Achieving Smart Grid Interoperability through Collaboration

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Abstract

Numerous analyses, including the "Prism" analysis at the Electric Power Research Institute (EPRI), show that energy conservation and distributed resource integration are critical elements of an overall strategy to reduce carbon emissions. The smart grid is the enabling infrastructure that makes much higher levels of distributed resource integration possible. The value is maximized by leveraging Distributed Resources at both the local and overall system level as a "virtual power plant" to better match energy supply with demand along with related value-added benefits.

Due to the complexity, number and scale of the systems and devices involved in creating a demand-side virtual power plant, interoperability between the various systems is the key to success. An interoperable smart grid fosters increased competition among suppliers, innovation, choice, reduced costs and reduced capital risk caused by technology or vendor obsolescence, and enables automation resulting in increased value and improved reliability.

Unfortunately, interoperability cannot realistically be achieved by a single entity and requires collaboration from numerous organizations including utilities, regulatory bodies, standards bodies, vendors and more. An approach of structured regional utility demonstrations designed to promote and evaluate integration of distributed resources at all levels of power system operations will further smart grid interoperability. Utilizing a standardized approach like the IntelliGrid® methodology to develop use cases and standard functional requirements can further communication, information, and control infrastructures required to support integration of emerging technologies as well as identify critical gaps in existing standards providing focus for future research and development.

1. A COMMON UNDERSTANDING

To start with, we need to have a common understanding of what is the smart grid, its value, what are the technology drivers of a smart grid and underlying assumptions. There is little argument regarding the level of hype related to smart grid. On Gartner's hype cycle [1] (figure 1), one could argue the smart grid is at the "Peak of Inflated Expectations."

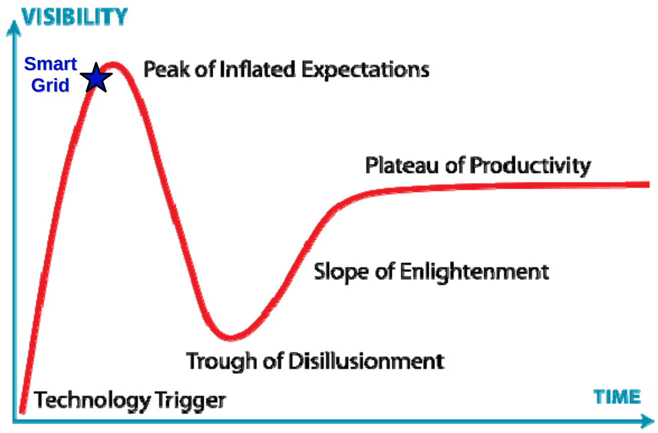

Figure 1: Gartner's Hype Cycle [1]

It is important that we minimize the time in the "Trough of Disillusionment" and one way to do that is to manage expectations by understanding the true capabilities of a smart grid. Electric utilities around the world realize the opportunity and are already investing in the communication and information infrastructure that is expected to be the backbone of a smart grid. Deploying collaborative smart grid demonstration projects that uncover gaps in standards and open communications related to integration of distributed resources will get the smart grid on the "Slope of Enlightenment" sooner. Investors and regulators want to know if the investments will be a technical and financial success. Customers want to understand if benefits will justify the costs that may ultimately be borne by them. Carefully structured demonstrations will result in a common understanding of benefits and practical applications of a smart grid. As the benefits of real demonstrations become accepted and the technology and related standards becomes increasingly stable, the smart grid will reach the "Plateau of Productivity."

1.1. What is the smart grid?

The smart grid has numerous definitions with a very broad scope. It's interesting to ask the question and see the responses you get because it varies significantly based on the field of expertise of the person asked. A smart grid is one that incorporates information and communications technology into every aspect of electricity generation, delivery and consumption in order to: minimize environmental impact; enhance markets; improve service; reduce costs and improve efficiency. This definition is basically about leveraging gains in the convergence of communication, computer hardware, and software technologies adding intelligence to the electric power industry infrastructure. This is the normal evolutionary path of technology development that has occurred in other industries such as telecom, industrial process control system development, and the entertainment media industry. This technology evolution applies to the electric power industry in the same manner and is referred to as the smart grid.

1.2. A Smart grid can reduce carbon emissions

One significant goal of smart grid demonstrations is to accelerate reduction of CO_2 emissions. First-order estimates of energy savings and CO_2 emissions impact is 56-203 billion kWh and 60 to 211 million metric tons of CO_2 per year in 2030[2]. Five key applications enabled by a smart grid provide this impact: 1) Continuous commissioning for commercial buildings; 2) Distribution voltage control; 3) Enhanced demand response and load control; 4) Direct feedback on energy usage; and 5) Enhanced energy efficiency program measurement and verification capabilities.

1.3. Integration of distributed resources

The most significant projected reduction on CO_2 emissions from a smart grid will result from developments associated with integration of distributed resources along with direct feedback on energy usage and market conditions. Distributed resources include demand response, distributed generation, storage, and renewable generation. It is estimated that these resources alone will make up 80% of the projected 60 to 211 million metric tons of CO_2 reduction per year in 2030[2]. Although distributed resources are being deployed today, they are not transparently integrated at the system operator level and not enough is being done to further interoperability. Today, advances in emerging computing hardware, software and communication technologies are making integration more cost effective than ever before. Efforts focused on integration of distributed resources will provide the most significant value for CO_2 reduction related to smart grid deployments.

1.4. Smart grid technology drivers

The Virtual Power Plant (VPP) (figure 2) is a relatively simple concept; aggregating multiple distributed resources that collectively can respond similar to a generator to form a VPP. The technology capabilities for a VPP exist today but they have not been integrated to make distributed resources part of the operation of the power system. The VPP concept is a particularly attractive way to demonstrate smart grid functionality because it touches on all aspects of a smart grid – communications infrastructure that goes all the way to the consumer and into the consumer premises, interfaces with advanced metering, distribution automation, energy management systems and optimization of system performance through a combination of enterprise level applications and distributed intelligence.

Figure 2: Virtual Power Plant (VPP)

Significant developments in communication, hardware and software technologies are enabling distributed intelligence to be embedded at the device level at a low-cost. As an example of technology advances, in 2006, the Wi-Fi semiconductor market shipped just under 200 million Wi-Fi chipsets, and reached over 500 million chipset shipments cumulatively. Research indicates that around the middle of 2008, the industry will have passed the one billion mark for cumulative chipset shipments. Even more impressive is the projection that there will be well over a billion chipsets shipped in 2012 alone, with cellular handsets and consumer electronics accounting for over two-thirds of that total [3]. This example of technology evolution is amazing. If this capability is applied to the smart grid, it is equivalent to nearly a billion devices per year capable of performing smart grid functions by 2012. A related impact on our industry is the evolution and growth of ultra low-power Wi-Fi now competing with ZigBee®. ZigBee has seen some recent successes in Advanced Metering Infrastructure (AMI) deployments, but lacks third party product availability unlike Wi-Fi.

Computing technology advancements coupled with an explosion in low-cost communication penetration are factors driving the capabilities of a smart grid. Here are some headlines regarding communication trends:

- Broadband to reach 77% of U.S. households by 2012, Gartner says [4].

- FCC Chairman Kevin Martin wants broadband across the USA and proposes “Free Broadband” as a condition to sale of the wireless spectrum stating that it is important to the welfare of U.S. Consumers and a social obligation [5].

Those headlines are related to public communication infrastructure, but there is similar growth in private communication infrastructure deployments in the utility industry related to AMI and system automation. AMI can be described as automated two-way communications between utility meters and the utility. Data from AMI systems is an enabler for additional services, but the data needs to be accessible in a common format. Unfortunately today, AMI system communications are not standardized from the meter to the enterprise, resulting in vendor lock-in or limited capabilities since systems can’t readily access the data.

Utility industry communication standards development is not keeping up with technology advancements. With standards processes taking years to evolve in a technology environment where communication bandwidth and computing power are doubling every 18-24 months (Moore’s law), creative methods must be used to further the standards development that will result in interoperability sooner rather than later.

2. THE NEED FOR INTEROPERABILITY

It is important that diverse devices and systems playing in a smart grid game achieve the ability to inter-operate. Although dynamic rates and systems are deployed across the country and world today to perform functions of a smart grid related to distributed resource integration, nearly every program has a different format for communicating prices and events. Without a standard format for communicating information, it is costly to develop products and services that function in every market. In addition, one cannot build products and services that function in this environment without knowing the regional energy market in which they will be deployed.

The significant challenge for successful deployment of a smart grid related to distributed resource integration is implementation of common standards. Agreed upon standards will unleash the free market to further develop innovative products and services that enable interoperability at all levels of power systems. In addition, to be truly effective, the grid must also be prepared to interact with standards from other industries, such as industrial equipment, building and process control systems, home automation, appliances, and plug-in hybrid vehicles (PHEV).

Until there is transparent communication interoperability from distributed resources to utilities and within utility systems, there will be significant risk when considering investing in non-standardized systems. This lack of interoperability is one of the primary factors holding back utilities from deploying systems and third parties from furthering the development of controllable system interfaces and devices.

2.1. The integration weak link

Where is the weak link in integration of distributed resources? There are numerous weak links and a lot of stakeholders. Standards are progressing and there are significant ongoing efforts to further those standards, but there still isn’t complete industry consensus resulting in uncertainty in smart grid and related AMI technology deployments. At a high-level, there should be agreed upon standards for presenting meter data to the utility AMI system. There is hope that the American National Standards Institute (ANSI) standards will provide part of the answer for communication between the meter and utility systems over an AMI network that is not dependent on the communication media. This could be part of the solution, but there are still integration issues when presenting data from the AMI system to the enterprise or meter data management system (MDMS). Common Information Models (CIM) such as those in IEC 61970 and IEC 61968 can be further developed extending to additional utility systems and processes.

Other standards for communicating in the home are competing. Recently, ZigBee® and HomePlug® announced an alliance to create a wired HAN standard [6]. This alliance demonstrates the interest among organizations to come to an understanding to reach a common goal, but controversy continues. Less than a month after the ZigBee, HomePlug announcement, the IP for Smart Objects (IPSO) Alliance announced the “New Industry Alliances Promotes Use of IP in Networks of ‘Smart Objects’.” [7] The IPSO alliance has a goal of promoting Internet Protocol (IP) as the network technology best suited for connecting and delivering information to devices. Ideally, standards will be developed that are media agnostic, but there are clearly differing views and no clear cut winner creating uncertainty and risk when considering investments in these systems.

These are just a few examples of how integration standards need to mature to ensure interoperability but there are many more areas of integration weaknesses at the enterprise level. For the integration of distributed resources, AMI data should be usable across the enterprise including Distribution Management Systems (DMS), system planning and real-time integration with system operations. Distributed resources need to be able to communicate information necessary to be treated on the same plane as generation. A collaborative effort pulling stakeholders together can facilitate communication to assemble seemingly competing solutions that ultimately have the same end-state and goals in mind.

3. THE POWER OF COLLABORATION

The well-known adage, the whole is greater than the sum of its parts, acknowledges the power of collaboration. Uniting utilities, research organizations, regulatory bodies, and standards bodies strengthens positions and solves common problems more effectively. Issues associated with integration of distributed resources are common among nearly all electric utilities.

Achieving all the benefits of a smart grid will not be easy. The task is very complex and furthering standards alone will not get the job done. The scope is global and thousands of companies and organizations working together are necessary to achieve a smart grid. By collaborating to further standards as well as identify critical gaps in standards and technologies, the collaborative becomes a powerful force that will result in a market that fosters a capitalistic environment with a long-term goal of system wide interoperability.

3.1. Stakeholders

The stakeholders with a vested interest in the success of a smart grid are wide ranging. It includes utilities, consumers, users groups, policy makers and vendors. The list is large and growing, also including EPRI, the Department of Energy (DOE), NETL, State Regulators, NYSERDA, PIER, LBNL, PNNL, DRRC, DRCC, SAP AMI Lighthouse Council, The Galvin Initiative, European Smart Grid Initiative, GridWise™ Alliance, Grid-Interop™, UCA International User's Group, IEC, IEEE, IEN, AHAM, NIST, NEMA, SAE, ANSI, NAESB, FREEDM, ZigBee® Alliance, IP for Smart Objects Alliance, HomePlug® Powerline Alliance, Insteon® Alliance, CableLabs®, OBIX™ and more. We apologize for all the acronyms, but the point of this list is to demonstrate the enormous amount of activity around the nation and world to further a smart grid.

Believe it or not, vendors are not the enemy and many of the listed organizations are representing vendors and manufacturers. In most cases, vendors want standards as much as the utility industry and consumers. The lack of standards forces vendors to develop bridge-the-gap solutions systems that perform the functions necessary for integration of new and legacy systems.

Until standards exist and are demanded by consumers, vendors will continue to develop closed or proprietary systems that provide the competitive advantage necessary for today's market conditions. They understand customer resistance to vendor lock-in and it doesn't make good business sense for vendors to force it.

All stakeholders must be involved in a collaborative effort to provide a well-rounded view of the wide-ranging impacts of the smart grid. Regulatory policies vary widely and systems must be designed to accommodate this broad range of requirements. Standards bodies have a long-term view and technology development is advancing rapidly. Standards development must evolve more rapidly to minimize the amount of non-standard deployments in the industry. Utilities understand the assumed value of what a smart grid can bring to their shareholders and ratepayers. Demonstrations must test assumptions to bring more certainty to the business case and the value must be transferred to consumers.

3.2. The value of a collaborative demonstration

Utilities are investing in smart grid solutions today, but those solutions, individually, are not furthering the industry. From a functional perspective, today's smart grid deployments perform as specified, but additional effort is required to further interoperability outside of the utilities direct needs to gain additional societal benefits. By joining a collaborative effort, additional resources can be applied to projects that lay a foundation and can further industry development of the interoperable smart grid. Collaboration encourages the sharing of human knowledge and saves countless hours of labor in research, studies, evaluation and software development. In addition, the result of having standards for system integration lays a foundation for opportunities such as the development of open source software. In fact, a collaborative effort should not ignore an opportunity to develop open source software for market and system integration.

The book Wikinomics: How Mass Collaboration Changes everything [8], describes the opportunity at hand. The concept of mass collaboration is about harnessing the collective capability and genius to spur innovation, growth, and success. Although Wiknomics has perhaps an overly optimistic viewpoint, it does outline a good general overview of the opportunity at hand with advancing a smart grid with collaboration.

3.3. Business issues arising from collaborative demonstrations

Several business issues arise from collaborative demonstrations. Poor project management can result in chaos and a slow-down in productivity. With the number of stakeholders involved, decisions will be made by consensus as well as by monitoring the results of successful technology deployments. The collaborative needs to be careful of dissention or taking sides that can result in situations similar to a two-format landscape such as BETA vs. VHS or HD DVD vs. Blu-ray. A controversial landscape will keep technology and integration from reaching mass adoption.

It must also be understood that there will be a significant period of time before full interoperability can be realized. Utility systems and even appliances have a long life span ranging from years to decades. It will be important to evaluate bridge-the-gap integration solutions to maximize the lifetime of existing legacy systems so they survive their intended lifespan. A significant portion of a smart grid demonstration initiative should be focused on identifying this reality and understanding how to best manage it.

4. DEVELOP A SOLID FOUNDATION

It is important to have a solid foundation on analytical integration approaches when understanding the impact of distributed resources as it applies to a smart grid. It is equally important to understand critical technologies and systems that are instrumental in achieving widespread integration of distributed resources. An approach developing an analytical framework and architecture reference design for integration of technologies and systems should be used as the foundation to evaluate multiple collaborative demonstrations equally.

The foundation should support demonstration design, implementation, and application of key integration technologies. The IntelliGrid® architecture should be applied to develop use cases and specify highest priority requirements for communication and control of distributed resources. For each demonstration project implemented, a combination of performance, security, benefits, and/or interoperability assessments must be conducted based on data collected through lab and field deployments and communicated to stakeholders.

4.1. Analytical framework and tools

Analytics provide a structured framework for characterizing the integration issues to be addressed and guiding principles for scoping regional demonstrations. A framework should include a wide range of demonstration tasks and objectives. Objectives may include environmental and economic impact, system reliability, power quality, system security, and other goals for applying distributed resources. Demonstration objectives should be mapped to a common integration framework. The framework should track the extent that the existing demonstrations address integration barriers, and reveal critical gaps that may be addressed through the design of future demonstrations. Tasks must include review of work by standards bodies, regional system operators, vendor products, technology assessments, and CO_2 emission calculation methods. An assessment of how distributed resources impact forecasting and network planning and operation should also be considered.

The objective is to establish the set of analyses required to resolve the established barriers and to provide credible data and a consistent set of methods and processes to aid decision making in several critical areas. These areas include: distributed resources as a factor in planning and operations, integration approaches, quantifying the firmness of these resources that can be coordinated to support grid and market operations, and their potential impact in mitigating green house gas emissions. The analyses should include a broad mix of distributed resource applications, from merely sending information signals that coordinate voluntary demand response to dispatching energy storage and distributed generation for system reliability. The scope should also include investigation on enhancing customer choice through electric service innovations, as in the application of microgrids to support the supply system and to deliver quality power and reliability at customer-preferred levels.

4.2. Critical Integration Technologies and Systems

Examples of critical integration technologies include common information model, local controller, communications interfaces and protocols. Identifying and influencing the design and deployment of technologies are instrumental in achieving widespread integration of distributed resources. Project efforts should include developing common information models for distributed resources, system interfaces, and local controllers. These efforts will be designed to identify critical gaps in market and system protocols and develop workable methods that can be demonstrated to address the identified gaps. System-level technologies to be investigated include system controls interfaces (e.g., for integration with distribution management systems), new system topologies (e.g. microgrids), and communications infrastructures that integrate distributed resources with market management systems.

4.3. Communication and technology transfer process

Technology Transfer provides stakeholders timely and useful interpretations of the results and syntheses of lessons learned across all demonstrations. It is important to frequently communicate the status of field demonstrations, lessons learned, architectural challenges, issues impacting standards, and common interest areas to explore further. The goal is to inform and coordinate with standards bodies, regulators, and industry at large on critical issues towards overcoming challenges in distributed resource integration. The electric power industry must be engaged in influencing the development of communications interface standards for distributed resources to support utility and consumer energy management needs.

5. KEY DEMONSTRATION ACTIVITIES

Demonstration activities must be challenging enough to test existing distributed resource integration standards and interfaces while also able to identify gaps and weaknesses.

The demonstrations must test business case assumptions and communicate the results to stakeholders. The collaborative demonstrations must employ the analytical and technical framework designed as the foundation for achieving smart grid interoperability

5.1. Multiple demonstrations

Multiple regional demonstrations can effectively accomplish overall collaborative goals if each demonstration integrates multiple levels of integration of multiple types of resources. No single demonstration can cost effectively accomplish the goals, but having an aggregate of demonstrations in diverse geographical regions and in varying power system infrastructures provides an overall picture of the state of the smart grid.

5.2. Leverage existing and planned investments

To minimize financial risk, demonstrations should leverage existing and planned utility projects related to integration of distributed resources. There are a sufficient number of national and international smart grid-type deployments that can be leveraged without having to devise custom demonstration projects. The scope of existing and planned utility smart grid projects must be expanded to include foundational analytical and integration framework and architecture to accomplish overall goals of the collaborative demonstration initiative.

A five year term of this initiative should be sufficient to test existing and emerging technologies and systems to increase the learning and define the overall industry needs for system-wide integration. This will build a consensus on the approaches that work best while outlining needs for future demonstration needs to further interoperability.

5.3. Multiple levels of integration, multiple types of resources

By deploying multiple demonstration projects that have varying levels of integration of multiple distributed resources it collectively results in data that otherwise is not achievable. Integration deployments should test systems including the Home Area Network (HAN), AMI, Distribution Management System (DMS), Supervisory Control and Data Acquisition (SCADA), System Operations and Planning, Markets, as well as the numerous utility Enterprise systems.

Multiple types of distributed resources (demand-response, storage, distributed generation and renewable generation) should be integrated transparently so they have visibility at the system operator and market in the same manner as generation resources effectively creating a VPP.

6. NEXT STEPS

Stakeholders interested in furthering smart grid interoperability are encouraged to collaborate with leading organizations with common goals. EPRI is collaborating with the numerous stakeholders in a smart grid demonstration initiative along with DOE and European Smart Grid demonstrations. By having strong stakeholder relationships that are collaboratively working towards a common goal, we can more rapidly provide a foundation for widespread adoption of a smart grid that provides real value.

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Biography

Matthew P. Wakefield – Mr. Wakefield is a Senior Project Manager at the Electric Power Research Institute (EPRI) managing EPRI's smart grid demonstration initiative. He has over 22 years of energy industry experience and prior to joining EPRI, was the Manager of Applied Technology for Integrys Energy Group focused on developing and applying information and communication technologies related to real-time energy information transfer between control centers, generators, markets and consumers. This team developed a number of innovative solutions including DENet® and

eMiner® that utilized open source software and low-cost embedded hardware while leveraging customer owned Internet communications for smart grid applications in both regulated and deregulated energy markets. He received his BS degree in Technology Management from the University of Maryland University College.

Mark McGranaghan – Mr McGranaghan is a Director in the EPRI Power Delivery and Utilization (PDU) Sector. His research area responsibilities include overhead and underground distribution, advanced distribution automation, Intelligrid®, and power quality. Research priorities include developing the technologies, application guidelines, interoperability approaches, and standards for implementing the smart grid infrastructure that will be the basis of automation, higher efficiency, improved reliability, and integration of distributed resources and demand response. He is also directing EPRI's extensive smart grid demonstration initiative (5 year effort) to help coordinate the industry approach for distributed resource integration with the operation of the grid.