The Edison Foundation
INSTITUTE for
ELECTRIC INNOVATION

IEI Whitepaper

Grid Modernization Technologies: Key Drivers of a Smarter Energy Future

May 2017

Prepared by:
Jonathan Blansfield and Adam Cooper

Introduction

Technology is a key driver of the ongoing transformation of the electric power industry – it changes what we can do, how we do it, and what it costs. The U.S. electric power industry is investing billions in smarter energy infrastructure to enhance the reliability, resiliency and security of the energy grid; to integrate and manage growing numbers of distributed energy resources (DERs) and other devices; and to improve grid efficiency and optimization. In 2016 alone, investor-owned electric companies invested about $53 billion in the energy grid – $21 billion in the transmission grid and $32 billion in the distribution grid. Today, more than 70 million digital smart meters are deployed across the United States, covering more than 55 percent of all households. While smart meters are a key building block to a smarter energy grid, digital meters represent only a fraction of the grid modernization technologies being deployed across the country today.

As electric companies engage in grid modernization initiatives, it's important that policy makers, regulators, consumer advocates, and other stakeholders understand what this means. This report discusses electric company investments in smarter energy infrastructure from the substation to the customer meter – largely digital technologies that are the building blocks of the future energy grid. It provides a non-technical overview of today's grid modernization technologies – not future technologies – and covers the following:

- Why are electric companies modernizing the energy grid?
- What does smarter energy infrastructure achieve?
- What technologies are being deployed today?
- What is the role of data analytics?
- What is the future of grid modernization?

Why Are Electric Companies Modernizing the Energy Grid?

Grid modernization is unfolding state-by-state – at different paces and in different ways – across the country through investments in smarter energy infrastructure. What is new to one company may be business-as-usual for another, but grid modernization is largely driven by the need to: (1)

enhance resiliency, reliability, and security; (2) integrate and manage DERs; and (3) improve grid efficiency and optimization.

Enhance Resiliency, Reliability, and Security

Electricity is central to the everyday lives of all Americans. In today's digital world, customers need and expect safe, affordable, highly reliable, and increasingly clean energy for quality of life and well-being. Grid modernization is about ensuring that electric companies are able to deliver the energy customers need, when they need it. Electric companies across the United States are building a more resilient and more reliable energy grid by investing in both physical asset modernization and technology upgrades. Physical asset investments include conductor upgrades, improved insulation, concrete poles, automated switches, and others. Technology upgrades enhance outage detection and restoration capabilities, energy grid visibility and power management, and customer communications.

Integrate and Manage Distributed Energy Resources (DERs)

Today, electric companies are investing in digital technologies to ensure seamless integration of DERs, to enable two-way power and information flows, and to utilize DERs as energy grid assets. Digital technologies – like advanced metering infrastructure (AMI), smart inverters, power line monitors that enable Volt/VAR optimization, and micro-phasor measurement units that facilitate real-time voltage and current measurements and visibility into energy grid conditions – are increasingly used to integrate and manage DERs.

Improve Grid Efficiency and Optimization

Installing intelligent grid devices for sensing and analytics can provide visibility into distribution grid operations, similar to the extensive visibility that exists for bulk power markets and the transmission grid. These devices can improve situational awareness to help identify the source of technical losses along the distribution system, allowing for right-sizing of electrical equipment based on customer load profiles. Advanced sensing and voltage management technologies also can increase solar photovoltaic hosting capacity on certain feeders.

What Does Smarter Energy Infrastructure Achieve?

Investments in smarter energy infrastructure to date are enabling the following: energy grid optimization; optimized power quality and power flow; data systems integration; grid visibility and diagnostics; automated outage management and service restoration; and DER integration and management. These are described briefly below.

1. *Energy Grid Optimization*. More intelligent control and dispatch of generation and distributed energy assets as a result of real-time grid-edge visibility, data analytics, and increased substation or circuit capacity to integrate variable generation.
2. *Optimized Power Quality and Power Flow*. Use of digital sensing and control technologies to monitor line conditions, enable bi-directional power flows, ensure power quality to certain customers, and increase variable energy resource hosting capacity.
3. *Data Systems Integration*. Integration of data sets and systems into an enterprise-wide database to realize operational and customer benefits (e.g., merging operations technology and information technology systems).
4. *Grid Visibility and Diagnostics*. More frequent and granular visibility into grid conditions out to the grid edge enables real-time, efficient, and decentralized decision making, including the ability to predict and prevent anomalies and service disruptions and improve system utilization.
5. *Automated Outage Management and Service Restoration.* Use of "self-healing" outage technologies that autonomously detect faults, isolate/island outages, more quickly dispatch work crews, and provide near real-time service restoration updates to customers.
6. *DER Integration and Management.* Supports increased DER integration by solving feeder and circuit-level issues, and provides visibility into resource availability and performance.

Grid Modernization Technologies

Whether electric companies are just beginning to invest in smarter energy infrastructure or are embarking on the next phase of grid modernization, a key question is: which technology investments will yield the greatest customer and/or system benefits? Grid modernization investments fall into three broad categories: AMI; power flow management technologies; and distribution automation and outage management technologies (see Table 1).

Table 1: Smarter Energy Infrastructure Features & Grid Modernization Technologies

	Features of Smarter Energy Infrastructure					
Grid Modernization Technologies	Energy Grid Optimization	Optimized Power Quality & Power Flow	Data Systems Integration	Grid Visibility & Diagnostics	Automated Outage Management & Service Restoration	DER Integration & Management
AMI	○		●	●	●	○
Power Flow Management Technologies						
Smart Inverters	●	●	○	●	●	●
VOLT/VAR Management	●	●		○		○
Power Line Monitors	●	●		●	○	○
Distribution Management and Outage Management Technologies						
OMS	○		●	●	●	
DMS	○	○	●	●	●	○
WMS			○	●	●	
FLISR	○	○	●	●	●	
ADMS	●		●	●	●	○
DERMS	●	●	●	○	○	●

Key	
Primary Benefit	●
Secondary Benefit	○

Advanced Metering Infrastructure (AMI)

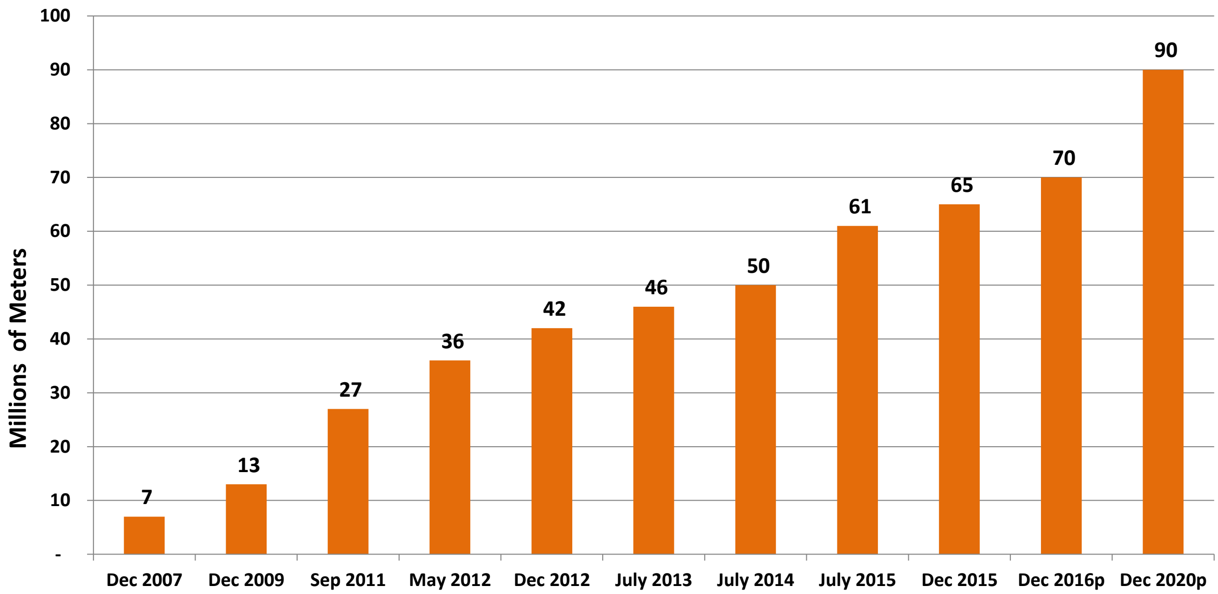
AMI, commonly known as "smart meters," facilitates daily, digital communication between an electric company and its customers, and provides "on/off" power status, voltage, and energy consumption information for each customer. Over the past decade, electric companies have installed about 70 million smart meters (see Figure 1).

- *Meter data management system (MDMS).* Gathers, processes, verifies, and stores meter data for future applications such as billing, energy use notifications, and outage management.

- *Communication systems.* Smart meters collect data locally and transmit over a communications network using radio frequency (RF) or power line carrier (PLC) technologies. RF mesh technology either transmits data from meter to meter (i.e., hopped) to a central collection point or transmits from individual meter to a collector. PLC technologies transmit data using electric company power lines from meter to a collection point, usually in the distribution substation feeding the meter.

The integration of AMI data with outage management systems provides major benefits to customers in terms of outage restoration and notification, and is the foundation for connecting the smart grid to the smart home.

Figure 1: Smart Meter Installations in the United States Pass 70 Million; Projected to Reach 90 Million by 2020



Source: Institute for Electric Innovation, Electric Company Smart Meter Deployments: Foundation for A Smart Grid, October 2016.

Power Flow Management Technologies

Power flow management technologies enable DER integration, assist in energy grid optimization, and provide grid-edge visibility and diagnostics.

- *Smart Inverters.* Smart inverters enable intelligent control, aggregation, and dispatch of DERs, such as private solar PV and battery energy storage, when capacity or ancillary services are needed. Advances in smart inverter technologies and cost declines allow electric companies to control and manage DERs as a system resource.

- *Volt/VAR.* Volt/VAR optimization (VVO) technologies balance line voltage and system reactive power to reduce system line losses (e.g., help avoid overheating, balance harmonics), reduce peak demand, and improve the efficiency of the distribution grid. VVO also can help manage power quality issues associated with high penetration of variable energy resources.

- *Power line monitors.* Power line monitors provide situational awareness along the distribution grid to assess real-time power line and power quality conditions, and detect anomalies such as overloading or line sagging.

Distribution Automation and Outage Management Technologies

Distribution automation (DA) and Outage Management (OM) systems integrate existing and new systems and technologies for more intelligent energy grid operations using data analytics and modeling. These systems allow electric companies to automate distribution grid operations and detect and manage outages to improve reliability and resiliency.

- *Outage Management System (OMS).* System that combine geospatial information system (GIS), customer information system (CIS), and automated call handling system to prioritize and direct service restoration crews in the field.

- *Distribution Management System (DMS).* System that integrates data from OMS, Supervisory Control And Data Acquisition (SCADA), networked field devices, and other communications networks for more efficient and intelligent energy grid operations, and improved situational awareness. Networked field devices include: automated feeder switches; reclosers; capacitors; and voltage regulators.[1]

- *Workforce Management System (WMS).* A mobile, integrated planning, scheduling dispatch, and communications platform that automates work orders, enables field crews to seamlessly communicate with central command and customers, and embeds analytics into in-field operations.

---

1. For more on the relationship between the technologies in a DMS, for example VVO optimizing capacitor bank switching, *see* U.S. DOE, Application of Automated Controls for Voltage and Reactive Power Management, December 2012, available at https://www.smartgrid.gov/files/VVO_Report_-_Final.pdf.

- *Fault Location Isolation Service Restoration (FLISR).* System comprised of automated feeder switches and reclosers, line monitors, communication networks, DMS, OMS, SCADA systems, and data analytics. FLISR systems integrate these technologies to prevent faults, mitigate their effects when they do occur, and automate power restoration, including field operations communications.[2]

- *Advanced Distribution Management Systems (ADMS).* System that connects and aggregates many energy grid operational functions to provide grid-edge and system conditions visibility, and outage management and restoration capabilities. ADMS combines OMS, DMS, and WMS with VVO, FLISR, peak demand management, data analytics, and communication networks to enable a highly visible and controllable distribution grid.

- *Distributed Energy Resource Management System (DERMS)*. System that aggregates and controls DERs and is integrated into a DMS or ADMS. A DERMS leverages sensing technologies, data analytics, existing energy grid assets, plus DERs to enable and optimize interconnection, facilitate and manage DER load, and provide visibility into DER asset behavior.

The Role of Data Analytics

Data analytics is a common thread among nearly all of the digital grid modernization technologies covered in this paper. Electric companies are just beginning to put the massive amounts of data available from an increasingly digital grid to work.

One of the most important uses of data analytics today is in asset health and performance management systems to leverage asset-level intelligence for predictive maintenance and proactive replacement of critical infrastructure. By tying into existing OMS or (A)DMS, this data analytics capability enhances reliability and achieves significant cost savings. Some additional areas where data analytics are being used today include:

- Outage detection, management, and restoration;
- Integrating and managing DERs;
- Customer solutions based on personalized insights; and
- Next-generation grid management, including 24/7 real-time visibility.

2. U.S. DOE, Fault Location, Isolation, Service Restoration Technologies Reduce Outage Impact and Duration, December 2014, available at https://www.smartgrid.gov/files/B5_draft_report-12-18-2014.pdf.

To put electric company data to use and enable the features of a smart grid, data analytics must work across business units. Data analytics is becoming increasingly important to operating the energy grid and delivering services to customers.

The Future of Grid Modernization

As DERs and renewable energy resources continue to grow, the distribution grid is becoming more complex. Some trends are clear:

- The customer is central to grid modernization efforts. AMI, enhanced resiliency and reliability, and enterprise software systems and data analytics all improve customer service. Digital connections and communications with customers that enhance customer value will continue to be a high priority in smarter energy infrastructure investment decisions.

- Integrated distribution planning – an integrated resource plan for the distribution grid – likely will become the new normal. This means engaging in a planning process that coordinates DERs and related technologies with other planning and investment decisions.

- Increased decentralization will pave the way for the next wave of grid modernization, focused on the deployment, siting, and integration of DERs.

- Identifying additional metrics to track and evaluate grid modernization efforts will become critical.

- Energy storage and microgrids will continue to grow: to facilitate DER integration; to improve distribution grid operations; to provide resiliency benefits; and, to meet customer needs.

- Technology advances will continue to provide more opportunities for electric companies to optimize and for customers to contribute to the energy grid. Interoperability and flexibility remain key, and investments must be made recognizing this future.

Conclusion

Today, the U.S. electric power industry is investing more than $100 billion annually in smarter energy infrastructure and cleaner generating assets. These investments are paving the way for the energy grid of tomorrow. Over the past 10 years, electric companies have made great progress. But more remains to be done.

In some states, smart meters are fully deployed, and the focus is now on integrating larger numbers and greater concentrations of DERs. In some states, DER penetration is low, and the focus is on optimizing grid operations and enhancing resiliency. And, in other states, grid modernization is just beginning.

It is critical that, as the electric power industry moves toward realizing the digital energy grid of the future, all stakeholders – electric companies, technology providers, regulators, policy makers, governments, consumer advocates, venture firms, and other private investors – understand what it will take: strategic deployment of technologies combined to achieve specific capabilities over the medium-to-long term. These technology investments must deliver cost savings and operational efficiencies today, and be flexible enough to accommodate the changing conditions of tomorrow. It's a complex and dynamic task, but has resulted in significant benefits already and will continue to yield benefits well into the future.

About the Institute for Electric Innovation

The Institute for Electric Innovation focuses on advancing the adoption and application of new technologies that will strengthen and transform the energy grid. IEI's members are the investor-owned electric companies that represent about 70 percent of the U.S. electric power industry. The membership is committed to an affordable, reliable, secure, and clean energy future.

IEI promotes the sharing of information, ideas, and experiences among regulators, policy makers, technology companies, thought leaders, and the electric power industry. IEI also identifies policies that support the business case for the adoption of cost-effective technologies.

IEI is governed by a Management Committee of electric industry Chief Executive Officers. In addition, IEI has a Strategy Committee made up of senior electric industry executives and a select group of technology companies on its Technology Partner Roundtable.

About the Edison Foundation

The Edison Foundation is a 501(c)(3) charitable organization dedicated to bringing the benefits of electricity to families, businesses, and industries worldwide. Furthering Thomas Alva Edison's spirit of invention, the Foundation works to encourage a greater understanding of the production, delivery, and use of electric power to foster economic progress; to ensure a safe and clean environment; and to improve the quality of life for all people. The Edison Foundation provides knowledge, insight, and leadership to achieve its goals through research, conferences, grants, and other outreach activities.

The Edison Foundation
INSTITUTE for
ELECTRIC INNOVATION

Institute for Electric Innovation
701 Pennsylvania Avenue, N.W. | Washington, D.C. 20004-2696
202.508.5440 | Visit us at: www.edisonfoundation.net