Smart Grid Standards Assessment and Recommendations for Adoption and Development

EnerNex Corporation

October 2008

Executive Summary

This paper addresses four fundamental questions related to standards and technology for building a Smart Grid for California:

- What new and emerging technologies are on the horizon that impact the Smart Grid of the future;
- How to avoid incompatible systems being fielded that result in costly replacements ahead of projections;
- How to help foster open access, competition and commercial growth of new and exciting technologies that offer energy consumers new ways to meet their energy needs while at the same time saving them money; and
- Where government can help and where government should stay out.

A key factor in addressing the Smart Grid problem is a decomposition of the power system and underlying standards and technologies into coherent parts that allow targeted research to be applied, while exposing the problems that have precluded solution development.

First, a high-level overview of available and developing standards and technology will juxtapose the disparate demands of standards development and interoperable systems. The differences between standards developing organizations and technology alliances are used to explore why standardization does not always result in interoperability. Included in this overview is a discussion of how policy and regulation, jurisdictional scope and the roles of the standards and technology developers shape Smart Grid solutions.

Following this, the Smart Grid problem is decomposed into four key areas: Generation, Transmission, Distribution, and Consumer. This will clearly delineate the areas of impact as well as expose the seams between systems where more investment is needed to develop the standards and best practices necessary to link up Smart Grid technologies. Cross cutting decompositions of the communications infrastructure necessary to link the components in the four utility infrastructure zones noted above are also evaluated including Home Area Networks (HAN), Field Area Networks (FAN), Substation Area Networks (SAN), Wide Area Networks (WAN), Utility Local Area Networks (LAN), and Enterprise integration.

Next, an inventory of specific existing or developing standards, best practices, legislation, and regulations in these key areas will be presented that are relevant to smart grid deployment in California. Particular attention is paid to how these standards come into play over time according to the California Smart Grid Roadmap.

Finally, solutions are proffered that address the four questions from the standpoint of what standards and technologies should be recommended, required, or researched to meet the goals of a modern Smart Grid.

One of the key findings of this paper is that there are many mature standards and best practices already available that can be readily deployed to facilitate smart grid deployment. The main problem with adoption seems to be a lack of awareness of those standards by those involved in designing smart grid systems at a high level and a lack of clear best practices and regulatory guidelines for applying them.

Key recommendations include:

- Policy makers should utilize the DOE GridWise Architecture Interoperability Checklist to evaluate utility proposals for projects involving rate recovery.
- Regulations should be developed that encourage utilities and product vendors to support standards based technologies over proprietary solutions.
- Regulations should avoid mandating specific standards or technologies where possible in favor of specifying desired outcomes and important characteristics of the standards to be employed.
- Research should be conducted to accelerate the development of standards that fill existing gaps including those for security, smart grid network and device management, information privacy management, and field area network interoperability.

I. Introduction

Standards development organizations (SDOs) operate under similar rules worldwide. In general terms, the members of the committees doing the actual development work are limited by anti-trust rules or laws from engaging in anti-competitive behavior such as market division, pricing discussions and the like. Also, intellectual property is treated as a potential source for standards language, and requires disclosure by the holder. For balloting, strict control of the candidate voters with respect to balanced interest is performed to provide a measure of fairness and balance. As an example, the American National Standards Institute (ANSI) has three categories, producer, user and general interest, and for balloting groups no single category can exceed forty (40) percent of eligible voters.

Standards usually begin as *de facto*[1] standards; i.e., enough commonality among enough users to call the product/approach/protocol "standard." Beyond this, SDOs actually author *de jure*[2] standards; i.e., those that are codified in a manner similar to laws. Given the careful attention to balloting balance, open rules and open participation, standards are often adopted in place of actual laws.

In North America, the following organizations are some well-known SDOs related to the utility industry:

ANSI – American National Standards Institute (www.ansi.org)
DIN – *Deutsches Institut für Normung*, German Standards Institute (www.din.de)
IEC – International Electrotechnical Commission (www.iec.ch)
IEEE – Institute of Electrical and Electronics Engineers (www.ieee.org)
ISO – International Organization for Standardization (www.iso.org)
ITU – International Telecommunication Union (www.itu.int)

Distinct from SDOs are what are known as "alliances." These are entities and individuals that recognize the value of a particular technology, and form an interest group to promote for example the codification of design and marketing of that technology. The difference between an alliance and a standards group lies with both the rules and the work products. Since any number of interested parties can form an alliance, the rules under which they operate vary widely. An example is the ZigBee Alliance, which has a fifteen (15) member board ("Promoters") made up of technology vendors and two other classes of membership, "Participant" and "Adopter". The work products of the ZigBee Alliance are known as "profiles", or agreed-upon specifications. Since an alliance is not required to have a balanced membership or in some cases to follow certain anti-trust regulations, the work products must be submitted to a SDO in order to become true *de jure* standards.

The following organizations are some well-known alliances related to the utility industry:

HomePlug Powerline Alliance (www.homeplug.org)
Z-Wave Alliance (www.z-wavealliance.org)
ZigBee Alliance (www.zigbee.org)

How to go beyond standardization

Standards meet the goal of creating a common basic understanding of a technology. Unless the scope of a standard includes interoperability tests or guidelines, at best a technology would be in compliance with the standard. In electronic and power technology, unlike physical technology (sizes), interoperability is at best an aspiration of the community that developed the standard. This highlights

[1] WordNet: "existing in fact whether with lawful authority or not."
[2] WordNet: "by right; according to law;"

the need for a dedicated user's community tasked to identify interoperability challenges (requirements), write tests to validate products, and certify those results.

In addition to SDO's and alliances, a third important entity is a "user's group". A differentiator between user's groups, standardization organizations and alliances is that user's groups rules often permit more free discussion between those actually using standards and specifications than those of the developing organizations. An example of the relationship is shown by the IEC 61850 standards developing committee (Technical Committee 57, Working Group 10) and the UCA International User's Group IEC 61850 committee. The IEC technical committee is made up of national experts, nominated and accepted by the IEC. Each committee follows a prescriptive process for producing IEC standards, in this case the IEC 61850 suite of standards. Part 10 of that suite is interoperability tests. The UCAIug IEC 61850 committee is composed of experts that meet on a semi-annual basis to discuss how the compliance of products to IEC 61850 is demonstrated. This is accomplished by that committee validating that the standard tests are applied in a consistent, transparent and fair manner, and thereby conforming products meet the goals of the standard.

Another group laying the foundation for true interoperability is the GridWise Architecture (GWAC). In a partnership with NIST, the GWAC sponsors the Grid-Interop conference, which has the goals of achieving system-to-system interoperability, business process interoperation, preparing for a sustainable electricity system, developing policies for integrated smart energy and a holistic view of generation to consumption.[3]

Finally, to move beyond standards that are regional in scope, there are pacts in place to allow co-publication of standards between the IEC and IEEE, ANSI and IEEE, and others. This is the first step toward true harmonization, whereby a standard is in place for a global market.

[3] [Online]. Available: www.grid-interop.com/2008/

II. Methodology

Power System Infrastructure

For the analysis in this paper, the utility power system is broken into three parts along traditional lines of generation, transmission, and distribution. All of the different load classes, industrial, commercial and residential are grouped into the "Customer" category.

Generation

For the purposes of discussion, Generation means high-capacity (500 MVA and up) central plants connected through a transmission network and distribution system to the Customers. This may include wind farms whose total capacity exceeds this minimum threshold when treated as a single generating station for analytical purposes.

Transmission

The transmission network, along with the distribution system, is sometimes also referred to as the "bulk power" system. This network in North America is broken into four coherent, synchronous areas: the Québec Interconnection, the Eastern Interconnection, the Western Interconnection (also known as the Western Electricity Coordinating Council, or WECC)and the Electric Reliability Council of Texas Interconnection (also known as ERCOT and the Texas Regional entity, or TRE). The Eastern Interconnection includes the following regional entities: Florida Reliability Coordinating Council (FRCC), Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability*First* Corporation (RFC), SERC Reliability Corporation (SERC), and the Southwest Power Pool (SPP).[4] By "coherent, synchronous area", this defines how the generation supply of that area is coordinated to meet the load. It also defines the reach of problems, such as blackouts. The transmission system operates at the highest voltage level, 138 – 1000 kV.

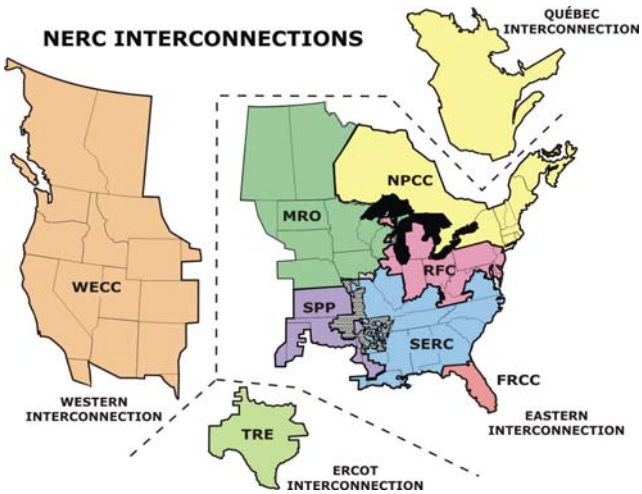

Figure 1a: NERC Interconnections

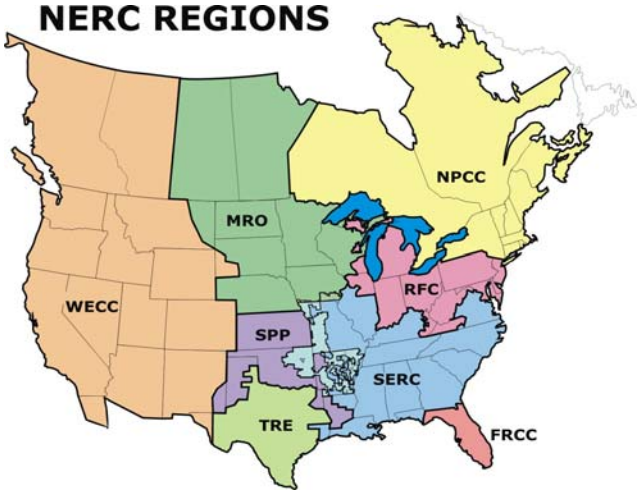

Figure 1b: NERC Regions

>>> note: can we use FERC diagrams from website? (http://www.nerc.com/page.php?cid=1|9|119)

Distribution

[4] [Online]. Available: www.nerc.com

The distribution system is the most equipment and maintenance-intensive portion of the bulk power system. The design of the distribution system is not a true "grid"; i.e., multiple power delivery paths for a single load. Rather, each load can be clearly paired with a generation source, typically a substation delivery point. Some industrial sites have multiple feeds with switchover equipment to provide a higher degree of reliability. It is possible to connect generation on the distribution system, known as distributed generation, or distributed resources. The power provided by this generation ranges from 5 to 500 MVA, and includes wind turbines, solar arrays, solar thermal, small hydroelectric plants, fuel cells, microturbines. When considering the definition of distributed resources, technologies such as battery energy storage, superconducting magnetic energy storage, as well as many others are added to the generation mix.

The maintenance needed to support this system is revealed through the quantity of devices required to support its function: for every 250,000 customers there are up to 60,000 secondary or service transformers, up to 227 feeders and 45 substations.[5] Each feeder may also have a power transformer at the substation to convert from the transmission or sub-transmission voltage to the distribution voltage. The distribution system operates at 13.8-138 kV.

Customer

The customer was once treated as a pure revenue source for the utility, but is in the near future (and in some cases today) treated as a "partner". Once a ubiquitous communication system is in place linking customers to the utility, monitoring and control of each load will be simpler. Customers will be encouraged through rate programs and incentives to moderated their consumption of energy (and demand) to allow the utility to avoid whenever possible the need to purchase power during peak consumption periods. These demand response programs then enable the utility to defer investment in infrastructure, with its long litany of complaints, and instead invest in continual efficiency improvements.

One vision for this does include some investment in infrastructure; however, this is communications infrastructure, which is easier to emplace. Advanced devices such as two-way communicating meters, communicating thermostats, and home automation devices such as programmable and communicating outlet controllers will assist energy customers in managing their demand for energy.

Communications Infrastructure

A smart grid is achieved by overlaying the power systems infrastructure with communications infrastructure. Benefits are derived by delineating the communications infrastructure along functions that are not quite tied on a one-to-one basis with the power system infrastructure.

Home Area Networks (HAN)

This zone includes devices with a single premise (industrial site, commercial business or home) communicating over one or more networks. Electric utilities are looking to leverage these networks to provide relief during high demand periods (demand response) by communicating through some type of home gateway bridging utility and home networks.

Field Area Networks (FAN)

This zone includes devices communicating over one or more networks between the individual service connections and the utility back office applications. This network is primarily supported by an Advanced

[5] Willis, p. 11, Table 1.3.

Metering Infrastructure deployment, as this is the most widespread communications network a utility can install. Included in a FAN are distribution automation and control (DAC) devices.

Substation Area Networks (SAN)

This zone includes devices communicating over one or more networks inside of a single electric substation. These typically are capacitor banks, relays and other substation automation equipment. This network is often the farthest zone of operation of a SCADA (supervisory control and data acquisition) system. One group is working to extend a SAN standard (IEC 61850) to include more than one substation (substation-to-substation communications).

Wide Area Networks (WAN)

This zone is the bridge between FANs and SANs and the utility LAN and back office. This includes communications from control centers to the substations. This is commonly referred to as 'backhaul' communications.

Local Area Networks (LAN)

This zone identifies a "close" set of devices in communication, as the name implies, in a local configuration. Often each floor of a building may be on its own LAN, or a single server room may be a LAN. HANs, FANs and SANs are types of local area networks.

Enterprise Integration

This identifies the connection of disparate applications needed to drive the utility business needs. This typically includes applications with "system" in their name such as outage management systems (OMS), graphical information systems (GIS), distribution management systems (DMS), energy management systems (EMS), customer information systems (CIS),meter data management systems (MDMS), or even an enterprise resource planning (ERP)system. Common practice is for each of these systems to be supplied by a different vendor, leading to difficulties in managing the data needed to run the utility business. The industry is moving toward common information model (CIM) development and away from proprietary integration development.

A Deeper View of the Problem

Figure 2 is a pictorial representation of the different networks mentioned here with some example devices, systems and actors. One can easily trace from the HAN, through a LAN and WAN, and into the Utility Enterprise. Beyond this dimension, there are seven layers[6] represented, following the OSI (open systems interconnection) model: Application, Presentation, Session, Transport, Network, Data Link and Physical. This is a more accurate representation of the hurdles to true interoperability. To demonstrate proper integration and function, two actors must agree on standards and protocols for each of the seven layers.

[6] Wikipedia, "OSI model"

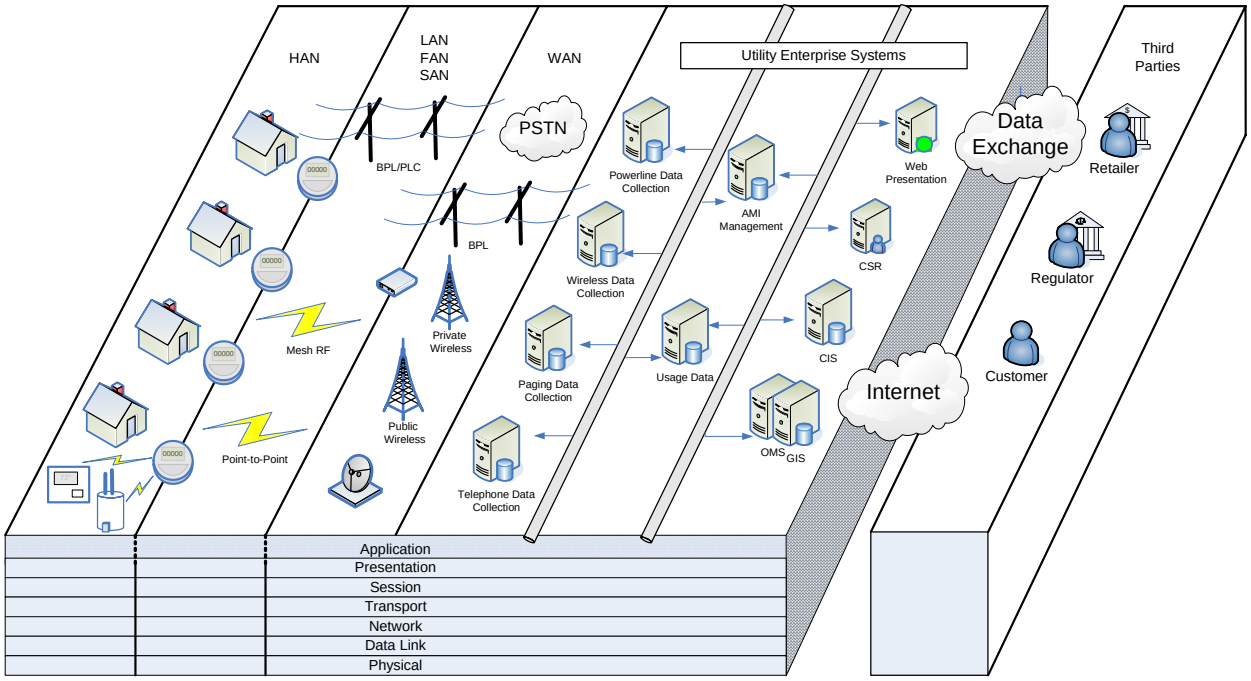

Figure 2: Communications and Layers[7]

[7] Adopted from Gray, "AMI Enterprise, A Framework For Standard Interface Development"

Smart Grid Gap Identification and Decomposition

Generation

Transmission

Distribution

Consumer

Cross-cutting Decompositions

III. Technology Enumeration

Standards

Standard	Enterprise	LAN	WAN	SAN	FAN	HAN
Internet Protocol version 4 (IPv4)	Y	Y	Y	Y	Y	Y
Internet Protocol version 6 (IPv6)	Y	Y	Y	Y	Y	Y
Multi Protocol Label Switching (MPLS)	Y	Y	Y	Y	Y	Y
X.509 Public Key Infrastructure (PKI)	Y	Y	Y	Y	Y	Y
Federal Information Processing Standard (FIPS) encryption	Y	Y	Y	Y	Y	Y
Federal Information Processing Standard (FIPS) authentication	Y	Y	Y	Y	Y	Y
Internet Protocol Security (IPSec)	Y	Y	Y	Y	Y	Y
Transport Layer Security (TLS)	Y	Y	Y	Y	Y	Y
Common Management Information Protocol	Y	Y	Y	Y	Y	Y
OSI (Open Systems Interconnection) network management	Y	Y	Y	Y	Y	Y
IEC 62351 Security	Y	Y	Y	Y	Y	Y
Simple Network Management Protocol (SNMP)	Y	Y	Y	Y	Y	Y
Remote Network Monitoring (RMON)	Y	Y	Y	Y	Y	Y
IEEE 1588 Precision Time Protocol (PTP)	Y	Y	Y	Y	Y	Y
IEC 61334-4-41 DLMS (Device Language Message Specification)			Y		Y	Y
IEC 62056 COSEM (Companion Specification for Energy Metering)			Y		Y	Y
ANSI C12.18 Optical Port and Protocol Specification for Electric Metering						Y
ANSI C12.19 Utility Industry Data Tables			Y		Y	Y
ANSI C12.21 Telephone			Y		Y	
ANSI C12.22 Networking			Y		Y	Y
ANSI C12.23 Testing			Y		Y	Y
Building Automation and Control Networks (BACNet)						Y
HomePlug						Y
IEEE 802.15.4 with ZigBee						Y
IEEE 802.11b/g "Wi-Fi"						Y
IEEE 802.15.1 "Bluetooth"						Y
Radio-frequency Identification (RFID)						Y
IEEE 802.11i Wi-Fi Protected Access 2 (WPA2)						Y
IEEE 802.3 Ethernet						Y
LonWorks						Y
X10						Y
6LowPAN (IPv6 over Low power Wireless Personal Area Networks)						Y
Z-Wave						Y
Insteon						Y
WirelessHART (Highway Addressable Remote Transducer protocol)						Y
Open Services Gateway initiative (OSGi)						Y
IEEE 802.1Q Virtual LANs (VLANs)						Y
Fieldbus			Y	Y	Y	
Profibus			Y	Y	Y	
IEEE 1390 Telephone Meter Reading			Y	Y	Y	
Cellular Digital Packet Data (CDPD)			Y	Y	Y	
IEEE 802.16 WiMAX			Y	Y	Y	
Multiple Address Systems (MAS) / Trunked Radio			Y	Y	Y	
IEC 60870-5-101/104 Telecontrol			Y	Y	Y	
Modbus			Y	Y	Y	
DNP3			Y	Y	Y	
IEC 61850 Substations			Y	Y	Y	
2G Wireless (1xRTT, GPRS)			Y		Y	
HomePlug Access BPL (Broadband over Power Line)			Y		Y	
X-Series Networking	Y		Y	Y		
Frame Relay	Y		Y	Y		
Synchronous Optical Networking (SONET)	Y		Y	Y		
Synchronous Digital Hierarchy (SDH)	Y		Y	Y		
Asynchronous Transfer Mode (ATM)	Y		Y	Y		
Wavelength Division Multiplexing (WDM)	Y		Y	Y		
Virtual Private Networks (VPNs)	Y		Y	Y		
IEC 60870-6 Inter-Control Center	Y					
IEC 61970 Common Info Model	Y		Y	Y		
IEC 61968 Distribution Interfaces	Y		Y	Y		
OpenGIS (Open Graphical Information Systems)	Y					
MultiSpeak	Y		Y	Y		
HTTP/HTML	Y					
Common Object Request Broker Architecture (CORBA)	Y					
Web Services	Y					
Structure Query Language (SQL)	Y					
OPC (Object Linking and Embedding for Process Control)	Y					
Web Services Security	Y					
HTTPS (Hypertext Transfer Protocol over Secure Socket Layer)	Y					
IEC 62325 Energy Markets						
ebXML (Electronic Business using eXtensible Markup Language)						
Point-to-point Microwave	Y		Y			
Licensed Point-to-Multipoint Radio			Y	Y	Y	Y
Unlicensed Point-to-Multipoint Radio			Y	Y	Y	Y
Licensed Mesh Radio Network			Y	Y	Y	Y

Best Practices

Legislation

Regulations

IV. Solutions

Recommendations

Requirements

Research

Conclusions and Recommendations

One of the key findings of this paper is that there are many mature standards and best practices already available that can be readily deployed to facilitate smart grid deployment. The main problem with adoption seems to be a lack of awareness of those standards by those involved in designing smart grid systems at a high level and a lack of clear best practices and regulatory guidelines for applying them.

Of particular concern is an over-reliance on using standards as the "final" request to meet requirements. Often products conforming to standards fail to meet the hidden requirement of being truly interoperable in the context of a greater system.

Key recommendations include:

- Policy makers should utilize the DOE GridWise Architecture Interoperability Checklist to evaluate utility proposals for projects involving rate recovery.
- Regulations should be developed that encourage utilities and product vendors to support standards based technologies over proprietary solutions.
- Regulations should avoid mandating specific standards or technologies where possible in favor of specifying desired outcomes and important characteristics of the standards to be employed.
- Research should be conducted to accelerate the development of standards that fill existing gaps including those for security, smart grid network and device management, information privacy management, and field area network interoperability.

References

G. R. Gray, “AMI Enterprise, A Framework For Standard Interface Development”, [Online]. Available: http://osgug.ucaiug.org/utilityami/AMIENT/Shared%20Documents/Presentations%20and%20General%20Info/AMI-ENT%20Application%20Integration%20-%20A%20Framework-1.ppt

H. L. Willis, Power Distribution Planning Reference Book, 2nd ed. Boca Raton: CRC Press, 2004.