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CIGRE US National Committee
2017 Grid of the Future Symposium

FirstEnergy DOE Smart Grid Experience / Distribution Grid of the Future

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SUMMARY

In 2010 FirstEnergy was awarded roughly $115 million for the implementation and study of Distribution Automation and Integrated Volt Var Control, Smart Metering Infrastructure and customer response to Critical Peak Pricing signals (CPP). In Ohio, SGMI implementation was targeted in the Cleveland Electric Illuminating (CEI) service territory. This section of the CEI deployment footprint covers 400-square-miles and serves 45,000 customers. At CEI, SGMI deployment characteristics were as follows:

- 14 substations
- 36 13.2kV circuits
- 55 NC Reclosers
- 45 NO Reclosers
- 138 Capacitor Banks

A core SGMI objective was to leverage the integration of multiple technologies across within single distribution substations. This allowed FirstEnergy to examine critical aspects of grid modernization in real time operational settings.

There was a great deal of operational, event and performance data gathered from the SGMI and accordingly, many objective, data-related lessons learned. As a result, FirstEnergy is well positioned to advance their efforts from technology performance testing to real, integrated technology operationalization.

With new Smart Grid tools, FirstEnergy can select and implement technologies with an end in mind, in the process considering the needs of their customer base now and in the future. Grid modernization gives FirstEnergy the opportunity to reach out to our customer base to initiate new conversations about the services they need and the value we can provide. FirstEnergy is dedicated to fulfilling their unique responsibility of providing safe, reliable service to our customers as they work together to meet evolving customer needs.

KEYWORDS

Smart Grid, Distribution Automation, Integrated Volt Var Control, Advanced Distribution Management System

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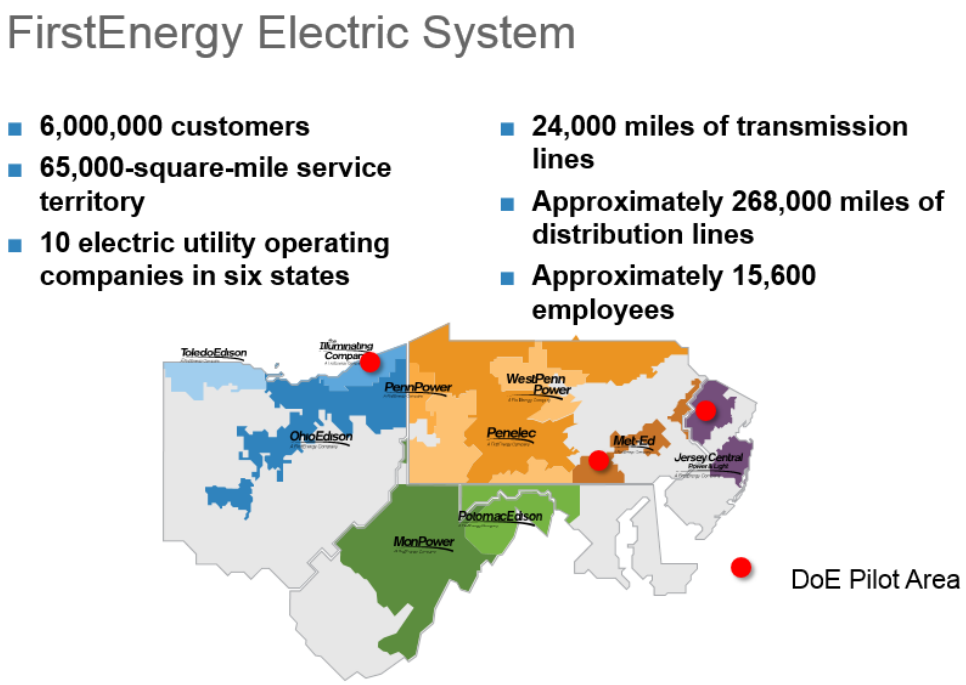
FirstEnergy Smart Grid Modernization, Introduction
In 2010, FirstEnergy submitted the Smart Grid Modernization Initiative (SGMI) as an *Integrated and Crosscutting System Topic* to the Department of Energy (DOE) for funding under the American Recovery and Reinvestment Act (ARRA). DOE awarded FirstEnergy approximately $57 million[i] for the implementation and study of Distribution Automation and Integrated Volt Var Control, Smart Metering Infrastructure and customer response to Critical Peak Pricing signals (CPP) and a Direct Load Control customer system (IDER DLC) implemented to reduce peak demand. While the SGMI project was formally administered through the second quarter of 2015, FirstEnergy continues to operate major components of the project, collecting and analysing performance data and fine tuning the operational integration of those technologies. This further evolution of the SGMI system serves as the foundation for FirstEnergy's Distribution Grid of the Future.

About FirstEnergy
FirstEnergy serves approximately 6 million customers within a 65,000-square-mile service territory. The red dots indicate deployment areas for the FirstEnergy SGMI.



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Smart Grid Modernization Initiative Description
The original SGMI deployment at FirstEnergy's CEI operating company involved Distribution Automation, Integrated Volt Var Control and Automated Metering Infrastructure

which was deployed in parallel with the development of a Consumer Behaviour Study (developed to evaluate customer response to Critical Peak Pricing signals).

The initiative encompassed a highly variable set of climatic conditions, existing infrastructure designs and customer demographics which enhanced the value of technical and operational experimentation, data analysis and ongoing findings.

Smart Grid Technology	CEI	ME	JCPL
Distribution Automation	✔	✔	✔
Volt / VAR Control	✔	✔	
Smart Meters Consumer Behavior Study	✔		
Integrated Distributed Energy Resource		✔	✔

Smart Grid Modernization Initiative Objectives

A core SGMI objective was to leverage the integration of multiple technologies across within single distribution substations. This allowed FirstEnergy to examine critical aspects of grid modernization in real time operational settings. Objectives identified at the project's outset included 1) creating a pervasive communications network that would support multiple objectives related to distribution system reliability, energy efficiency and operational efficiency; 2) integrating distribution automation, direct load control and metering devices into standard operational procedures as practical to broadly understand their individual and combinatorial benefits; 3) identifying an optimal approach to the development of technical upgrades and improvements across the distribution system; and 4) developing a methodological foundation for assessing technology value and capitalization requirements.

The DOE required FirstEnergy and other award recipients to report a standard set of Metrics and Benefits that were produced via the deployment and implementation of the new grid technology. FirstEnergy took this requirement steps further by developing experimental plans and procedures for project technology implementation and operation. This allowed FirstEnergy to develop strong data collection and analysis procedures and to assess ongoing progress toward objectives in a disciplined fashion.

Smart Grid Modernization Initiative Approach

FirstEnergy expanded analytical approach for the initiative was organized into three critically important areas:

The SGMI Consumer Behaviour Study

FirstEnergy undertook a three-year consumer behavior study (CBS) to evaluate residential customer response to alternative inducements (experimental treatments) to alter their electricity usage during the afternoon hours of hot summer days. The focal point of the study was to quantify how residential customers respond to a monetary inducement, such as peak

time rebate (PTR), to reduce load during pre-specified hours (events) with a day's advanced notice.

To measure the customer response the Companies installed smart meters and provided customers access to their hourly information through a web portal. In addition, the study evaluated the impacts of two enabling technologies on customer response: the in-home display (IHD) and programmable controllable thermostat (PCT). Only customers identified as having central air conditioning were eligible to receive a PCT. The customers without central air were eligible to receive IHDs.

The Company found statistically significant demand response results with the technology with pricing treatments. Results of the study are available on www.smartgrid.gov under Consumer Behavior Study.

The SGMI Metrics & Benefits Reporting Plan - Execution Manual

Data analysis requires significant expertise and a lot of iteration. In the SGMI Metrics and Benefits Execution Manual (MBRP-EM) FirstEnergy explained the integration approach for each of the SGMI involved technologies and provided its plan for evaluating and reporting the core metrics for each technology. This is included 1) how technologies would be physically implemented and configured; 2) the design and application of operational treatment plans and/or operational event evaluation; and 3) how baselines would be developed and performance would be measured. As FirstEnergy has continued to evolve its strategy, certain concepts that were grounded in the MBRP-EM are guiding the FirstEnergy team as future grid modernization planning and evaluation tools evolve. Concepts that will be further explored and developed include:

- Baseline development, involving methodologies to properly and accurately establish what distribution operational characteristics would have been, had the SGMI technology not been deployed
- Data collection protocols, involving the definition of operational data outliers, the determination of proper intervals and the logical location of data vis-à-vis operational devices
- External database mining (for example PowerOn and PI Historian), involving determination of data points for collection and run schedules to populate analytical tools
- Analytical tool development, involving the organization and processing of data for the elimination of outliers, application of algorithms and characterizations of performance
- Temperature normalization, involving the application of temperature indices to isolate actual/accurate performance from integrated devices, given defined operational settings

The SGMI Network Communications Task Force

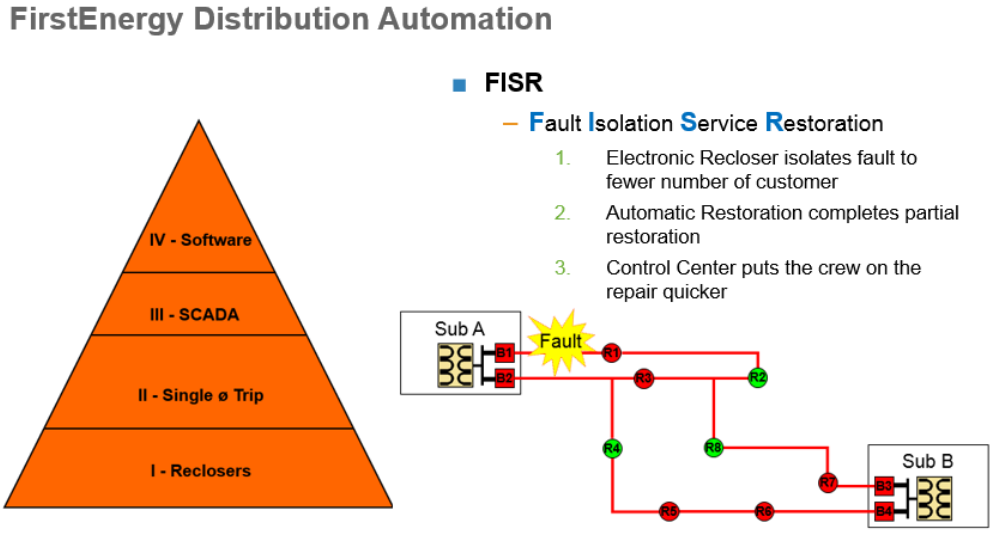
- Network architecture (to be completed)
- Reliability and redundancy (to be completed)
- Critical path components/communications (to be completed)

Smart Grid Modernization Initiative, Field Testing and Experimentation

At CEI, Distribution Automation was used primarily to provide reliability benefits. Project circuits were selected because they required minimal upgrade to support DA and because some of the circuits had higher outage statistics comparable to all CEI circuits. While SAIFI and SAIDI were designated as primary SGMI objectives, FirstEnergy looks most closely at Customer Minutes Interrupted (CMI).

Distribution Automation

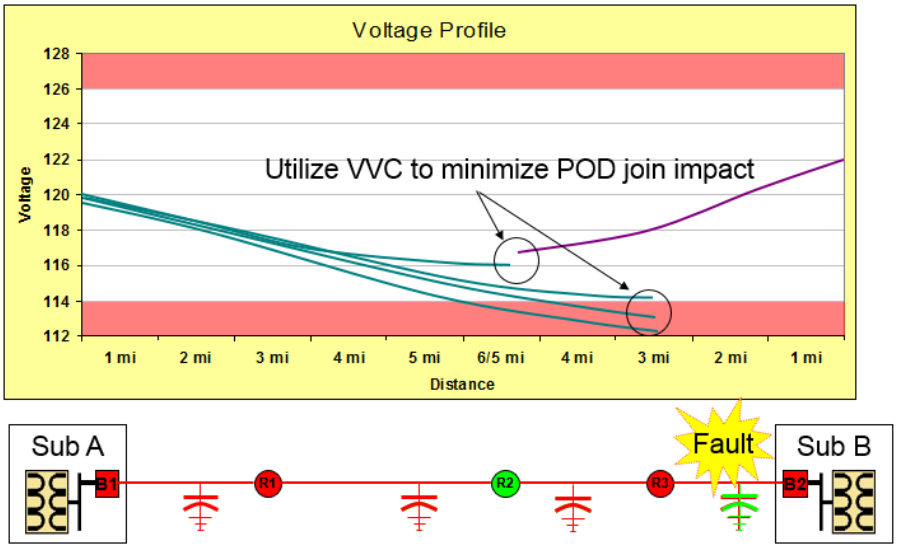
Through the implementation of electronic reclosers with SEL relays using single phase trip (FirstEnergy has determined that > 70% outages are single phase trip), centralized integrated Distribution Automation (DA) and Integrated Volt Var Control (IVVC) software, and using SCADA for grid visibility. Because CMI is a central reliability metric FirstEnergy looks closely at reduced outage frequency (down 12% since the operationalization of CEI SG) and outage duration (down 25% since the operationalization of CEI SG).



Integrated Volt Var Control

Integrated Volt Var Control (IVVC) was deployed at CEI to produce overall energy efficiency benefits and provide peak load reduction. The integration of IVVC was also expected to optimize the operation of new and existing voltage devices – Load Tap Changers (LTC), capacitor banks and regulators. The experimental design for IVVC was set up to test system voltage settings and thresholds and to assess the impacts of voltage tuning. Once tuned, the deployed IVVC system will allow FirstEnergy to optimize the voltage setting (flatten the voltage and establish the most favourable setting based on operational requirements), and to monitor and maintain that setting until changed operational conditions require setting revision. A core aspect of IVVC is bracketed by ANSI specified limits on upper and lower voltage levels. In addition to the being an ANSI specification, these voltage thresholds ensure that FirstEnergy is maintaining good customer quality with electricity delivery.

DA Operation with VVC



Automated Metering Infrastructure
The CEI Automated Metering Infrastructure (AMI) was deployed to assess cost effectiveness and to bring FirstEnergy into compliance with OhioSB221 which requires utilities to reduce peak demand. The SGMI AMI has its own database from which event and other performance data can be derived and analysed.

The SGMI AMI was critical to the analytical activities of the SGMI Consumer Behaviour Study as the smart metering devices that were integrated into the AMI network were key to data collection as were the field aggregation sites which assembled and forwarded data to the FirstEnergy Operations Centre.

FirstEnergy, Operationalizing the Grid of the Future
As FirstEnergy continues to develop and evolve plans for the deployment and operationalizing their grid of the future a balance must be struck between what we see developing on the horizon and what we have learned to date.

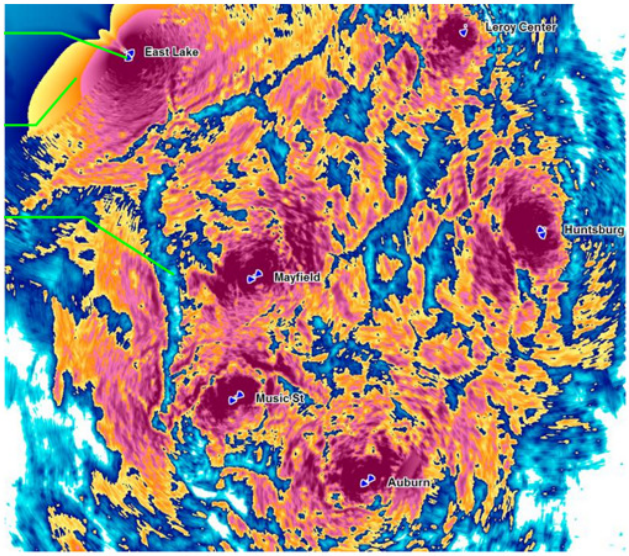
Lessons Learned
There was a great deal of operational, event and performance data gathered from the SGMI and accordingly, many objective, data-related lessons learned. There were also numerous lessons learned by the FirstEnergy and CEI engineering and operations staffs living with and managing the SGMI deployment on a day-to-day basis for nearly five years.

Included among lessons learned are the following:

- **Communications**
  It turned out that the communications network that underpinned the technology deployment was one of the biggest project challenges. A modernized grid requires more than 99.99% uptime. FirstEnergy evaluated several technologies mid-initiative before finding a suitable solution. This included 700 MHz (vendor went bankrupt)

and 1.4 GHz (poor performance required extensive mitigation with CDMA; CDMA costs were prohibitively expensive) before Tropos demonstrated a 2.4/5.8 GHz Mesh Radio solution that was ultimately deployed across the CEI project footprint.

1.4 GHz Performance



- Dark Red great coverage
- Orange Yellow marginal coverage
- Blue zero no coverage

- Doubled the number of 1.4 GHz towers from 6 to 12 but saw no significant improvement.

- ALWAYS IN MITIGATION MODE

- Conclusion: 1.4 GHz was not providing needed performance

After several years of operation FirstEnergy has achieved their targeted 99.99% uptime with many communication network devices. There are occasional outliers; communication issues with these devices are "troubleshooted" as they appear. Lessons learned also lead to the following guidance for future projects:

- A mix of networks is the best approach for a large utility like FirstEnergy and the business needs of multiple groups within the organization should be considered in determining requirements
- SCADA communications with remote field devices require a hybrid solution – there is no perfect "out-of-the-box" solution available
- Design placement of distribution equipment and the placement of network equipment together. Placing one above the other calls for sometimes significant compromises
- Insure you document network communications requirements to a great level of detail to measure the performance of the "system" and to hold internal and external operators accountable

- **Benefits of an Integrated Smart Grid System**

  A clear value component of grid modernization is the opportunity to join systems onto a common platform. The common platform allows grid information to be shared between technologies and it provides line-of-sight for grid operators all the way down to the consumer endpoint for outage management and voltage control.

  Integration also means coordination. An AMI meter can provide an individual customer outage notification to determine outage scope which is a significant upgrade from previous technical generations. More importantly, AMI meters can provide restoration validation, ensuring that outages are nested and that restoration is achieved

as efficiently as possible. In a coordinated environment that same AMI meter can provide locational voltage details to fine tune IVVC algorithms.

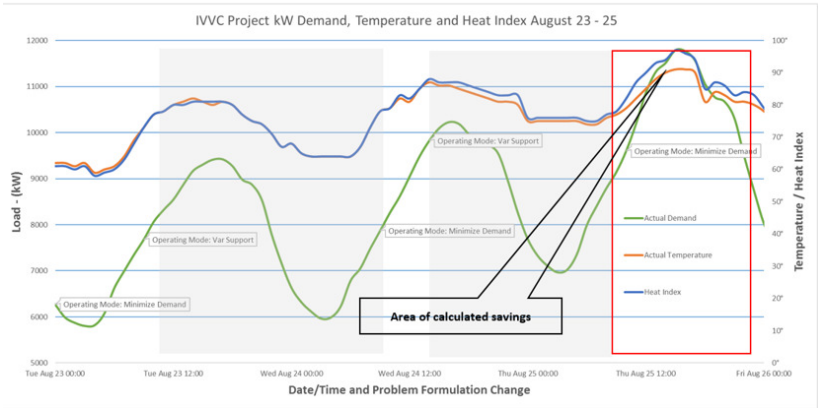
In a coordinated environment managed from a common platform, IVVC and DA behave as teammates. IVVC can help synchronize voltages when closing DA devices at tie points. All DA and IVVC devices within specific operational areas can be coordinated to optimize results.

These capabilities add the flexibility that will be required to accommodate distributed generation, storage potential and new technologies such as electric vehicles at various levels on the distribution system.

- **Temperature Normalization Technique is Important**

Temperature compensation of kW loading is a necessary step in computing Conservation Voltage Reduction factors using operational data and measurement and verification techniques. Conservation Voltage Reduction is an important IVVC value stream. Because of experiences with the SGMI IVVC deployment, we now believe that heat index is a better indicator of peak demand that high temperature. This allows for accurate estimation of actual energy conservation resulting from IVVC operation without the effects of heat on the performance metrics. Using kW loading which has not been temperature compensated when computing CVR factors hides much of the effect of voltage reductions and understates actual energy conservation and demand reduction results.

Load, Heat Index and Temperature Profiles



FirstEnergy has determined that collecting regional data as opposed to site specific data can have a significant impact on results as well.

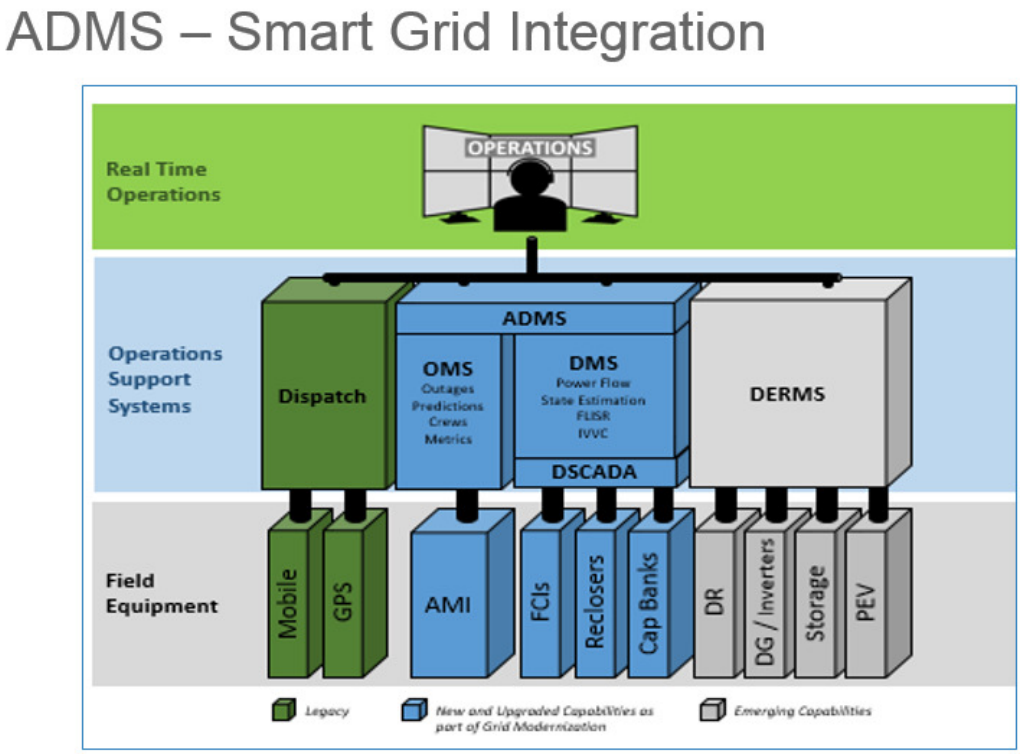
Temperature compensation has been an important component in FirstEnergy's Integrated Volt Var Control data collection and performance evaluation methodology. Both time and temperature characteristic accuracy are key factor in our time series approach. Originally, FirstEnergy used temperature data from Cleveland Hopkins temperature for analysis. Based on analytst suspicion that Cleveland Hopkins was too distant a collection point and that the temperature characteristics were significantly different from conditions immediate to the substation, FirstEnergy piloted a local weather station at one of the project substations. FirstEnergy found that the local weather station provided significantly enhanced and relavent

temperature characteristics which, in turn, has a meaningful impact on system performance analysis:

For Winter 2016-17 (December, January and February)

- Average Temperature ~ 3 degrees (F) difference
- Maximum temperature difference 19 at 11:15 on 1/12/17
- Improved confidence for temperature compensation algorithms

- **Requirement for Advanced Distribution Management System**
  It was previously noted that a common platform will allow grid information to be shared between technologies and it provides line-of-sight for grid operators all the way down to the consumer endpoint for outage management and voltage control. An Advanced Distribution Management System (ADMS) a real-time nerve center that coordinates the other grid modernization components and enhances their effectiveness, is one such platform. FirstEnergy has identified the acquisition and implementation of an ADMS into their distribution system as a critical path requirement for successful distribution grid modernization.



It's important to install the ADMS early in the process of modernizing the grid to provide operators and engineers with a tool they can use to effectively organize and interpret increasing amounts of information. ADMS allows grid operators to leverage data from all the various sources, including outage management system, distribution automation, automated meter infrastructure and integrated volt VAR controls. An ADMS can provide line of sight for grid operators all the way down to the customer location for outage management and voltage control. As most

utilities recognize, the separation of transmission concerns from distribution concerns is critically important for two reasons:

- To properly limit alarms at appropriate network levels thereby; FirstEnergy wants Distribution system alarms and notification to go to distribution operators, not flood the Transmission SCADA system
- The security change management requirements are different between Distribution and Transmission levels; the separation of concerns will help ensure that change management protocols and routines are properly managed at the respective levels

As more and more information is available to the system operators, ADMS performs decision analyses that assist the system operator in better managing the distribution system. For example, when distributed generation comes on line it increases the voltage on the system or when electric vehicles are being charged it reduces voltage on the system, ADMS captures this information in the real time and allows the operator to adjust as necessary to accommodate real time changes like these on the distribution system.

Practical Technology Integration

As an industry, we can't lose sight of the clear practical realities of grid modernization. To a large extent, we are "fixing the plane as we fly it," and as we integrate new technologies and different operating procedures into a live distribution system, we need to stay mindful of the practical realities of maintaining service expectations in a safe manner as we upgrade.

As an industry, we also need to be realistic about the extent to which vendors can deliver "turn key" technical solutions. For over a decade, papers and presentations have been distilling the clear truth that there are few if any "out-of-the-box" solutions or applications that can be instantaneously deployed and operationalized. Practical integration has been proven to be a multi-step process organized around requirements development, tool selection, integration planning, deployment, testing and tuning. Literally hundreds of integration steps underlie these main Project Management line items. Because of the sophistication of new tools and the complexity of grid modernization initiatives, critical path communication and change management processes are simultaneously more complex and more important in terms of successful outcomes.

Modelling outcomes and developing operational requirements to meet the needs of customers is as important as another other aspect of practical integration. With new Smart Grid tools, FirstEnergy can select and implement technologies with an end in mind, in the process considering the needs of their customer base now and in the future.

New Opportunities for Customer/Utility Interaction

The status quo is good news for FirstEnergy. When we assessed our current distribution system customers, it is clear it that we continue to serve them well. The primary requirements for our distribution system are *reliability* ("are my lights on?") and *safety* ("is the power delivered safely to my home or business?"). Safe, reliable electric service is the bedrock of the day to day activities of FirstEnergy's 4,000 Ohio distribution employees and that goal is achieved daily. FirstEnergy's three Ohio utilities are consistent top performers in the state for reliable service as measured by frequency of outages and duration of outages.

Not only does our distribution system perform well among our peers but our residential and business customers also affirm that FirstEnergy reliability matches their expectations. When surveyed, 73% of the customers who experienced outages considered the number of interruptions they experienced to be reasonable. Equally telling, the number of outages our customers recall experiencing is trending down, meaning customers believe their reliability is improving.

Any discussion of grid modernization always starts with recognition of the unique responsibility FirstEnergy's operating companies have in providing safe, reliable service to our customers. Grid modernization, though, gives FirstEnergy the opportunity to reach out to our customer base to initiate new conversations about the services they need and the value we can provide. To understand our grid modernization requirements, we need to understand our customers' electricity utilization requirements. Accordingly, we have been reaching out a lot and our building a knowledge base that will help us to continue to meet needs as they change and expand.

FirstEnergy, Focused on Meeting Customer Requirements

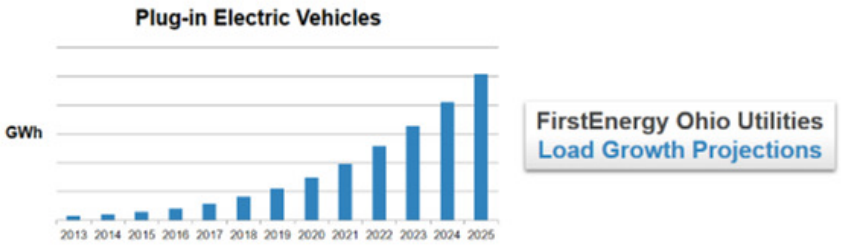
There are, however, a whole range of technologies that are or will become part of our distribution system that provide:

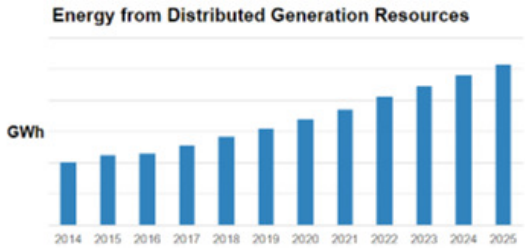
- More customer choices
- Greater transparency on energy usage information
- Greater flexibility to restore outages
- Integration with renewables and distributed energy resources
- Integration of new technologies

Along with greater expectations on reliability and restoration, FirstEnergy customers are increasingly aware of new energy innovations hitting the market. Vendors are doing a good job communicating the breadth and range of products available to customers. These are products that can help improve their quality of life, save energy and money, and have a positive impact on the environment. When surveyed, our customers said the following were "somewhat or extremely" important:

- 71% online tools to help with costs,
- 69% renewable energy options, and
- 40% electric vehicle charging.

We are already seeing adoption of these technologies on our distribution system. Our customer end-use studies show increased penetration for distributed generation, in-home automation, and electric vehicles. As shown in these charts, we expect adoption will accelerate in the years ahead. Whether it's electric plug-in electric vehicles or distributed generation, these innovations pose new challenges and opportunities to operating our distribution system in a safe, reliable fashion.





Integration of these technologies provides us a unique, new opportunity to interact with and improve their satisfaction of the customers served on our system. Technology plays a key role in improving our customers experience, and that technology isn't limited to things that attach to our distribution system. We are continually improving the way we touch our customers and how our customers reach us.

We offer a variety of mobile communications tools that make it convenient and simple for our customers to get up-to-date information on their electric service. We were among the first in our industry to offer a mobile website, and now we are rolling out a new responsive website that will provide even greater convenience to our customers on the go. We've been recognized multiple times by J.D. Power as a top performer among utilities for mobile optimized websites and apps (2013, 2014 and 2016).

With our mobile optimized website and smartphone apps, our customers can easily manage their electric accounts on the go. Customers can also report outages through text messaging and Facebook, and sign up to receive automated text alerts or e-mails to stay informed about restoration efforts and planned interruptions, or to get billing reminders or severe weather alerts. Our Ohio customers can also stay updated on social media channels including Facebook, Twitter, LinkedIn and YouTube.

[i] FirstEnergy received roughly $58 million in combined matching funds via investment recovery from 1) the Public Utility Commission of Ohio (PUCO)/Ohio ratepayers, the New Jersey Board of Public Utilities (NJBPU)/New Jersey ratepayers and 3) Pennsylvania Public Utility Commission (PAPUC)/Pennsylvania ratepayers.