today. In some cases, if you choose an IED that is commercially available with UCA2 MMS capability today, then you may chose UCA2 MMS as your protocol. However, if your time frame is one to two years, you should consider UCA2 MMS as the protocol. You should monitor the results of the Utility Substation Communication Initiative utility demonstration sites, implementing new supplier IED products which have implemented UCA2 MMS as the IED communication protocol, and using Ethernet as the substation local area network.

If your time frame is near term, such as six months, it is important that the protocol choices you make are from suppliers who are participating in the industry initiatives and are incorporating into their products' migration paths to this future technology. In this way, you are assured of protection in your current investment, so that it does not become obsolete, and must be thrown away and replaced by new technology, but can be incrementally upgraded to the new technology as much as possible.

SUBSTATION PROTOCOL APPLICATION AREAS

There are various protocol choices depending on the protocol application area of your system. In the previous section the first question to ask is the area of the system being considered. The protocol choices vary with the different application areas. In the following sections different application areas are reviewed with respect to the present state of protocol development and industry efforts. The time frame of development efforts is discussed to help determine what is real for your specific project and its schedule for implementation.

IED to RTU/PLC (Within the Substation)

The need for a standard IED protocol dates back to the late 1980s. IED suppliers will be the first ones to say that their expertise is in the IED itself, and not in the addition of two-way communications capability to the IED, not in the communications protocol, and not in the added functionality from a remote user. At the same time there were industry efforts to add communications capability to the IEDs, each IED supplier was extremely concerned that any increased functionality did not drive the cost of their IED so high that no utility would buy it, and that the performance would not be compromised by the added functionality. Therefore, the cost must remain competitive, and the performance must remain the same, as standardization is incorporated into the IED.

With the IED suppliers' lack of experience in two-way communications and communication protocols, the result was IEDs with crude, primitive protocols and, in some cases, no individual addressability and improper error checking (no select-before-operate). Therefore, each IED required its own communication channel, and RTUs at the time were limited in the number of these channels that were available, if they were available at all. There was pressure on the Supervisory Control and Data Acquisition (SCADA) system and RTU suppliers to be able to communicate to these IEDs purchased by the utilities. Each RTU and IED interface required the implementation of a new protocol, and a proprietary protocol not used by any other IED.

It was at this point that the Data Acquisition, Processing and Control Systems Subcommittee of the Institute of Electrical and Electronics Engineers (IEEE) Power Engineering Society's (PES') Substations Committee recognized the need for a standard IED protocol. The Subcommittee formed a task force to examine existing protocols and determine, based on two sets of screening criteria, the two best candidates. IEEE Standard 1379, *Trial Use Recommended Practice for Data Communications Between Intelligent Electronic Devices and Remote Terminal Units in a Substation*, was published in March 1998. This document does not establish a communication standard. To quickly achieve industry acceptance and use, it instead provides a specific implementation of two existing communication protocols in the public domain.

The first protocol is DNP3, the Level 2-subset implementation as published by the DNP User Group. The DNP protocol was developed by GE Harris Canada (at the time, Westronic, Inc.) in order to stabilize the expansion of unique protocols used to communicate between SCADA RTUs and a variety of IEDs. The DNP protocol used as its basis several IEC 870-5 documents, which were then in development, but extended and/or modified these to accommodate North American preferences and practices. There has been work done to harmonize the IEC 870-5 documents, which were later made International Standards, with the DNP variations. DNP is essentially a four layer protocol using layers 1, 2 and 7 of the ISO/OSI communications profile set, and adding a pseudo-transport layer 4 to facilitate transmission of large data messages. It is specifically designed for data acquisition and control applications, and focuses its application information in the area of electric utility data transmission.

The second protocol is IEC 870-5-101, developed by IEC Technical Committee 57 Working Group 03, including the 101 companion standard (profile). The IEC TC57 WG03 was chartered to develop protocol standards for telecontrol, teleprotection, and associated telecommunications for electric utility systems, and it created IEC 870-5, a group of five utility-specific protocol standards. IEC 870-5 specifies a number of links, frame formats and services that may be provided at each of three layers, similar to the EPRI UCA specification. IEC 870-5 uses the concept of a three-layer Enhanced Performance Architecture (EPA) reference model for efficiency of implementation in devices such as RTUs, meters, relays, etc. Additionally, IEC 870-5 includes a “User Layer”, which is situated between the OSI Application Layer and the user’s application program to add interoperability for such functions as clock synchronization and file transfers. Another document developed by IEC TC57 WG03 is IEC 870-5-101, a companion standard (profile) that contains definitions specific to RTUs and IEDs. Three other companion standards that support the communications requirements for other utility devices have been defined. These are commonly known as 102 for metered values, 103 for substation protection and automation, and 104 for network communications.

The task force decided to use the IEEE “trial use recommended practice” designation for this work, with a limited lifetime, that these recommendations would fill a void on an interim basis until a longer term, more permanent solution was ready to be implemented.

The EPRI/UCA Substation Automation Project began over five years ago, to produce industry consensus regarding substation integrated control, protection and data acquisition, and to allow interoperability of substation devices from different manufacturers. An open process has been followed on this project, to review each major project document and milestone in the open forum of standards-related organizations. There have been over 600 participants in this review process worldwide. The Substation Protocol Reference Specification recommended three of the ten UCA2 profiles for use in substation automation. Future efforts in this project are integrated with the efforts in the Utility Substation Communication Initiative.

Generic Object Models for Substation and Feeder Equipment (GOMSFE) are being developed to facilitate suppliers in implementing the UCA/Substation Automation Project substation and feeder elements of the Power System Object Model. The GOMSFE work merges the UCA Forum Substation and Feeder Automation work with that of UCA2 in order to produce common generic object models for implementation of UCA2 compliant field devices in electric utilities.

New IED products with this functionality are commercially available. The utilities are providing demonstration sites for the implementation of the new IED products to demonstrate interoperability between IED equipment from different suppliers and to evaluate and recommend a suitable UCA-compliant substation LAN.

In summary, for IED communications, if the time frame for implementation is within six months or so, the choice should be for products existing today, with DNP3, Modbus or Modbus Plus communication protocols. However, if the implementation time frame is longer, say one year or more, you should seriously consider EPRI UCA2 with MMS as the communications protocol. With all suppliers, it is imperative that you evaluate their product migration plans. For example, can you migrate from today's IED with DNP3 to tomorrow's IED with EPRI UCA2 MMS without replacing the entire IED? In this way, even with a short time frame for implementation, you have the future option of migrating the IEDs in the substation to EPRI UCA2 in an incremental manner, without wholesale replacement. As stated previously, if you choose an IED that is commercially available with UCA2 MMS capability today, then you may choose UCA2 MMS as your protocol.

RTU/PLC to Master (Substation to Utility Enterprise)

This is the area of traditional SCADA communication protocols. The Data Acquisition, Processing and Control Systems Subcommittee of the IEEE Power Engineering Society (PES) began work on a recommended practice in the early 1980s as an attempt to standardize master/remote communications practices. At that time, each supplier of Supervisory Control and Data Acquisition (SCADA) systems had developed a proprietary protocol based on technology of the time. These proprietary protocols exhibited varied message structures, terminal-to-Data Circuit Terminating Equipment (DCE) and DCE-to-channel interfaces, and error detection and recovery schemes. IEEE Std 999-1992, *IEEE Recommended Practice for Master/Remote Supervisory Control and Data Acquisition (SCADA) Communications*, addressed this non-uniformity among the protocols, provided definitions and terminology for protocols, and simplified the interfacing of more than one supplier's remote terminal units to a master station.

Unfortunately, this work was completed well after the industry need for the work. In the absence of a standard, suppliers continued to develop their own proprietary protocols. Many of these protocols became de facto standards due to their widespread use. However, these protocols did not incorporate all of the advanced features offered by some other protocols already in use.

The major standardization effort that has been undertaken in this application area over the last few years is an international effort in Europe as part of the IEC standards making process. The effort resulted in the development of the IEC 870-5 protocol, which was slightly modified by GE Harris (Canada) to create DNP. A number of years ago Working Group 03 of IEC Technical Committee (TC) 57 commenced work on a "telecontrol" protocol. The primary idea was to develop a single international standard that all suppliers would implement. It addressed the telecontrol domain where the primary constraints were low bandwidth communication channels (in Europe, these typically ranged from 75 bps to a maximum of 600 bps), and a configuration of a single master station interacting with simple devices (RTUs).

The design of the resulting telecontrol protocol, IEC 870-5, reflects these constraints. It is a very efficient protocol, and assumes a single master station scanning status and analog values from simple RTUs over point-to-point communication channels. In the United States, GE Harris (Canada) modified the protocol, primarily at the Data Link Layer, and named it DNP (Distributed Network Protocol). This protocol incorporated a "pseudo" transport layer, allowing it to support multiple master stations. The goal of DNP was to define a generic standards-based

(IEC 870-5) protocol for use between IEDs and data concentrators within the substation as well as between the substation and the SCADA/EMS control center. Success led to the creation of a supplier-sponsored user group that currently maintains full control over the protocol and its future direction. DNP3 has become a de facto standard in the electric power industry, and is widely supported by suppliers of test tools, protocol libraries, and services.

CONCLUSIONS

As we look to the future, it seems the time between the present and the future is shrinking! When a PC bought today is made obsolete by a newer model with twice the performance at less cost in six months, how do you protect your investment made today? Obviously, there is no way you can keep up on a continuous basis with all the technology developments in all these areas. You must rely on others to keep you informed, and the choice of these "others" is critical. Every purchase you make must evaluate the supplier not only on their present product(s), but also on their future product development plans. Is the supplier continuously enhancing and upgrading their products? Is the supplier developing new products to meet future needs? Do the existing products have a migration path to the enhanced products, and the new products? These are all important questions. The choice of the right supplier today will help ensure you stay current with future industry developments and trends, and allow you to take advantage of these new technologies with the least impact on your current operation.

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