The Smart Grid Experience: Applying Results, Reaching Beyond

Summary of Conference Proceedings

1. Introduction and Summary

> ***Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested about $7.9 billion in 99 cost-shared Smart Grid Investment Grant projects and about $1.6 billion in 32 Smart Grid Demonstration Program projects to modernize the electric grid, strengthen cyber security, improve interoperability, and collect an unprecedented level of data on smart grid and customer operations.***

The Electric Power Research Institute (EPRI) and the U.S. Department of Energy's (DOE's) Office of Electricity Delivery and Energy Reliability (OE) held a conference[1] to assess progress, impacts, benefits, and lessons learned from utility smart grid projects and to exchange information about future challenges and opportunities. The conference provided participants with information and analysis resulting from unprecedented investments in smart grid deployments over the past five years, funded in large part through cost-shared grants under the American Recovery and Reinvestment Act of 2009 (Recovery Act). More than 150 participants representing electric utilities, federal and state government agencies, equipment manufacturers, vendors, universities, and national laboratories attended and contributed their experiences, perspectives, and insights.

The event featured results from field experience gained in both the EPRI Smart Grid Demonstration Initiative and DOE's Smart Grid Investment Grant Program (SGIG) and Smart Grid Demonstration Program (SGDP), with a focus on smart grid successes, surprises, and challenges. Utility presentations and panel discussions covered a variety of topics such as technology readiness, customer responses, and future directions and possibilities for grid modernization. There were nine panel presentations and discussions:

- Realization of the Smarter Grid
- Transforming the Grid Through Integration
- Conservation and Optimization via Volt/Var Control
- Systems Driving the Integrated Grid – Including DMS, DA, DERMS, DRMS
- Communications and Cyber Security – Foundations of the Modern Grid
- AMI: Beyond Meter Reading
- Studying the Smarter Consumer
- Engaging the Smarter Consumer (begins on Slide 19 of previous presentation)
- Reaching Beyond the Smart Grid (no presentations)

[1] The EPRI-DOE "Smart Grid Experience: Applying Results, Reaching Beyond" conference was held in Charlotte, North Carolina, October 27–29, 2014.

This report summarizes the information presented during the conference and the key points raised during the group discussions that followed the presentation sessions.

The table below presents several of the key points from presentations and discussions; the following sections offer more details. Note that the final panel, Reaching Beyond the Smart Grid, was a summary discussion and thus is not included in the table.

Summary of Key Points	
Topics	**Key Points**
Realization of the Smarter Grid	• Accomplishments so far, including significant progress in interoperability and visibility into the grid, provide a significant foundation to leverage future investments. • Further innovation and change are needed and are coming, including improved strategies for system resilience, better data analytics for planning and operations, and new approaches for market models and regulatory policies.
Transforming the Grid Through Integration	• Distribution systems present a "new frontier" for design and operations. New tools and techniques for managing vast quantities of data and complexity are needed. • Integrating distributed energy resources (DER) is challenging because of a variety of factors including technical requirements, standards and protocols, regulatory policies, and business cases.
Conservation and Optimization via Volt/Var Control	• Benefits from automated voltage controls for conservation voltage reduction (CVR) typically produce 2%–4% reduction in energy use, but high variability in voltage data measurements often makes it difficult to verify and validate savings. • Maximizing value involves selectively choosing feeders for volt/var optimization (VVO) and CVR operations. Feeders serving industrial customers that are sensitive to voltage fluctuations are less ideal than feeders serving mostly residential and commercial customers.
Systems Driving the Integrated Grid	• Distribution automation and management systems have proven valuable for fault isolation, outage management, and improved storm restoration. Measured improvements in reliability indices have been found by many utilities in a variety of applications. • Early deployments faced multiple problems with systems integration. Those due to lack of experience with vendors and equipment were largely resolved as projects progressed.
Communications and Cyber Security	• Effective communications networks and related systems are critical to a functioning smart grid. Failures or gaps in these systems represent real challenges. • There is extraneous information in the vast quantities of data being transmitted from field devices on overloaded communications networks. Exception-based data logging and communications is one method to address this.

Summary of Key Points	
Topics	**Key Points**
	• Field area networks (FANs) represent a method to overcome latency and timing challenges by placing systems and processing closer to the electric infrastructure and customers served by communications systems. • While substantial progress has been made, cyber security is an ongoing challenge to effective grid operations. Utilities must continue sharing lessons learned and best practices to ensure that appropriate protections are in place.
Advanced Metering Infrastructure (AMI): Beyond Meter Reading	• Early and frequent customer engagement is one of the keys to AMI deployment success. • Benefits of AMI extend beyond meter reading to other areas such as capacitor bank monitoring, power quality management, and improved outage management.
Studying and Engaging the Smarter Consumer	• Customers want tools for managing consumption and costs, and are open to new rates and incentive programs for reducing demand. • Not all customers are interested in, or able to use, in-home devices. Technical problems with the devices were encountered, but they are evolving rapidly as vendors learn more about utility and customer needs. • Targeted customer messaging through multiple communications vehicles improves enrollment rates in time-based rate and other customer-facing programs and participation in critical peak events. • Financial benefits are the primary way to motivate changes in customer behavior. Factors such as reducing environmental impacts can also motivate customers to a lesser degree.
Topics Voiced in Multiple Sessions	• Several “early adopter” issues were addressed in smart grid projects, typically in close coordination with vendors. Issues such as lack of vendors with equipment or services that meet utility requirements, lack of specific standard application profiles for development of interfaces between systems from multiple vendors, vendor bankruptcies, and equipment that did not perform as expected were challenges of the demonstrations. • Microgrids are a complement to the grid, not a replacement. • Given the newness of many aspects of measuring impacts and benefits and establishing business cases, development of common and consistent industry metrics would be a valuable addition and would help policy and decision makers evaluate alternative investments and strategies. • One of the greatest challenges to an integrated grid is having robust communications systems.

2. Realization of the Smarter Grid

This session opened the conference and included discussion about accomplishments and future directions. Speakers addressed overarching benefits and lessons learned from large-scale programs such as EPRI's Smart Grid Demonstration Initiative, SGIG, and SGDP. Speakers also offered comments about the future of the electric grid and suggestions for utilities, regulators, government agencies, equipment manufacturers, and other stakeholders.

The panel included presentations from Patricia Hoffman, Assistant Secretary of DOE-OE; Mark McGranaghan, Vice President of Power Delivery and Utilization, EPRI; and Becky Harrison, Chief Executive Officer of the Gridwise Alliance.

Key accomplishments were identified:

- Improved outage management technologies and systems benefit customers by providing quicker problem identification and faster service restoration.
- Voltage management technologies and systems provide peak and overall energy reductions and bill savings for consumers.
- Initial insights from the data acquired via phasor measurement units (PMUs) give transmission operators unprecedented visibility into system states.
- Customers benefit from AMI and the new services AMI supports, including time-based rates, remote service connections/disconnections, and access to usage and bill data and dashboards such as those provided through the Green Button Initiative.
- Development and use of interoperability standards by utilities and manufacturers has led to improved integrated systems. Continued work to refine standards will help expedite integration of systems and operations.

Significant investment has been made in both demonstrating and deploying new technologies, but this is just a beginning. Future investment is needed to continue to continue grid modernization activities, build out the base of technologies and systems, and more fully utilize the smart grid investments deployed thus far. Future needs were identified:

- Telecommunications infrastructure lies at the heart of the new grid, so continued investments will be needed to support further grid modernization.
- Verifiable cost–benefit analyses built on consistent definitions, data, and analysis methods are needed to support regulatory decision making.
- More experience is needed with cyber security protections and strategies to support implementation and improvements in equipment specifications and procurement language.
- Better tools for grid analytics are needed to obtain actionable information from the vast quantities of data collected via newly deployed devices, systems, and sensors.
- The future grid must be agile and flexible enough to serve as an enabling platform for new technologies and market models.

3. Transforming the Grid Through Integration

This session addressed the integration of systems for DER; distribution automation; and fault location, isolation, and system restoration applications. While renewable generation such as rooftop solar comprises the majority of new DER interconnections today, other options are also viable, such as combined heat and power, voltage control technologies, and energy storage. When electric vehicles and demand response are added to the portfolio, utilities are tasked with efficiently operating the grid with multiple DER technologies along with the traditional supply- and demand-side options.

The panel consisted of representatives from organizations conducting smart grid projects: Con Edison, Exelon (PECO), FirstEnergy, PNM Resources, and Kansas City Power & Light. During their presentations, speakers shared information about their projects, including project successes, surprises, and next steps.

A common challenge involves complications from processing, managing, and putting to use vast quantities of new data from various field devices, sensors, and smart meters. Processing data on two-way power flows and enabling integration of data from multiple sources that were not initially designed to communicate with each other are critical factors for successful DER integration. Interoperability standards have made a real difference in this integration, but their maturity was a big challenge in initial phases of smart grid demonstrations. Standards have been refined, with work yet to do, and better data visualization and operations management tools are helping to meet integration challenges.

Microgrids offer localized benefits for campuses, hospital complexes, and multi-building office and industrial parks, but integrating their demand- and supply-side operations with the local utility can present technical and regulatory challenges. Utilities can partner with microgrid developers and operators to understand the unique impact of each microgrid on the utility system and to educate them about system needs and requirements. Both parties can learn from each other to address operations and integration challenges as the systems are deployed.

4. Conservation and Optimization via Volt/Var Control

This session addressed VVO and CVR technologies for providing energy savings, demand reductions, and reduced system losses. The session included presentations from American Electric Power, Central Lincoln, Hydro-Québec, Sacramento Municipal Utility District, Duke Energy, EPRI, and DOE. A variety of approaches are being applied, including centralized and decentralized control schemes, using automated capacitors, load-tap changers, and voltage monitoring at the customer premises using smart meters. Project results included 2%–4% reductions in line losses and energy use. Customers had up to a 2% reduction in energy consumption. Results vary because of the diversity of feeders and methodologies used to quantify VVO and CVR impacts.

Key findings include the following:

- Deploying reliable, cost-effective, and high-bandwidth communications infrastructure is a foundational requirement for many VVO and CVR applications.

- Addressing the unique circumstances of each installation – which can vary from feeder to feeder, depending on customer loads, line conditions, substation configurations, and other factors – is essential for success. Planning deployments on a feeder-selective rather than system-wide basis was an effective strategy for several utilities.
- Simplifying complex data and converting them into useful information is an ongoing challenge for VVO and CVR operations. Distribution models and management systems provide solutions by accounting for a range of conditions. One utility developed a statistical model to predict CVR impacts; the model accounted for a variety of variables and conditions. This helped identify workable solutions for each deployment, which ultimately meant less tweaking of the system.
- Recognizing from the outset that VVO and CVR technologies and systems require ongoing operations and maintenance support is important. Utilities cannot simply "set it and forget it," as system conditions and customer requirements change over time. With the exception of certain voltage-sensitive industrial and commercial consumers, customers were generally unaffected by CVR operations and realized only small reductions in energy consumption and bills. As customer bill savings from CVR are relatively small, they are not often noticed.

5. Systems Driving the Integrated Grid – Including DMS, DA, DERMS, and DRMS

This session addressed systems that enable DER coordination. Discussions covered development and demonstration of distribution management systems (DMSs), distribution automation (DA), distributed energy resource management systems (DERMSs), and demand response management systems (DRMSs). Presentations were provided by Battelle, CenterPoint Energy, Duke Energy, Electricité de France (EDF), EPB (Chattanooga, Tennessee), Snohomish Public Utility District, and Southern Company.

Key findings include the following:

- Models for DER integration are still in their early stages of development. Some utilities are having early successes in using these models to understand how many DER systems are in operation and their relative contributions to meeting system needs. State-level regulatory and policy priorities vary between service territories, and there is much uncertainty about the future. As the speed of development of new models and tools for DER integration increases, regular information exchanges between utilities and regulators will be helpful in aligning actual performance with policy needs and requirements.
- Several projects demonstrated utilities' capabilities to coordinate incentive signals and responses across multiple utilities in multiple states using market-based transactive control tools and techniques. Standardization of data and communications protocols can help build more efficient and cost-effective deployments of transactive control technologies, and decrease the time to test and validate controls.
- Automated feeder switching and other DA techniques led to measurable improvements in reliability and faster restoration following outages. Utilities applying these techniques achieved better fault location and isolation, more efficient dispatch of line crews, and decreases in

restoration times. In one case, outage times for certain customers following a major storm were reduced from an expected 1.5 days to 1.8 seconds.

- As with other smart grid applications, the complexity and volume of data represent an ongoing challenge, and reliable and robust communications systems are essential for success. The overall burden of data management on communications networks can be managed through the use of exception-based communications approaches wherever possible. This involves logging and communicating exceptions, or events that fall outside of averages or normal values, rather than logging and communicating the "normal" status of devices and systems at high levels of frequency.
- The complexity and newness of these systems resulted in two vendor challenges: 1) unproven or underdeveloped systems were not able to meet original specifications, and 2) new vendors with limited exposure to utility-scale operations and procurement cycle time were not able to remain in business for the duration of the project. In both cases, this left projects with an increased burden to engage the vendor further or take on more development and configuration themselves.
- Challenges were not limited to technologies alone. Integration of a variety of systems equates to integration of lines of business across utility departments. An important example is the convergence of information technology and operations technology (IT/OT). Smart grid projects often see IT network and back office systems experts working in tandem with utility planning and operations engineers. The cultural change associated with integrating these lines of business should not be underestimated. Some projects addressed this by hand-picking experts from both areas to work side-by-side on their smart grid projects.

6. Communications and Cyber Security – Foundations of the Modern Grid

This session covered communications systems, FANs, and cyber security practices. Smart grid projects are using a variety of different communications systems including wireless, fiber optics, and power line carrier systems; there is no single approach or system that can work effectively for all utilities. One size does not fit all. This session addressed the technologies and systems being used today and what has been learned about the challenges of cyber security, a core piece of any modern grid system involving communications. The panel included presentations from Duke Energy, the National Rural Electric Cooperative Association (NRECA), Southern California Edison, San Diego Gas & Electric, and Salt River Project.

A fundamental theme of this session and the entire conference involved the importance of effective communications networks and related systems for an efficient and fully capable modern grid. Failures or gaps in these systems presented real and significant challenges. A common concern included the challenges involved in getting various systems to communicate with each other using shared protocols, data definitions, and control strategies. Developing standards and protocols for smart grid communications networks can help vendors provide better products and services and promote improvements in interoperability between systems.

One approach involves the use of FANs and their application for improving grid operations. FAN deployments are being driven by the high volumes of data, as well as the need to push data processing and decision-making into the field, closer to the electricity infrastructure and customers. Resulting benefits can include faster responses to system conditions and better-equipped field personnel. Utilities pointed to this localized field data management as a way to overcome several communications network challenges.

Effective cyber security was noted as an ongoing challenge that is increasingly becoming a day-to-day part of power system planning and operations. One speaker cited a representative study that identified 30,000 attacks per utility per month, ranging from probes to targeted infiltration attempts. Frequent information exchange on best practices and practical applications is helpful for addressing ongoing cyber security challenges.

7. Advanced Metering Infrastructure: Beyond Meter Reading

This session covered the opportunities for utilities to lower costs and to improve services through AMI. Going beyond automated meter reading, benefits can include outage detection and management, remote service connections/disconnections, theft/tamper detection, and new customer offerings such as time-based rates and web portals. Customer benefits include new tools and capabilities for managing consumption and costs and for enrolling in new programs and rate offerings, as well as achieving faster service restoration following outages.

Speaker presentations included reports on results from AMI deployments that demonstrate these applications and benefits and provide examples from actual experiences of utilities, service providers, and customers. This panel included representatives from Florida Power & Light, Baltimore Gas and Electric Company, Central Maine Power, the Iowa Association of Municipal Utilities, and Southern Company.

Outage management improvements from AMI include new capabilities for identifying outage locations and dispatching repair operations to precise locations. Ways to leverage AMI investments and build on communications and data management systems include monitoring premise-level voltage profiles and using these and other smart meter data to boost the effectiveness of outage management, voltage controls, and customer services.

Operational savings from AMI include better outage pinpointing and subsequent crew dispatch and reduced truck rolls for service connections/disconnections. Utilities with AMI systems can improve customer services and energy efficiency through increased customer awareness and engagement, peak pricing and rebate programs, and advanced bill alerting for customers showing abnormal usage and costs. AMI also supports innovative uses such as capacitor bank monitoring.

AMI deployment challenges include smart meter opt-outs and the consequence of dealing with these exceptions to both system design and customer communications. Customer openness to AMI can vary with service territory or region. For the most part, the presenting utilities experienced little customer pushback, and complaints appear to be diminishing.

Methods for addressing the challenges include early and frequent customer communication during AMI deployment, such as participation in public meetings and events; communications should establish clear and realistic expectations for AMI installations.

Future opportunities include mining the vast quantities of data collected on AMI devices; continued understanding of consumer behavior and acceptance, retention, and response to demand-side programs; and use of AMI for additional benefits such as power quality monitoring and support for DA, VVO, and CVR.

8. Studying the Smarter Consumer

This session engaged panelists on a series of issues relevant to the design, implementation, and evaluation of DOE's and EPRI's consumer behavior studies. Panelists provided insights into the ability to implement randomized control trials (the original intent of the SGIG funding opportunity announcement), the degree of success in getting customers to participate in the studies, installation and use of enabling technologies offered as treatments, and findings in terms of statistically significant responses. This session included presentations and discussion from Commonwealth Edison, FirstEnergy, and Sacramento Municipal Utility District.

Key findings include the following:

- The use of technologies such as in-home displays, programmable communicating thermostats, and web portals had varying degrees of success. Many customers encountered problems with the devices, particularly in-home displays, but the marketplace is evolving rapidly as utilities and equipment manufacturers learn more about customer needs and requirements.
- Enrollments using opt-in approaches require extensive marketing and customer research to identify effective recruitment strategies. Messaging is key, and clarity and simplicity are important for recruitment efforts. Many customers discussed their interest in participating because of potential benefits to the environment or society, but after-the-fact surveys found that financial benefits from incentives or new rates were more critical factors.
- Using opt-out approaches (default service) achieves much higher enrollment rates with far fewer recruitment costs. Utilities using this approach have found customer acceptance high, but concerns remain about widespread use, especially for vulnerable customer groups such as the elderly and low-income.
- Problems were encountered in processing data from smart meters and using these data to support billing, outage management, and web portals. To boost the effectiveness of customer programs and information feedback strategies that target energy savings, data processing and communication need to be closer to real time than they are today.
- Many customers accepted time-based rates and responded accordingly by reducing peak demand and shifting consumption to off-peak periods. Rates for critical peak events motivated customers to reduce peak demand during periods of system need, as did day-ahead notifications. In one area, hot summers in 2012 and 2013 produced measurable demand

reductions, even during multi-day critical peak events. However, the mild summer of 2014 did not provide the opportunity to measure ample event-day customer response data.

9. Engaging the Smarter Consumer

This session built on the previous one and included additional panelists in a broader discussion about how utilities collectively engaged various types of residential consumers. The discussions covered further experiences with customer devices such as in-home displays and web portals, as well as strategies for maintaining customer participation and involvement in programs and studies. This session included presentations and discussion from Kansas City Power & Light, the City of Fort Collins, and Pepco, as well as previous panelists from Commonwealth Edison, FirstEnergy, and Sacramento Municipal Utility District.

Two of the primary pricing tools for achieving demand reductions on critical peak event days include critical peak pricing and peak-time rebates. Experiences with both strategies showed high levels of customer acceptance and measurable levels of demand response. One utility noted $4 million in bill credits in 2014 from its peak-time rebate program. Developing definitive information about cost effectiveness is an ongoing challenge in communicating the benefits of these programs to regulators and policymakers.

Messaging about smart meter roll-outs addressed a number of challenges. Utilities that kept customers informed about deployment and installation schedules found fewer customer complaints than those that had less emphasis on this. Messaging that emphasizes customer control over usage was typically well received and resulted in better acceptance. Utilities found attending public meetings and events to be a useful mechanism for communicating with customers and educating them about pricing and other offerings.

Customers appreciated having the opportunity to choose among various rate offerings and programs. Customers have different needs, and as long as cost-effective options can be developed, there can be value in providing customers with a variety of rate offerings.

10. Reaching Beyond the Smart Grid

This final session summed up the findings and lessons learned about smart grid deployments. Speakers reflected on previous discussions, summarized findings, and discussed applying results, identifying common themes in application of technologies and "reaching beyond." Topics involved in "reaching beyond" included common next steps, challenges, roles, and enablers. This session was discussion only, with no formal presentations. Panelists included speakers from Kansas City Power & Light, Sacramento Municipal Utility District, Duke Energy, NRECA, Florida Power & Light, Pepco, DOE, and EPRI.

Key findings are provided below.

Successes

- Smart grid technologies delivered improved performance in a variety of areas, including outage management, reliability indices, voltage controls, operational savings, and consumer engagements.
- Smart grid technologies, including communications systems, provide opportunities to add future technologies and capabilities in new areas such as grid resilience.
- Tools and strategies for engaging customers and implementing time-based rates and other customer-facing programs are accepted and effective in achieving demand reductions.
- The Recovery Act smart grid programs are having a major impact in progress on grid modernization, interoperability, and cyber security.

Challenges

- Communications infrastructure and integration is an essential ingredient for smart grid success, and further development is needed to reduce latency and enhance cyber security protections.
- Better tools and methods for measurement and valuation are needed for making business cases and boosting expanded deployments of cost-effective smart grid technologies, tools, and techniques.
- Uncertainties about future policies and regulations, slowdowns in electricity demand growth, and competing investment opportunities affect the pace of grid modernization and underscore the need for strong business cases for smart grid projects.
- New organizational approaches and business models for utilities will be needed to support smart grid deployments. Changes in culture present obstacles for addressing new needs and hinder the pace of innovations. This includes issues such as IT/OT integration, management of legacy systems, and workforce training.

Insights and Surprises

- No single solution fits all. Impacts, costs, and benefits from smart grid investments vary on a utility-to-utility, feeder-to-feeder, and customer-to-customer basis. Strategies for mass customization of smart grid offerings are not fully developed. As a result, location-specific grid configurations are a critical factor in delivering project benefits.

- Integrated, cross-functional teams and senior management buy-in are keys for organizational effectiveness and project success.
- Measuring grid impacts and benefits from smart grid technologies is a new area for many utilities, and improved data analytics are needed. Measured benefits are dependent on good baseline data.

Next Steps/Future Needs

- With so many uncertainties about future markets, technologies, and policies, development of a unifying architecture for the future electric grid would be a useful contribution in further grid modernization activities.
- Given the newness of many aspects of measuring impacts and benefits and establishing business cases, development of common and consistent industry metrics would be a valuable addition and would help policy and decision makers evaluate alternative investments and strategies.
- To support decision making by grid planners and operators, tools are needed to manage, process, and leverage the vast quantities of new data. There should be greater focus on high-performance data, not big data.
- The distribution system is a "new frontier" in electricity, and evolution is under way toward more highly automated and controlled operations. Operations centers at the distribution level are likely to become more commonplace; trained workers and more effective models and tools will be needed to support this trend.
- Cyber security remains an ongoing and important priority. Changes brought about by the Recovery Act smart grid programs have been instrumental in raising cyber security awareness and the importance of sustained cyber security programs.

Additional Information

1. "Jumpstarting a Modern Grid", prepared by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, October 2014 – provides a high-level overview of the Smart Grid Investment Grant Program and the Smart Grid Demonstration Program with descriptions of the projects that presented at the EPRI-DOE Conference, October 2014. https://smartgrid.gov/sites/default/files/doc/files/EPRI_DOE_smartgrid_Brochure_FINAL.pdf
2. "EPRI Smart Grid Demonstration Initiative – Final Update", prepared by the Electric Power Research Institute, October 2014 – provides a high-level overview of EPRI's Smart Grid Demonstration Initiative with descriptions of funded projects. http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004652
3. "Grid Impacts, Benefits, and Lessons-Learned", prepared by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, December 1014 – provides a listing and linkages of key documents from the Smart Grid Investment Grant and Demonstration Programs. https://smartgrid.gov/document/grid_impacts_benefits_and_lessons_learned