Smart Grid U.S. Transmission Grid: Issues And Opportunities

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ABSTRACT

No one can tell you today exactly what technologies will make up the smart grid of the future, but smart grid is not just about the technology. It will involve designing an architecture that will utilize the data that is generated by the technology to automate the grid. It will also involve a paradigm shift in the utility industry with the active participation of customers in the energy delivery process. Deploying smart grid technologies will not be measured in months, but in years and decades. Public policy stands to have a huge impact on this time frame.

Keywords: smart grid transmission government policy issues

INTRODUCTION

Numerous pressures on the electric delivery system are converging, forcing the system to evolve. Aging infrastructure, combined with increased demand, integration of renewable energy sources and carbon legislation, are all indicating that the industry will need to embrace a new approach to how it manages the grid, peak demand and system security to drive efficiency while meeting economic, environmental and social priorities. Public policy, particularly around renewable energy sources, will drive the need for a smarter grid. The purpose of this paper is to explain smart grid, provide examples of pilot projects happening around the country, and explore the political and regulatory environment.

EVERYONE'S TALKING ABOUT SMART GRID

The new buzzword in Washington and across the country when talking about a new energy policy is "Smart Grid". The Washington elite from President Obama to Nancy Pelosi are touting the benefits of a smart US transmission grid, but does anyone actually know what that means? Have any of the sound bites included on the nightly news or morning shows been able to give the general public a definition? At the National Governor's Association last February, the CEO of a major utility started his speech with the confession that he didn't really know what "Smart Grid" meant. If the leaders in the utility industry cannot explain the term to the general public, do we really expect the politician's to do a better job of explaining it?

Part of the reason that we don't understand a smart grid is due to the fact that it's not just one simple fix that can be implemented to make the grid smarter. As one industry executive explains it, there is no silver bullet for enabling technologies for a smarter grid; there is instead "silver buckshot," an array of technological approaches that will make it work.

If Edison and Westinghouse could see today's transmission system, they would be familiar with the basic infrastructure of the grid. This is unlike the telephone industry where Alexander Graham Bell would not begin to recognize the technology associated with cell phones, texting, PDAs, etc. This is not to say that Edison would not be just as dazzled as Bell with the technology behind the scenes. Electrification as made possible by the grid has been noted by the National Academy of Engineering as "the most significant engineering achievement of the 20th century." So, is everyone saying that the grid is dumb? Hardly. Because electricity has to be used the moment it is generated, the grid represents the ultimate in just-in-time product delivery. However, we've neglected the technological upgrades needed to make the grid more efficient, reliable, and secure. Research and development funding as a percent of revenue is less than two percent in the electric utilities industry as compared to seven percent in the healthcare industry and twelve percent in energy and management services. Also, implementing large scale technology upgrades to the grid while it is running is a huge risk for utilities to take on when they are charged with delivering safe and reliable electricity to their customers. And, last but certainly not least, is the huge cost in upgrading a system that connects some 16,000 power plants to more than 300,000 miles of high-voltage transmission lines which power hundreds of millions of customers which is currently valued in big round numbers around $360 billion.

WHAT IS SMART GRID

So, what exactly is a smart grid and why do we need it? There is no one definition; but, there are over 40 industry groups formed to help define the vision of a smart grid. Morgan Lewis, an industry consulting group, defined it as an initiative that incorporates technology onto the electricity grid for the purpose of displaying real-time data, managing resources and demand, detecting disruptions, and providing consumers with flexibility in electricity use. Smart grid would result in a digitized grid from the generation site to the consumer. The nation's goal is to transform its electric power delivery system into a more intelligent, resilient, reliable, self-balancing, and interactive network that enable enhanced economic growth, environmental stewardship, operational efficiencies, energy security and consumer choice.

The North American Electric Reliability Corporation (NERC) projects that over the next 10 years, summer peak demand will grow by 16.6 percent. Nationally, the current grid is struggling to keep up with today's demand. If we do nothing, this additional demand will require new transmission lines which come with a whole host of issues including siting, permitting and construction costs. Add to that the pressure to comply with applicable renewable portfolio standards (RPS), the trend toward plug-in hybrid electric vehicles (PHEV's), and legislation to reduce greenhouse gas emissions, the nation would have a hard time justifying a "do nothing" approach.

A smart grid could have numerous economic and environmental benefits. According to the Galvin Electricity Initiative, Smart Grid technologies would reduce power disturbance cost to the U.S. economy by $49 billion per year, reduce the need for massive infrastructure investments by between $46 and $117 billion over the next 20 years, and consumer control of power consumption could add $5 to $7 billion per year back into the U.S. economy by 2015. On the environmental front, smart grid technologies could reduce carbon emissions by facilitating energy efficiency, leveraging demand response programs, facilitating mitigation of renewable generation variability of output and integrating plug-in hybrid electric vehicles, distributed wind and photovoltaic solar energy resources, and other distributed generation.

In order to understand and explain the smart grid, we need to simplify. The best practical description comes from Jay Birnbaum from the Current Group, and industry consultant, where he describes a smart grid as adding a brain and a central nervous system to the grid. This can be broken down into three main parts:

1. Two-way communication - broadband high speed communication system
2. Smart devices - sensors placed throughout the grid
3. Advanced control systems - computer / analytics to process what is happening

The world talks about the smart grid as a single entity, but, it will actually be built as a series of related projects over the course of more than two decades. Over this time, the electric industry will transform from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. To maximize the benefits and minimize the pain, utilities must plan for the individual projects to plug together seamlessly. This is commonly referred to as interoperability.

To use the central nervous system analogy, the spinal cord of the smart grid is the communication platform. This includes a high-bandwidth communication infrastructure as well as wired and wireless communication systems as required by the technology used. Just as the spinal cord sends signals back to the brain, this communication system will be responsible for relaying the data back to the control center. In order to determine what this communication platform should look like, the utility must determine the timing and data requirements. According to the experts at Capgemini, an industry consulting firm, there are five main activities to focus on:

1. Gathering data - how many devices, how big is the data, and how often do you want to talk to the devices
2. Analyzing and forecasting needs - plan for bulk transfer of data during certain circumstances
3. Security requirements and security overhead - bandwidth requirements due to adding security measures on the network
4. Monitoring, managing, acting - careful analysis of who needs what/when in order to make a good decision and act on it
5. Rebuilding the grid to support bidirectional power flow, looping circuits and transfer of power from substation to substation - This will be the most expensive part of the deployment of smart grid and in most cases take 20 years or more to complete.

The amount of data that can be generated with smart grid technologies can be overwhelming and useless if the management of the data is not clearly defined.

The next component in a smart grid is the "smart" devices or grid hardware. This is the part of the "central nervous system" that collects the data to send through the communication network as well as receive information from the "brain" to respond to various signals. These are the sensors that range from digital advanced metering systems (AMR-Advanced Meter Reading-one way communication flow, AMI-Advanced Metering Infrastructure-two way communication), home area network devices (HAN) and smart appliances at the customer location to transmission technologies such as phase shifting transformers, reclosers and sectionalizers, superconductivity, and storage.

Advanced meters provide a steady stream of information back to the utility, allow meters to be read remotely and help to identify power outages. They can also give the customer a more detailed view of their electricity consumption. Communication sent back to the consumer of the real-time cost of electricity through price signals are relayed through "smart" home controllers or end consumer devices like thermostats, washer/dryers and refrigerators. The devices will then process the information based on the consumers' programmed wishes and power accordingly. This type of technology is referred to as demand response systems. Demand response helps to balance the load on the system particularly during high cost, peak periods and in some cases shift that load to periods when demand is low and there is excess capacity available.

Phase shifting transformers are used to control the flow of power in transmission lines and are particularly useful in transmission bottleneck areas. Time-synchronized phasor measurement units are often described as "diagnostic MRI" for the electric grid, providing continuous synchronized real-time data. Reclosers and sectionalizers allow operators to more effectively and efficiently manage load with existing transmission and distribution infrastructure through real time feedback from controlled or automated capacitor banks on distribution circuits and this technology would also help to more effectively integrate renewable energy sources. Sensors that sit alongside power lines and detect sudden changes in the amount of current in the line can signal operators who can then reroute power and avoid wide-scale power outages.

Advanced control systems or the "brain" of the smart grid bring all of the data that is gathered through the communication networks and smart devices together to automate the grid control. This part of the smart grid has the longest way to go before full scale deployment. Utilities currently have Supervisory Control and Data Acquisition (SCADA) technology which monitors the flow from the generation sites to distribution substations. However, there is not a wide area network system that encompasses the entire network from generation to the consumer. Once the smart devices are in place, the availability of real-time data and system intelligence will create opportunities for "self-healing" grids, which can restore and prevent outages, to impact utility operations. Currently, the DOE has the VERDE (Visualizing Energy Resources Dynamically on Earth) project in development. VERDE will provide wide-area grid awareness, integrating real time sensor data, weather information and grid modeling with geographical information. The platform of the system is built on Google Earth.

Technologies that are already deployed or will be deployed in the near future will result in a smarter grid. Integrating all of these pieces together will signify the achievement of a smart grid. As previously mentioned this is a process that will encompass ten to twenty years. The decision to move to these new technologies must be customer focused, cost justified and purpose driven.

A smarter grid will help to address several issues with the current system. Today's grid is unable to fully utilize generation capacity and rapidly adjust to fluctuations. The grid does not have a system in place to collect and manage real-time data and appropriately respond to that data. The current grid is poorly set up to handle power coming on the grid from alternative energy sources such as large-scale wind or solar generation or distributed generation such as photovoltaic solar panels on a residence. Incorporating plug-in hybrid vehicles into the grid particularly during peak load will tax an already overloaded system.

PILOT PROJECTS

One of the smart grid pilot projects going on around the country is happening in Boulder Colorado. Excel Energy has installed two-way smart meters in 20,000 customer locations as a test pilot. The goal is to provide customers more information about their energy consumption which they believe will facilitate energy savings. These meters are capable of providing real time high-speed two-way communications throughout the distribution grid in Boulder. The substations remotely watch the system while thousands of control devices were installed inside homes so that the utility can adjust consumers' energy use based on pre-programmed consumer choices during peak periods. Excel's business case for the project was based on the premise of future energy savings. If customers use less energy during peak periods, Excel could avoid buying expensive power on spot markets. Currently the company needs to keep 16 percent reserve margins to accommodate high usage days. If a smart utility can reduce this requirement, then it would be a money saver. The test is going to be determining if that savings can offset the cost of the technology. The project cost was roughly 45 million, $20 million of which was paid for by Excel which includes people, software and equipment. Attached to this paper you will find a current price plan comparison chart that is being used for customers currently. This chart allows Excel to associate costs with actual customer usage based upon specific levels and time frames. The latest piece of the puzzle came in February of 2011 when the Colorado Public Utilities Commission slashed cost recovery dollar amounts unexpectedly.

The University of Hawaii, in partnership with local utilities and GE recently launched a research project to test how various smart grid technologies handle the use of wind power. The island of Maui has one large wind farm and when the wind suddenly drops, up to 15 percent of the total amount of power consumed can drop off the grid. GE will deploy rechargeable batteries that can store power when winds are high or demand is low and automatically send power back to the grid when the wind drops. Researchers will also incorporate the use of smart meters and appliances that will be controlled remotely by the utility to reduce demand if necessary.

Fort Collins Utility is testing an initiative called the Zero Energy District within the city. The project involved the integration of a mix of nearly 30 distributed generation, renewable energy and demand response resources across five customer locations for an aggregated capacity of more than 3.5 Megawatts (MW). The resources being integrated include photovoltaic, microturbines, duel-fueled combined power and heat systems, reciprocating engines, backup generators, wind, plug-in hybrid electric vehicles, and fuel cells. The project will help determine the maximum degree of penetration of distributed resources based on system performance and economics.

There is quite a bit of research being conducted on lithium ion batteries which will be installed in the plug-in hybrid electric vehicles (PHEV). With advancements in the battery technology, the thought process is to utilize the stored power from the battery to provide electricity to the home during peak demand times and recharge the car battery at night during off-peak periods. Some experts feel that the PHEV could be the "killer app", such as e-mail was to the internet, to accelerate smart grid advancement. This technology could be the ultimate in load balancing by enabling the grid to shed load during peak and also better utilize excess generation capacity during off-peak periods.

The questions are numerous as to the benefits of these types of projects. Will consumers be bothered to take the time to manage their energy consumption patterns or will they want the inconvenience it may impose? Will the infrastructure spending be offset by savings in reduced generation and transmission costs through better load balancing and efficiencies? However, the motivation of the consumer to more effectively manage their energy consumption may increase if the carbon cap and trade legislation is passed. In North Dakota, a homeowner's electricity bill could increase by 40 percent or $350 a year under the most modest, $20 per ton carbon tax proposal.

POLITICAL & REGULATORY ENVIRONMENT

The political environment in Washington is ripe for advancing smart grid initiatives at this time. The American Recovery and Reinvestment Act of 2009 provided stimulus funding of $4.5 billion and 50 percent cost share for smart grid projects to be administered through the Department of Energy (DOE). The Act also establishes an information clearinghouse to make real-time information about the Smart Grid available to the public to help facilitate the adoption of uniform technologies and standards. Funding for demonstration projects includes smart grid regional demonstrations, utility scale storage demonstrations and grid monitoring demonstrations. The guidelines also indicated that the DOE would allocate a portion of the funds for projects that deploy Phasor Measurement Unit technology within the transmission system infrastructure. Stimulus funding is actually a massive research and development initiative and could be the tipping point for smart grid deployment. There will more than likely be projects that will fail, but the information gleaned from these demonstrations will provide direction for the future.

The utility industry is regulated by the Federal Energy Regulatory Commission (FERC) under the Federal Power Act. The Commission has jurisdiction over the transmission of electric energy in interstate commerce by public utilities and over the reliable operation of the bulk-power system in most of the Nation. Under the Energy Independence and Security Act of 2007 (EISA), the Commission was given a new responsibility to adopt standards and protocols to ensure Smart Grid functionality and interoperability. FERC recently issued a proposed Smart Grid Policy Action Plan. FERC is looking for comments on the steps it proposes and other steps it can take to expedite the development of interoperability standards and implementation of projects for development of a smarter grid. The proposal includes prioritizing cyber security and a common communication framework. It also seeks comments on key grid functionalities for standards development of wide-area situational awareness, demand response, electric storage and electric transportation. The Commission also proposes a rate policy for smart grid investments that demonstrate system security and compliance with Commission approved Reliability Standards, the ability to be upgraded and other specified criteria will be eligible for timely rate recovery and other rate treatments.

To capture the latest regulatory perspective on Smart Grid and Renewable Energy issues, Capgemini in coordination with the National Association of Regulatory Utility Commissioners (NARUC) surveyed executives from 45 NARUC commissions between September and November of 2008. Forty percent of the survey respondents felt that Automated Metering Initiatives (AMI) were fundamental to their energy future while an additional 26 percent were still reviewing the issue. However, AMI must be justified on a case-by-case basis, even when regulations provide a general guideline for deployment. Most successful filings to date have relied on enhancements to existing or creation of new demand-side response programs as a key factor in developing a net-positive business case. It is interesting to note that 52 percent of regulators do not support real-time pricing for all customer classes and only 9 percent support real-time pricing for all. Since real-time pricing is the premise for motivating customers to reduce energy consumption during peak periods, this could be problematic for realizing the full benefits of demand response systems. Regulators are concerned about exposing customers to real-time sticker shock. The majority of regulators do not at this time support smart grid beyond AMI. Regulators still view smart grid in the "early adopter stage" and it is still a fairly new idea. As the technology evolves and can be cost justified with direct value to the customer defined, they expect the acceptance to increase. Regulation needs to change in order to facilitate wide-scale deployment of smart grid. In most states, there is no incentive for developing smart grid. However, there appears to be significant regulatory support for decoupling. Decoupling involves the removal of the revenue disincentive for a utility to sell less energy. They do not support a proposal by Thomas Friedman for "decoupling plus" which not only removes the revenue disincentive but pays them more (plus) to sell less energy. The survey results indicate that regulators are in the very early stages of an education and valuation process. Interestingly, the speed that both renewables and the smarter grid take hold will more than likely be dictated by a growing political belief that clean energy is necessary.

SUMMARY

No one can tell you today exactly what technologies will make up the Smart Grid of the future. But, smart grid is not just about the technology. It will involve designing an architecture that will utilize the data that is generated by the technology to automate the grid. It will also involve a paradigm shift in the utility industry with the active participation of customers in the energy delivery process. Deploying smart grid technologies will not be measured in months, but in years and decades. Public policy stands to have a huge impact on this time frame. Politicians and industry leaders recognize that one of the barriers standing in the way to meeting targeted RPS standards is the inability of the current grid to successfully integrate large amounts of renewables onto the system. The key to a successful smart grid will involve building a vision and architecture that allows for flexibility to evolve as the technology advances.

AUTHOR INFORMATION

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REFERENCES

1. Department of Energy – Notice of Intent to Issue a Funding Opportunity Announcement For the Smart Grid Investment Grant Program
2. FERC Orders – Smart Grid Policy – Docket No. PL09-4-000
3. http://www.capgemini.com Capgemini – Smart Grid: Leveraging Technology to Transform T&D Operating Models
4. http://www.capgemini.com Capgemini – The Latest Regulatory Views on Smart Grid and Renewable Energy
5. http://www.eenews.net Electricity Advisory Committee – Keeping the Lights on in a New World, January, 2009
6. http://www.energycentral.com Xcel's Vision, March 6, 2009
7. http://www.lw.com Latham Watkins Client Alert, March 2, 2009
8. http://www.nxtbook.com/nxtbooks/energycentral/energybiz0109/ EnergyBiz January/February 2009
9. http://www.oe.energy.gov Electricity Advisory Committee – Smart Grid: Enabler of the New Energy Economy
10. http://www.oe.energy.gov/1165.htm US Department of Energy - The Smart Grid: An Introduction
11. http://www.popsci.com Our Grid – Powering our 21st Century Lives by Design, April, 2009
12. http://www.smartgridnews.com Smart Grid Stimulus Bill: DOE Snubs IOUs and Meters, April 20, 2009
13. http://www.smartgridnews.com The Big Picture of Your Coming Smart Grid, March 5, 2009
14. http://www.smartgridnews.com Why the Smart Grid Industry Can't Talk the Talk, March 5, 2009
15. http://www.smartgridnews.com Why Your Smart Grid Must Start with Communications, February, 2009

16. Intelligent Utility Magazine – January/February 2009 and March/April 2009
17. Morgan Lewis webinar – FERC Smart Grid Policy, April 3, 2009
18. Richard Munson, *From Edison to Enron – The Business of Power and What It Means For The Future of Electricity,* 2005
19. *The Wall Street Journal* – Smart Road. Smart Bridges. Smart Grids, February 17, 2009

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