IMPROVING THE RELIABILITY AND RESILIENCY OF THE US ELECTRIC GRID

By Debbie Haught and Joseph Paladino

Across the US, efforts to accelerate the modernization of the nation's electric grid are progressing, with more than 300 Recovery Act funded projects supporting a wide range of initiatives to improve the reliability, resiliency and security of the grid, help consumers become more energy efficient, and enable the growth of renewable energy sources like wind and solar power currently underway.

The projects, which received $4.167 billion in funding and are managed by the Department of Energy's (DOE) Office of Electricity Delivery and Energy Reliability, address a wide range of grid modernization needs, including demonstrating the use and benefits of advanced smart grid and energy storage technologies, strengthening long term analysis and planning for the three grid interconnections that serve the lower 48 states, and expanding electricity sector workforce development.

The largest Recovery Act grid modernization activity funded by the Office of Electricity Delivery and Energy Reliability is the Smart Grid Investment Grant (SGIG) Program, which involves 99 projects with a total value of almost $8 billion, including about $3.4 billion in federal funding. To date, more than $1.9 billion has been paid to recipients. DOE's strategy for the SGIG program is twofold: capture and share the lessons learned and benefits realized from the SGIG projects to inform the industry's efforts on how to best move forward with the adoption of smart grid technology; and deliver an integrated portfolio of programmes and activities that directly address the major technical, economic, and institutional challenges. Those challenges include advancing grid functionality with new technologies, enhancing cybersecurity, building cost effective business cases for smart grid investments, developing interoperability standards, encouraging greater consumer participation, and sustaining a skilled workforce.

MOVING FORWARD WITH SMART GRID DEPLOYMENTS

Transforming the nation's current electric grid into a more intelligent, "smart" system involves deploying numerous advanced technologies that address such areas as outage management, voltage optimization and demand response to improve reliability, resiliency and security of the grid. SGIG grant recipients, which include investor-owned and municipal utilities, transmission operators, and electric co-ops, are rolling out technologies, tools, and techniques for modernizing all of the major segments of the electric delivery system, including transmission, distribution, and advanced metering infrastructures (Figure 1).

While modernizing the nation's grid is a complex task that will take years, we are already seeing tangible results from these initiatives. Devices are being installed, systems are being built, and equipment capabilities and functionalities are being tested (Figure 2).

By 2015, significant numbers of new smart grid technologies are expected to be in place, including:

- About 15.5 million smart meters in homes and businesses

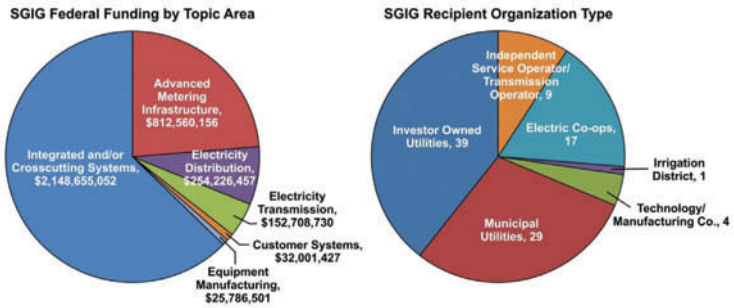

Figure 1 – SGIG projects by activity and organization

- Sensors, smart switches, and control devices for automating about 6,500 distribution circuits
- More than 800 networked phasor measurement units (PMUs) installed at strategic locations across the nation's transmission system.

DOE reports online on the status of these Recovery Act-funded deployments and their associated costs each quarter (www.smartgrid.gov). Beginning in October 2011, recipients also began reporting on the impacts of their deployments on grid reliability, operations and maintenance cost savings, and energy efficiency. DOE expects to post a report on these impacts in the Spring of 2012. As more impact data is reported by recipients, DOE plans to provide comprehensive updates every six months.

PROTECTING THE GRID

While the increased digitization of a smarter grid brings numerous benefits, it also introduces additional risks from cyber attacks. The security of the nation's electric grid is of critical importance, which is why we developed a rigorous, comprehensive cybersecurity approach for all of the SGIG projects. All recipients were required to develop cybersecurity plans that addressed how they would identify cybersecurity risks, how those risks would be mitigated, and how the processes would ensure that a sufficient cybersecurity posture is maintained. All 99 cybersecurity plans approved by the

Installed and Operational SGIG Smart Grid Equipment	
Advanced metering infrastructure	8.7 million smart meters (72 projects)
Customer systems	6,700 in-home displays (43 projects), 175,000 programmable communicating thermostats (44 projects), 209,000 direct load control devices (34 projects)
Distribution systems	3,000 circuits including 10,700 substation monitors (19 projects), 7,000 automated capacitors (47 projects), 5,000 feeder switches (44 projects)
Transmission systems	187 networked phasor measurement units, 38 phasor data concentrators (11 projects)

Figure 2 – Major SGIG equipment installations, as of February 2012

Energy Department addressed the Department's requirements. Throughout the life of these projects, DOE will continue working with recipients to measure progress against their required cybersecurity plans, conduct on-site visits, and share best practices to continually improve system implementations.

For years, DOE has worked closely and steadily with industry and federal partners, including the Department of Homeland Security, National Institute of Standards, and the Department of Defense, and other stakeholders to enhance the cybersecurity of the grid. DOE's cybersecurity activities directly support the "Roadmap to Achieve Energy Delivery Systems Cybersecurity"[1], which outlines a strategy for designing, installing, and maintaining a resilient energy delivery system capable of surviving a cyber incident while sustaining critical functions. Key activities include the development of security profiles for smart grid domains, vulnerability analysis of protocols and control systems, and development of advanced technologies such as a specification-based intrusion detection system for smart meter communications and NetAPT, a highly scalable and effective tool for analyzing global firewall configurations. Recently, DOE announced the launch of an initiative to develop a cybersecurity maturity model that will help utilities assess their own cyber strengths and weaknesses and prioritize their investments[2].

A CLOSER LOOK AT THE BENEFITS OF MODERNIZING THE GRID

While the full extent of impacts, costs, and benefits will not be known until all of the projects have completed their reporting to DOE in 2015, early evidence is beginning to shed light on the range of benefits and impacts that can be expected.

In Chattanooga, Tennessee, the Electric Power Board (EPB) is making its distribution system more robust while improving operations with the deployment of smart grid technologies, including 170,000 smart meters, a web portal for monitoring consumption and costs, and grid automation for about 50% of the system's 300 distribution circuits. Improved operator situational awareness allows EPB to improve system service seamlessly, while the smart switches help to improve reliability and reduce operations and maintenance costs. This will allow EPB to provide continued reliable electric service and respond more effectively to severe weather events, which are frequent in the Southeast.

"We expect the number of customer minutes lost to power outages to be down by 40% or more, and that's something that will benefit customers throughout the whole area," said Jim Glass, manager of Smart Grid Development at EPB. Overall, EPB officials estimate the increased reliability is worth about $40 million a year to Chattanooga area businesses and homeowners.

In April, 2011, a series of devastating tornados struck the Chattanooga area causing widespread outages. "The whole community was devastated by the damage done in terms of loss of life and property," says David Wade, EPB executive vice president and chief operating officer. "Three quarters of our customers — 129,000 residences and businesses — were out of power." When the storms hit, about 120 of the smart switches were in service, and only one of those switches went off line during the storms. While days were spent manually restoring circuits that would have been restored automatically had the smart feeder switches been fully deployed, service restoration was accelerated for many consumers thanks to the data from the 120 initial switches and other sensing devices. As a result, 250 service visits by repair crews were avoided because the switches provided outage information not previously available. This saved fuel consumption and labour costs from fewer truck rolls, and enabled faster service restoration for consumers.

Lessons learned with demand response

Oklahoma Gas & Electric Company's (OG&E) electric grid also faces significant challenges from severe weather and an annual load growth of about 2%. To better control costs and manage electric

reliability under these conditions, OG&E is pursuing demand response strategies made possible by implementing 770,000 smart meters, 48,000 customer systems such as in-home displays and programmable communicating thermostats, and distribution automation equipment for about 40% of the system's 1,000 feeders. OG&E is also working with DOE to design and conduct statistically rigorous customer studies to assess acceptance of time-based pricing programmes and information and control technologies and their impacts on peak demand. The aim is to prepare for a system rollout to reduce peak demand and defer construction of two 165 MW power plants.

"I cannot think of a more important initiative in our industry today than to partner with our customers to reduce peak energy use and gain other efficiencies using the smart grid platform," said Pete Delaney, chairman and CEO, OG&E Energy Corp.

OG&E released preliminary results in January 2012 of its two-year demand response study that showed such findings as customers with a smart thermostat achieving a maximum demand reduction of 48% during the peak period when compared to a control group. "These study results clearly demonstrate that smart technology coupled with dynamic pricing enables customers to reduce their maximum peak energy use, which will help delay the need for building incremental generation until at least 2020," said Ken Grant, managing director of customer solutions. OG&E now plans to expand its SmartHours programme to an additional 40,000 residential and small business customers.

Boosting capacity on the West Coast

Farther west, the Western Interconnection Synchrophasor Program (WISP), led by the Western Electricity Coordinating Council (WECC), is an initiative to modernize operation of the transmission system in the Western Interconnection, increasing reliability and system performance, and enabling greater use of renewable resources such as solar, hydro, and wind. The work involves installation of an extensive network of synchrophasor technology, including more than 300 PMUs and 60 phasor data concentrators (PDCs) across the Western Interconnection. Once complete, the project is expected to allow at least 100 MW of operational capacity on the California-Oregon Intertie, a critical transmission pathway in the Western Interconnection that delivers available power from the northwest to meet demand in California – enough power to supply over 100,000 homes. The system will help grid operators, reliability coordinators and engineers to better understand the complexities of a dynamic power system, reducing the frequency and scope of outages in the bulk power system.

Facing operating limits for power flows to meet reliability standards, grid operators will use synchrophasor technologies to detect destabilizing oscillations quickly, dampen them before they cause problems, and raise operating limits to allow more power to flow. "If you can't see what's wrong, you can't fix it," says WECC CEO Mark Maher. Better use of the existing grid will allow transmission owners to defer other investments to increase system capacity or build new lines, yielding significant financial savings. Real time monitoring of grid conditions should also enable better regulation and coordination of generation and load in the West. (A full description on the WISP is on page 56.)

These are just a few examples of ongoing SGIG projects. In depth profiles of individual projects, as well as deployment data and updates about the SGIG and other smart grid programmes including the Smart Grid Demonstration Program and the Workforce Training for the Electric Power Sector Program, are available on the smartgrid website (www.smartgrid.gov).

UNDERSTANDING THE DATA

The DOE smart grid projects represent a unique opportunity for the electric power industry to get a better understanding of information technologies and their application on the electric power system for a more modern and smarter grid. A major priority for DOE is quantitative analysis of the SGIG projects to address key topics of interest to power companies, regulators, and consumers. DOE collaborates closely with the project recipients and other electric power industry stakeholder organizations on key analysis activities including data collection, models and methodologies, and reporting of results. As the data begins to accumulate, DOE analysis is addressing numerous areas, including:

- Reductions in peak and overall demand, changes in consumer behaviour, and levels of consumer acceptance from advanced metering infrastructure (AMI), direct load control programmes, time-based rate programmes, and customer systems
- Improvements in operational efficiencies and reductions in costs from remote meter reading, reduced truck rolls, and better business practices
- Improvements in electric reliability through application of distribution automation equipment such as automated feeder switching, sensors for monitoring equipment failures, and faster restoration through automated outage management
- Improvements in the energy efficiency of electric distribution systems (e.g. line loss reductions) through the application of automated control technologies for voltage and VAR management, and
- Application of synchrophasor technologies in electric transmission systems to enhance visibility of grid conditions and control of power flows.

LOOKING AHEAD

Although the Recovery Act's smart grid investment of $4.167 billion is substantial, it represents only a fraction of the overall cost of modernizing the nation's grid. The Electric Power Research Institute (EPRI), in a 2011 report entitled "Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid", estimates that between $338 billion and $476 billion will be needed through 2030 to modernize the entire US electric system.

Clearly, a lot of work remains to be done. As more of the SGIG projects deploy smart grid technologies and strategies, DOE will continue to assess and report on the results. Further quantitative analysis is needed to understand what works, what doesn't work, and the reasons why certain impacts and benefits are being realized. Industry is counting on the availability of much more specific information from the SGIG projects to assess smart grid costs, benefits, and business cases. MI

1. http://energy.gov/oe/downloads/roadmap-achieve-energy-delivery-systems-cybersecurity-2011
2. http://energy.gov/oe/services/cybersecurity

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