"Metering Best Practices – Generation and Transmission Metering"*

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Abstract: *Manufacturers of highly advanced watt-hour meters have enabled utilities to be creative in their utilization of communication mediums and protocols to achieve their Energy Management System (EMS) goals for Transmission Systems and Distributed Control Systems (DCS) in Generation Plants. In most legacy applications at investor owned utilities with transmission and generation assets, the metering equipment now interfaces with a Remote Terminal Unit (RTU) serially using a specified protocol, or with hardwired analog and digital signals to provide monitoring capabilities at remote sites. More recently, utilities are exploring "Smart Grid" applications involving meters connected to IP-based networks. Within this new trend, many utilities are overlooking the power of these devices and the communications capabilities available within them. They can be used as a multi-faceted communication asset to standardize data streams across distribution substations, transmission substations, and generating stations using a litany of protocols. This presentation will focus on the use of these devices, and creative solutions for metering points lacking modern infrastructure.*

From an Electric Meter Engineering standpoint, planning for the future of metering can be a complex mix of planning and working with multiple departments to ensure both regulatory compliance and operational effectiveness. I believe most owners of Transmission and Distribution substations have been progressing very slowly in this area, utilizing tried and true techniques that are well behind solutions that push the creative envelope of metering solutions. Each utility, and unfortunately each department in utilities, have different goals that they want to accomplish with regard to implementation of metering solutions for Generation and Transmission sites. From the perspective of Transmission and Generation operations, the meter's role will be varied, based on the goals of the individual utility departments. The integral part that the meter can potentially play revolves around the flexibility in the communication medium and protocols. The operation of the meter in the substation environment and Generation plant can be broken up into four distinct areas:

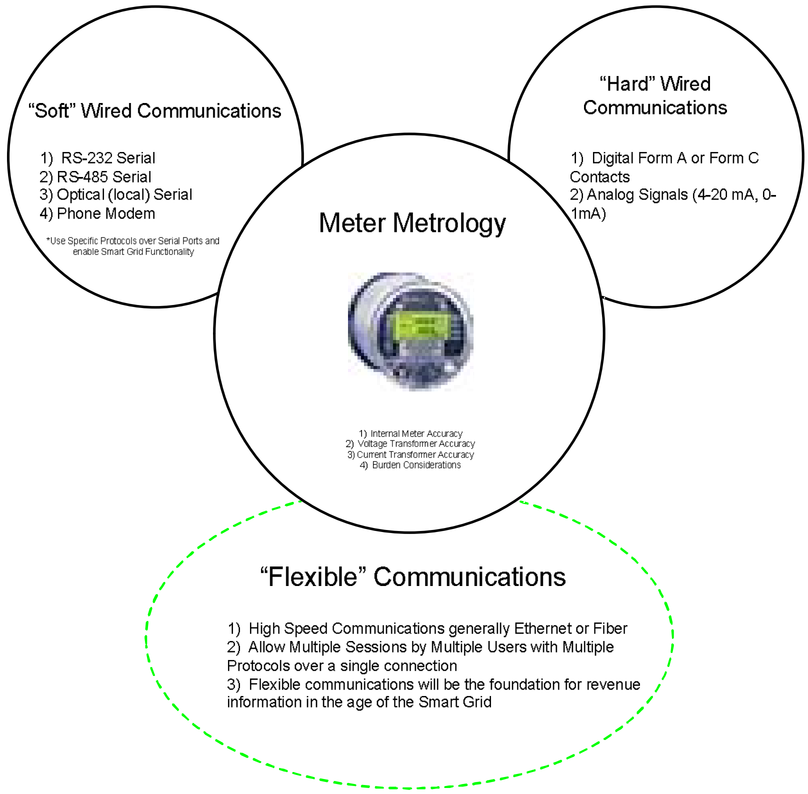
1. Metrology – The physical measurement technology used to compute revenue and service level measurements. The would be the "heart" of the meter as we know it. The basic metrology function has been in use by utilities for over 100 years. The traditional metrology function of the meter utilizes instrument transformers that supply A.C. voltage and current signals which are processed (either electro-mechanically or electronically) into measurements that are used by the utility. It is hypothesized that meters in substations of the future may forgo the traditional A.C. circuitry in favor of centrally processed measurement units, all communicating over a higher speed communication medium, such as fiber optic cable.

2. "Hard Wired" Communications – Traditionally, "Hard Wired" communication signal included both wetted and unwetted digital pulses and analog signals.

These were the first communications from revenue meters in a substation environment and are still heavily in use today at many utilities. Digital pulse signals are generally used to supply integrated values, such as kWh, to external devices. Analog devices use a DC current signal, typically 0-1 mA or 4-20mA that are calibrated to a particular value range for a given installation. These are typically used to supply external devices for instantaneous values such as MW, Voltage, and Current.

3. "Soft Wired" Communication – Soft Wired communications are a fairly new concept with revenue metering and include RS-232 and RS-485 serial communications. These communications typically use a software protocol for communicating with other compatible devices in the substation. Common "Open" protocols commonly utilized in the Utility industry include Modbus (RTU) and DNP 3.0. Also, there are many proprietary protocols available from individual meter manufacturers that may be used as well. These serial communications generally interface directly with an RTU or a network with RS-232 or RS-485 respectively. Soft wired communications allow for fast information exchange and is the bridge to the ultimate ""Smart Grid" ".

4. "Flex" Communications – Flex communications, are just that, flexible high-speed communications that allow for a great variety of communication options. These usually involve either Ethernet (wireless or wired) or Fiber connections that allow multiple sessions over one communication medium. Various protocols might be utilized, even simultaneously, to provide information over multiple ports to multiple users. The protocol use is much more varied, including Modbus TCP, DNP 3.0 over TCP, and HTML and XML over Internet protocol. Flexible Communications truly enable the "Smart" Grid.



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History

In order to understand where we are going in the Generation and Transmission metering world, it is critical to understand where we have been as an industry. In the early days of transmission systems, most systems operators realized that operational data is critical to both record and utilize for planning, maintenance, and investigation purposes. If you were to take a snapshot of a Substation in the 1930's-1960's, a competent individual trained today would be able to identify most of the components in the facility, but that individual would notice one stark difference; there may be a full time substation operator at the facility. This person would monitor all of the activities in the substation, take readings, and most important of all, relay information back to a central control center and take operational instructions based on that information. This was a very reliable way to operate the Transmission system, however, it was very labor intensive and required extensive training for facility operators. The era of the manned substation gradually transformed into unmanned facilities that used recording devices that were read on a periodic basis, perhaps daily, with only the most critical facilities manned. Eventually technology advances and cost reduction in the area of telephony gave way to remote monitoring of substations and the birth of what we know today as the "Modern" substation. Most 1980-1990's era substations included a Remote Terminal Unit, or RTU, that was monitored centrally by the control center. The RTU revolutionized the operation of the transmission grid by allowing a central unit in the substation for relaying operational values on a near real-time basis.

Knowing the history of the substation, the path of the revenue meter within that substation is equally important. Revenue metering in the early substation was really only critical with interconnecting substations. Monitoring the energy flow on all inlets/outlets of the system was and still is the primary function of the revenue meter. The early revenue meter was an electro-mechanical device, that was not much different than modern electro-mechanical meters, that had a register that was read on a periodic basis and accounted for. The electro-mechanical meter eventually added a communication feature, mechanical pulses, that could provide a contact pulse to external devices. This device was pretty much the standard until the advent of the RTU, when the use of transducers became very popular. Basically, transducers could take the revenue metering voltage and current signals and convert them into usable signals by the RTU. The prevalence of transducers started to recede in the 1990's with the advent of solid state meters that could mimic the functionality of the transducer and provided a stable source that could be tested against a standard. Within the last 15 years, revenue meters for substations have literally undergone a revolution, which is why they will play a critical role in the Smart Grid moving forward.

Role of the Revenue Meter

If one were to hold a straw poll regarding the importance of revenue metering among Substation and Transmission engineers, the importance of the device would probably be downplayed. However, the revenue meter will be one of the most critical components that will enable the Smart Grid of the future. One need only look at the current Regional Transmission Organizations (RTO) to see the importance of revenue metering in the Transmission and Generation arena. Each node in these systems relies on a measurement system, generally revenue metering, to provide real-time values for market operations. Moving forward with these markets, one can see the importance that revenue metering will have as a component in the Smart Grid. The critical functions of the meter in the Smart Grid can be broken down into three specific areas:

1. Revenue Measurement – This core function of the device will not go away, regardless of technology advances. The importance of providing an accurate source that is able to be measured against a standard and calibrated and provide revenue numbers to multiple parties will continue to be a critical component of all utility systems.

2. Operational Measurements – The revenue meter will be leveraged to provide key primary (or secondary) operational measurements in any Transmission or Generation Facility. The reason that the revenue meter will be utilized is that the accuracy of the measurements will be superior to any other source in the substation.

3. Multi-party Communications – The modern revenue meter has the ability to provide communications to multiple parties, such as other utilities, RTOs, or different organizations within a given utility. Modern revenue meters will provide the necessary flexibility to satisfy the requirements of all parties.

Metering System Architechture

Applying modern metering infrastructure will differ with different applications of the devices. Below, some of the common applications of Generation and Transmission Metering.

1. Transmission Substation – Interconnection: This is a very common application of revenue meter because of the number of parties that may be involved. When looking at interconnections between utilities the data requirement and ownership can be complex. The possibilities exist for utilities, transmission owners, and even RTO’s to request data connections for a given revenue metering point. With modern revenue meters, the ability to serve all of these devices with data connections is possible.

2. Transmission Substation – Internal: Internally owned Transmission Substations provide a much less complex picture of data required from the revenue meter, which at most utilities is informational. Regardless, a revenue meter can still provide all of the necessary data requirements for internal “Smart Grid” applications.

3. Distribution Substation – The distribution substation may be one of the greatest opportunities for the revenue meter in the modern utility. The reason for this is that development in this area at most utilities has been very minimal, and the potential benefits with optimizing this asset class in particular is great. Revenue metering may be used both at the Transformer and Feeder levels. Additionally, Distributed Generation resources located in small or remote transmission substations could also be controlled and monitored using only the revenue meter.

4. Generating Station – The Generating station presents a great opportunity for information sharing between the substation and Plant Distributed Control System, or DCS. This particular installation provides the opportunity for Gross Generation Metering, Net Generation Metering, and Station Auxiliary Metering to be utilized by both Generating Station Personnel and Transmission Operators to effectively manage and monitor Generating Facilities

Communication Modes for Revenue Metering

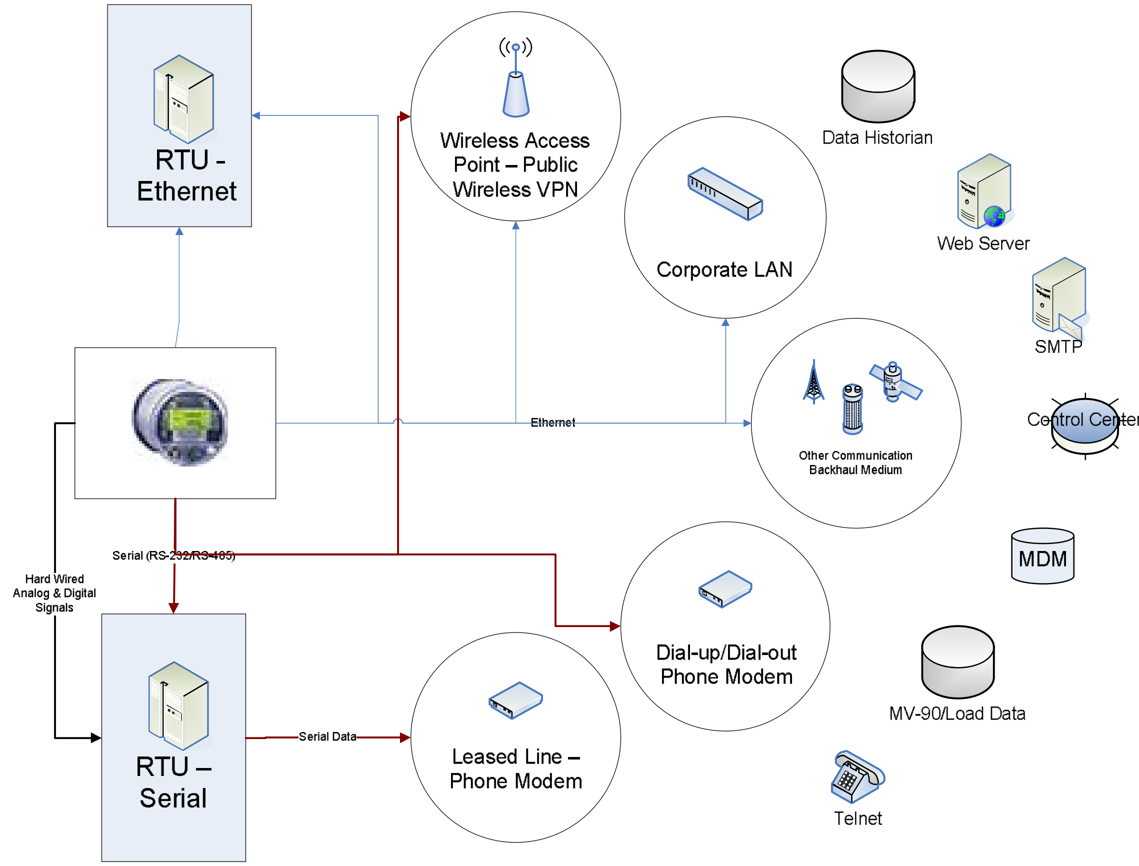

Figure 1 - Common Modern Communcation Modes

The above diagram highlights the potential communications connections that are present and will be present in the future. The head end systems, such as the control center, MDM, MV-90, and Web Server may utilize different communication paths to either directly interrogate the meter or communicate with the RTU. In essence, the variety of communications that allow information transfer, along with the information itself, is the essence of the "Smart Grid" . Multi-party communication around the revenue meter is the lever on which much of the "Smart Grid" information flow will depend on. Active examples of these individual schemes will be shown during the presentation.

Security and NERC Compliance Impacts

It is often said that "Security by Obscurity is <u>No</u> Security", this statement is very true and an individual security scheme for each substation is very important. As security of critical assets comes under NERC reliability requirement, several threats and mitigation of those threats can be seen below:

1. Physical Threats to Metering – Probably the most obvious threat to the grid is just this, somebody forcing their way into a substation to cause damage to the equipment therein. This may be a simple act of vandalism or a well thought out and executed plan to disable a

given utility asset. From a metering standpoint, this may result in the loss of instrument transformers or meters themselves.

Threat Mitigation: NERC CIP-006 – Physical Security of Critical Cyber Assets. For the highest profile sites, these facilities have compliance for access to all facilities. Though this is not failsafe, it is a good mitigation strategy.

2. Physical Tampering – This is in a similar ilk to physical threats, only much more passive and difficult to catch. Physical Tampering involves directly modifying the wiring or telephony circuits in a given substation to achieve a given purpose. This could be thought of similar to a home-owner diverting their electricity or tampering with their electric meter to achieve a benefit. This is a real, although uncommon, threat that faces utility substations (generally where there is a partnership in the substation).

   Threat Mitigation: Again NERC CIP-006 – Physical Security of Critical Cyber Assets. This requires logging of access of any personnel, so that only trusted personnel can access critical equipment.

3. Telephony Tampering – How many utilities have critical assets that have a dial-up telephone circuit for maintenance? This is one area that many utilities don't typically think of as a major security risk, however, this presents the same risk as any other network communications. With a phone number, a potential intruder could attempt to breach devices that are connected to a phone circuit. This is really the definition of Security by Obscurity.

   Threat Mitigation: This turns into a gray area, mostly because you would have to have specific information on a site, generally along with specialty software to access anything of importance, however, still an area that is very insecure.

4. Network Access/Data Confusion –The ability for multiple parties to directly interrogate devices in the substation based on their individual need is critical in today's modern utility. The reason that Network I.P. communications has been highlighted as a major security threat is the exact reason why it will so nicely enable Smart Grid communications. It has a multiple port, multi-user architecture that allows for a variety of protocols to be used simultaneously across the network. The other reason that network access is highlighted is the complete functionality is not well understood by a large population of people. Thus, designs by those unfamiliar with commonly used network security may be susceptible to breach from malicious parties.

   Threat Mitigation: Many NERC requirements cover issues in this area including several CIP (Critical Infrastructure Protection) and BAL (Balancing Authority) Standards. NERC requires a single meter source for a network connected substation, so that multiple utilities MUST interrogate the same source of metrology.

Emerging Standards

IEC 61850 - IEC 61850 is an Ethernet-based protocol designed for electrical substations. It is a standardized method of communications, developed to support integrated systems composed of multi-vendor self-describing IEDs (Intelligent Electronic Device) that are networked together to perform monitoring, metering, real-time protection and control. Meters can play a critical role in both supplying data and control in the Substation using IEC 61850.

IEC 62056 – IEC 62056 is the set of standards which outlines meter data formats and exchanges between systems. IEC 62056 is less focused on the control aspects that metering can provide, and focuses much more on standardizing how devices and systems “talk” to each other with meter data.

ANSI C12 – ANSI governs both the physical construction and operation of watthour meters in the United States. Although there are gaps on the high end devices that are typically used in Generation and Transmission applications, work on C12.19 portends to help standardize table for metering values for these devices in the future.

Conclusion

The utility of the future will rely on a well-designed revenue meter scheme that will enable instantaneous use and storage of all critical operation data necessary to improve our current operations and plan for the future. Knowing this, the road to achieving modernization in the majority of our substations to be will be a long and arduous one. There are so many developments, both on an equipment and network level, that it is critical to understand and have solid goals of where an individual utility wants to get to. Leveraging all of the communication abilities of current Revenue meters will give us the ability to manage the vast majority of the growing pains that may come up as we progress toward our own individual utility goals.

*This white paper has been authored as a supplemental overview by Dan Gunderson, P.E. – Minnesota Power for the presentation “**Meter Best Practices – Generation and Transmission Metering**” for the 2012 Minnesota Power Systems Conference

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