GRIDWISE ALLIANCE

Improving Electric Grid Reliability and Resilience:

Lessons Learned from Superstorm Sandy and Other Extreme Events

Workshop Summary and Key Recommendations

The GridWise Alliance
June 2013

About the GridWise Alliance

The GridWise Alliance (GWA) represents the broad and diverse stakeholders that design, build and operate the electric grid, and consists of: electric utilities; information and communications technologies (ICT); and other service and equipment providers; Independent System Operators (ISOs) & Regional Transmission Organizations (RTOs); colleges and universities; and, energy consulting firms. Since 2003, the GridWise Alliance has been at the forefront of educating legislators and regulators on the critical need to modernize our nation's electricity system.

Executive Summary

The evidence is clear that, in recent years, extreme weather events have severely affected our economy more than ever before. Disruptions to our power system from natural events pose more than an inconvenience in today's technology-driven culture; the United States depends on a reliable, resilient, safe, and secure electric power system to ensure vital necessities such as moving cargo and passengers on transportation systems, operating cellular networks and data centers, running fuel pumps, providing business and consumer access to banking systems, and maintaining home climate control and refrigeration.

Images from Superstorm Sandy of people standing in long fuel lines are stark reminders of our society's dependence on reliable grid operation.

Very large scale events (VLSEs) affect not only the electrical infrastructure in communities, but also many other infrastructure sectors, which are all interdependent with the electrical system (e.g., communications, financial, and health care) and often span several states and/or regions. Thus, individual electric utilities cannot adequately plan for a very large scale event (VLSE) and the necessary related infrastructure restoration efforts. Planning for, and responding to, an event of this magnitude requires coordination and collaboration at the federal, regional, state, and local levels to address the breadth and inter-related nature of these potential impacts. Policies and regulations that facilitate collective action are also vital.

Moreover, grid modernization ("smart grid") technologies alone cannot adequately improve and sustain the reliability, resilience, safety, and security of the electric system during a VLSE. Rather, solutions must integrate people, technologies, and processes to maximize the effectiveness of the preparation for such response efforts.

The GridWise Alliance (GWA) recognizes that the ability to prevent or reduce the severity of such power outages and to expedite restoration when outages do occur is a "call to action" for its members, the broader utility industry, and local, state, and national leaders. Each day that a power outage is reduced translates to substantial benefits across our economy. Yet, there are no "silver bullets" to addressing grid resilience. A multi-pronged approach is needed.

In January 2013, GWA conducted a workshop entitled "Grid Modernization Impacts During Superstorm Sandy and Other Very Large Scale Grid Events" (referred to as "Workshop") to explore electric system-related challenges experienced during recent significant events and potential opportunities to help alleviate their effects.

This Workshop was unique in that it brought together utility and vendor representatives—more than 60 experts in total—to discuss ways in which grid modernization capabilities (i.e., technologies, processes, and people) affect four key functions during these VLSEs: (1) preventing power outages; (2) safely and quickly restoring power to affected customers; (3) communicating with stakeholders before, during, and after the event; and (4) serving or restoring critical loads to avoid or alleviate the most serious impacts on society from the loss of electricity.

Summary of Recommendations

Workshop participants clearly articulated the value of modernizing our grid to improve reliability and resilience. Grid modernization technologies—when properly integrated with skilled workers and processes—can significantly reduce the impacts of VLSEs and reduce the costs to society from these types of events. The following outline presents lessons learned from the Workshop discussion followed by GWA's key recommendations of actions to address the needs identified during the Workshop. These lessons and recommendations—intended for electric utilities; other infrastructure providers; state commissions and other policy makers; and federal decision makers, including Congress and agencies such as the U.S. Department of Energy, the Federal Energy Regulatory Commission, the Federal Emergency Management Agency, the National Institute of Standards and Technology, and the Federal Communications Commission—are fully expanded upon in the body of this report entitled *Improving Grid Reliability and Resilience: Lessons Learned from Superstorm Sandy and Other Extreme Events* (referred to as "Report").

> *A combination of grid modernization technologies along with traditional "hardening" of infrastructure are required to optimize resilience of the twenty-first century grid and improve power restoration efforts during VLSEs.*

1. **Grid Modernization Technologies Can Prevent Outages and Decrease Projected Impacts**
    - 1.1. Leverage Grid Modernization Technologies to Facilitate Grid Reliability and Resilience
    - 1.2. Integrate Grid Modernization Technologies with "Hardening" of Critical Physical and Cyber Infrastructure to Increase Grid Resilience
    - 1.3. Develop Grid Modernization Technology Roadmaps to Enhance Electric System Reliability, Resilience, Safety, and Security
    - 1.4. Identify Policy and Regulatory Models and Develop Measures to Build a Twenty-First Century Grid
    - 1.5. Consider the Societal Benefits in Cost-Benefit Analyses of Grid Modernization Investments
2. **Enhanced Emergency Response Planning Processes Can Result in Better Deployment Coordination of Human and Other Resources**
    - 2.1. Develop Enhanced Damage Prediction Models Based on New Weather Modeling to Improve and Refine Emergency Response Plans
    - 2.2. Develop Interoperability Guidelines for People, Processes, and Technology to Ensure Effective Integration and Management of Mutual Assistance Resources

2.3. Develop and Conduct Joint Exercises of Emergency Response Plans to Improve Coordination Among Infrastructure Sectors and Government

2.4. Institutionalize Streamlined Emergency Response Procedures Employed During the Response to Superstorm Sandy

3. **Information and Communications Technologies (ICT) Infrastructures Should Be More Resilient, Reliable, and Secure**

   3.1. Plan and Test Primary and Backup Systems That Monitor and Control Key Points on the Grid to Increase ICT Resilience for Restoration Operations During VLSEs

   3.2. Grant Electric Utility Resources "First Responder" Status and Establish Electric System Communications Capabilities as Priorities to Ensure Reliable Access to Field Resources

4. **Systems, Capabilities, and Processes Can Be Leveraged to Improve Communications and Speed Restoration of Power**

   4.1. Integrate New Field Intelligence Processes, Tools, and Data to Rapidly and Accurately Pinpoint Outages and Assess the Condition of Physical Assets

   4.2. Fully Leverage Advanced Metering Infrastructure Capabilities to Facilitate Power Restoration and Improve Communications

   4.3. Deploy and Utilize Existing Remote Sensing and Control Capabilities to Proactively Address Outage-Causing Issues

   4.4. Link Information from Grid Automation Technologies into Business Processes and Operator Training to Facilitate Appropriate Responses to VLSEs

   4.5. Leverage Traditional and Grid Modernization Communications Channels and Capabilities to Increase the Accuracy and Timeliness of Estimated Times of Restoration

5. **Distributed Generation Technologies, Such as Microgrids and Mobile Generators, Can Enhance the Resilience of Electric Infrastructure Serving Critical Loads**

   5.1. Define and Update Existing and Emerging Critical Load Requirements to Develop Pre-Event Plans for Replacement Power to Critical Loads

   5.2. Enhance Monitoring and Control Capabilities to Effectively Dispatch Distributed Energy Resources (DERs), Generating Electricity as Needed

   5.3. Identify Policy and Regulatory Issues That Inhibit the Integration and Management of DERs During Emergencies

   5.4. Establish Emergency Operational Agreements with Critical Customers to Facilitate the Use of DERs

   5.5. Identify and Explore Potential Solutions to Regulatory, Policy and Operational Barriers Associated with Multi-Customer Microgrids

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Introduction

In recent years, multiple regions of our nation have endured severe and costly effects of extreme weather events. Superstorm Sandy, the July 2012 derecho storm that hit the Middle Atlantic region, Western wildfires in 2012, and other similar recent extreme weather and related events, all have significantly disrupted electric grid service to consumers and industry for days or weeks at a time. We will never forget Katrina for the devastation it brought to New Orleans in 2005.

2011-2012 Extreme Events and Reported Customers Affected by Power Outages

Event	Date	Region, Division, or State	Customers Affected*
Superstorm Sandy	October 2012	Northeast	8,100,000
Derecho	July 2012	Middle Atlantic	4,200,000
Early season snow	October 2011	New England	3,000,000
Tropical Storm Irene	August 2011	Middle Atlantic	3,200,000
Wildfires	July 2012	California, Colorado	2,000,000
Windstorm	November 2011	Southern California	400,000

When the Middle Atlantic region experienced three significant events in a 15-month period, culminating in Superstorm Sandy, utilities faced major challenges that could have been minimized had they leveraged and/or invested in an array of robust grid modernization technologies and fully integrated those technologies with emergency response plans.

These events highlight the increasing dependence of our entire economy on electricity and the potential impacts of its disruption on Information and Communications Technology (ICT), banking, water/wastewater, medical care, and transportation systems, including air, rail, and transportation infrastructure.

Because our critical infrastructure systems are increasingly interdependent, there is the risk of a "cascading effect" during a very large scale event (VLSE). That is, if the electricity goes out, so too can other critical systems (depending on the severity and duration of a power outage). As an example, fuel stations and pumps are powered by electricity. Without power for the fuel pumps, no additional fuel can be obtained. Without fuel, backup generators cannot be used to provide power to homes and businesses, to charge cell phones and computers, and to ensure essential services, such as medical care. Furthermore, if cars do not have enough fuel to transport people to safe locations, people could suffer in affected areas for days, as evidenced during Superstorm Sandy.

While electric utilities are investing in grid modernization ("smart grid") technologies, they are at different stages of implementation and have differing needs and priorities. Regulators must approve investments before utilities can adjust their rates to recover their investment costs. Approvals are often based on least-cost philosophies, which can result in the

* Adopted from the Energy Information Administration.

installation of technologies optimized for day-to-day operations but not for functionality during a VLSE. In addition, utilities that bear the costs of investing in grid modernization technologies generally would not experience all of the benefits or consequences of such capabilities during a VLSE.

For example, some utilities have installed advanced meter infrastructure (AMI) systems to read electricity usage, and perhaps to detect small-to-mid-level "power outage" events (e.g., storms). In the northeastern states, most of the utilities with AMI had planned, designed, and installed their AMI systems with these objectives in mind. In many cases, these utilities had limited recent experience with VLSEs and therefore had not invested in the human, financial, or technological resources needed to utilize the AMI capabilities effectively during such larger scale events.

Images from Superstorm Sandy of people searching for places to charge their cell phones and computers, and waiting in long fuel lines are stark reminders of our society's dependence on reliable grid operation.

To explore these challenges experienced and potential opportunities to help alleviate the effects, the GridWise Alliance (GWA) conducted a workshop in January 2013 entitled "Grid Modernization Impacts During Superstorm Sandy and Other Large Scale Grid Events" (referred to as "Workshop"). This Workshop was unique in that it brought together utility and vendor experts—more than 60 people in total—including those from approximately 20 utilities, representing more than 40 percent of the nation's electric customers.

Workshop Discussion: Grid Modernization Impacts During Superstorm Sandy and Other Large Scale Grid Events

Workshop participants discussed ways in which grid modernization capabilities (i.e., technologies, processes, and people) affect four key functions during these types of major events: 1) preventing power outages; 2) safely and quickly restoring power to customers; 3) communicating with stakeholders before, during, and after the event; and 4) serving or restoring critical loads to avoid or alleviate the most serious impacts on society from the loss of electricity.

As the effects of extreme weather events on society are better understood and the risks of cyber events increase, utilities, public utility commissions, and other key decision makers must consider high risk/low probability scenarios. Workshop participants underscored the growing importance of adopting a more holistic philosophy and approach, which consists of implementing grid modernization technologies and integrating such technologies with updated processes and an appropriately-trained workforce—not only for day-to-day operations but also for VLSEs.

The Workshop provided an opportunity to share lessons learned, best practices, and identify potential solutions in these key areas. The insights and recommendations that emerged from the Workshop have been organized into five categories:

1. Grid modernization technologies can prevent outages and decrease projected impacts.
2. Enhanced emergency response planning processes can result in better deployment coordination of human and other resources.
3. ICT infrastructures should be more resilient, reliable, and secure.
4. Systems, capabilities, and processes can be leveraged to improve communications and speed restoration of power.
5. Distributed generation technologies, such as microgrids and mobile generators, can enhance the resilience of electric service to critical loads.

GWA examined these lessons, and devised a set of strategic recommendations, presented in this report entitled *Improving Grid Reliability and Resilience: Lessons Learned from Superstorm Sandy and Other Extreme Events* (referred to as "Report"), to address the needs and goals highlighted during the Workshop.

GWA recognizes that the ability to prevent or reduce the severity of such power outages, as well as expediting restoration when outages occur, is a "call to action" for its members, the electricity industry as a whole, and for local, state, and national leaders. As one of our experts noted, there are no "silver bullets" to address grid resilience; rather it will take a multi-pronged approach and a clear understanding of the potential ramifications of implementing various technologies and measures.


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Lessons Learned and Key Recommendations

1. Grid Modernization Technologies Can Prevent Outages and Decrease Projected Impacts

Workshop participants clearly articulated the value of modernizing our grid to improve resilience and reliability both for day-to-day operations as well as during VLSEs. These measures should be undertaken prior to and during such events to restore service faster than typically has occurred to date. Deploying grid modernization technologies more broadly also would help prevent outages and serve critical customers more effectively during VLSEs. Yet, technologies alone will not solve all of our problems, as described throughout this Report.

1.1 Leverage Grid Modernization Technologies to Facilitate Grid Reliability, Resilience, Safety, and Security

Improved situational awareness and control of grid equipment significantly enhance a utility's ability to reduce the impacts of VLSEs and speed up restoration efforts. The ability to know the status of service to individual customers not only increases a utility's overall situational awareness, but also provides the utility with the ability to personalize messaging to individual customers to assist them in making informed decisions throughout the VLSE. Electric utilities that have not effectively integrated or invested in grid modernization systems are not as cognizant of grid conditions and have a greater risk of communicating inaccurate information to the public during a VLSE.

Recommendation: State and federal policy makers and electric utilities must accelerate the integration of existing grid modernization technologies and investments in new systems to enhance grid resilience, reliability, safety, and security. Such technologies include:

- Energy management systems (EMS)
- Distribution management systems (DMS)
- Supervisory control and data acquisition (SCADA) systems for transmission and distribution
- Advanced meter infrastructure (AMI)
- Line sensors and smart relays
- Outage management systems (OMS)
- Enhanced automated mobile work management systems (WMS)

Investments in grid modernization technologies prior to a VLSE proved to greatly enhance utilities' situational awareness, which resulted in more accurate and timely information and improved their responses.

Appendix C provides a brief description of these technologies.

As key decision makers evaluate the types of improvements would increase the resilience of the grid during VLSEs, the following objectives should be considered:

- ✓ Enhance modeling and analytics to better forecast impacts and facilitate responses to conditions on the grid
- ✓ Increase situational awareness to improve decision making and communications

- ✓ Expand grid automation to remotely and automatically sense and respond to field conditions
- ✓ Enhance data collection from non-utility systems to provide more accurate and targeted communications with all stakeholders
- ✓ Ensure information is shared in a manner that is timely and "actionable"
- ✓ Increase data integration across the utility's systems as well as with external entities to enhance situational awareness and improve coordination and communication
- ✓ Integrate people, processes, and technologies to drive optimal benefits
- ✓ Build appropriate redundancy into communications network infrastructure to improve communications with key monitoring and control equipment and among first responders
- ✓ Increase the use of distributed energy resources to serve critical loads during VLSEs

1.2 Integrate Grid Modernization Technologies with "Hardening" of Critical Physical and Cyber Infrastructure to Increase Grid Resilience

Grid modernization technologies alone are not sufficient to increase the grid's ability to withstand VLSEs. Nor is simply replacing lines and poles with identical infrastructure adequate to plan and prepare for the magnitude of the natural, cyber, and other potential threats the grid faces. "Hardening" investments need to be made, which could include undergrounding of circuits, upgrading poles and towers to withstand hurricane force winds, and providing flood protection for substations. Nevertheless, upgrades to physical infrastructure alone will no longer meet our needs.

A combination of grid modernization technologies along with traditional "hardening" of infrastructure are required to optimize resilience of the twenty-first century grid and improve power restoration efforts during VLSEs.

Preventing outages in systems and substations during VLSEs in which flooding occurs is particularly challenging. While investments in hardening of substations have proven worthwhile during some VLSEs and placing utility lines underground may eliminate the susceptibility to wind and lightning damage that is typically experienced with overhead lines, underground systems are more costly to construct and can take more time to repair than overhead systems.

Thus, a combination of cost-effective grid modernization technologies along with "hardening" of critical physical and cyber components of the electrical, telephone, and cable television (TV) infrastructure is needed to ensure these systems remain operational during a VLSE, while not introducing new failure modes. For example, supplementing hardening of infrastructure with modern remote monitoring capabilities enables a utility to make decisions to protect critical assets when needed with preemptive switching and isolation.

Recommendation: Electric utilities must integrate grid modernization technologies and "harden" critical physical and cyber infrastructure to prevent and decrease the projected impacts of VLSEs (e.g., number of affected customers and duration of outages).

1.3 Develop Grid Modernization Technology Roadmaps to Enhance Electric System Reliability, Resilience, Safety, and Security

Grid modernization technology roadmaps could unite diverse stakeholders by defining a common vision of what a twenty-first century grid should look like—including sufficient grid resilience for anticipated VLSEs—and outlining a strategy to achieve that vision. Roadmaps can also be used to build the business case for investments by helping utilities describe the benefits of grid modernization programs.

Recommendation: States should require the development of statewide or utility-based grid modernization technology roadmaps to optimize deployment efforts among utilities and government stakeholders. These roadmaps should consist of near-, medium-, and long-term strategic steps to help modernize the grid and incorporate regional and cross-sector planning efforts, when possible. These roadmaps should be regularly updated and should define the metrics to be used to hold relevant parties accountable for meeting established goals and objectives.

1.4 Identify Policy and Regulatory Models and Develop Measures to Build a Twenty-First Century Grid

Appropriate changes in policy and regulatory environments are needed to facilitate vital investments and upgrades in grid modernization technologies that enable more rapid emergency responses and ongoing grid reliability, resilience, safety, and security. These investments would improve grid performance in day-to-day operations and would help avoid the worst potential impacts from more extreme weather events, such as Superstorm Sandy, and cyber threats.

Recommendation: Local, state, and federal government agencies should develop and implement policy measures and remove existing regulatory barriers to build a twenty-first century grid, ensuring the grid is robust and can withstand VLSEs.

1.5 Consider the Societal Benefits in Cost-Benefit Analyses of Grid Modernization Investments

Utilities are making investments to provide affordable, reliable and safe power. Individual investment decisions are evaluated based on benefits exceeding the costs. Where options are present, the least cost option is considered the most prudent by regulators. Utilities typically do not consider the societal costs of a VLSE, when evaluating measures to reduce outage frequencies or durations. This situation needs to be re-evaluated by state policy makers. Business case analyses must consider the potential for properly integrated grid modernization technologies, supported by skilled workers and appropriate processes, to enhance grid reliability, resilience, safety, and security during VLSEs, cyber, and other potential events, and the value and avoided costs to society these technologies can bring.

Recommendation: State policy makers and electric utilities must consider the societal benefits in cost-benefit analyses of grid modernization investments. Such analyses must include consideration of the potential impacts of a VLSE, as well as the ways in which such impacts could translate into potential costs to society (e.g., impacts to the digital economy; lost work days; loss of manufacturing output; loss of tourism; food spoilage due to lack of refrigeration; interruptions to transportation systems, including air, rail, and other ground transportation; and related "cascading effects").

2. Enhanced Emergency Response Planning Processes Can Result in Better Deployment Coordination of Human and Other Resources

Electric utilities, in conjunction with the appropriate federal and state agencies, should develop predictive restoration plans at a regional level based on enhanced weather and damage forecasting and advances in situational awareness, and should use real-time validations to continually refine and update such plans. In addition, input from social media and other emerging grid modernization capabilities can help improve preparation for and response to VLSEs.

2.1 Develop Enhanced Damage Prediction Models Based on New Weather Modeling Capabilities to Improve and Refine Emergency Response Plans

Improved systems modeling capabilities would help utilities and other emergency response organizations better predict potential storm damage and enhance utilities' initial power restoration plans in the following ways:


By PECO Energy

- By reducing damage to the system—New modeling capabilities can help better predict facility susceptibility to high winds or other highly localized weather conditions. Such innovations have enabled utilities to reduce outages during such events by identifying facilities that should be de-energized during an event to reduce damage.
- By improving response planning, increase personnel safety, and reduce costs—Weather forecast and damage prediction models can improve emergency preparedness and response efforts. Advances have reduced errors in pre-staging resources and equipment, allowing resources to remain safe during a storm while being positioned to move into the affected area once the storm has passed. These capabilities help avoid unnecessarily or preemptively requesting assistance from utilities outside a region, which reduces restoration costs.
- By better informing the general public and officials of projected VLSE impacts—Improved weather forecasting integrated with better situational awareness can inform a "storm infrastructure impact index." Although it does not exist, such an index could be used to inform officials and the public of anticipated VLSE damage and recovery times.
- By prioritizing future resilience investments—In "blue sky" times (i.e., normal operations), new predictive models could be used to conduct sensitivity analyses of potential resilience improvements, enabling utilities to prioritize future investments.

Recommendation: Electric utilities should integrate improved weather modeling capabilities, including hurricane, wind, storm surge, and flood modeling, with enhanced damage prediction models. In conjunction with the appropriate federal and state agencies, electric utilities should integrate model outputs into regional predictive restoration plans to increase safety, accelerate power restoration, and reduce costs.

2.2 Develop Interoperability Guidelines for People, Processes, and Technology to Ensure Effective Integration and Management of Mutual Assistance Resources

Mutual assistance resources are vital to an electric utility's ability to respond to a VLSE. These resources include crews and equipment from other utilities and contractors that are brought in to assist with restoration efforts. Effective "pre-event" planning must incorporate coordinated and consistent communications and interoperable supporting technologies to minimize duplication of efforts and confusion. Key technologies include laptops, tablet computers, and/or smart phones that include field force automation from work management systems (WMS) and geographic information systems (GIS). Although most utilities have already deployed these technologies to assist in their day-to-day operations without new interoperability standards and guidelines they will not be able to leverage them during VLSE restoration efforts. Typically, a utility's systems and technologies are not integrated with those of other utilities and, therefore, are incapable of communicating with one another. This will need to change to fully leverage such mutual assistance resources during VLSE restoration efforts.

Utilities also need practices for effectively coordinating mutual assistance resources. Improved collaboration that enables interoperable dispatch and work order systems that incorporate travel conditions (e.g., road closures, low bridges, and traffic) would optimize the system repair process, thereby reducing the time and cost to restore power. New internal policies that specify standard operating procedures during a VLSE will advance the adoption and deployment of grid modernization technologies. In addition, these procedures can guide coordination of communications efforts within the utility and between the utility and mutual assistance resources.

Workshop participants stated that enhanced procedures and emergency drills to integrate and leverage available grid modernization technologies specifically during VLSEs would provide significant benefits.

Guidelines to improve coordination and interoperability of internal and external messaging processes and technologies will ensure timely, consistent information-sharing with all stakeholders. Guidelines can include ways to integrate grid modernization systems and non-utility communications technologies. For example, utilities may use social media to collect photos of damaged equipment from the public and/or emergency responders, and GIS to identify the equipment's location. Nevertheless, a utility must integrate the appropriate systems to be able to incorporate this information into their WMS. Developing physical telephone and cable TV infrastructure network redundancies in advance of a VLSE will also improve preparedness and reduce the impacts of a VLSE.

Improved utility internal and external messaging processes and integration of data sources into their systems to coordinate resources is an important step. New standards could facilitate the interoperability and alignment of deployed technologies and better coordination of all restoration resources during a VLSE.

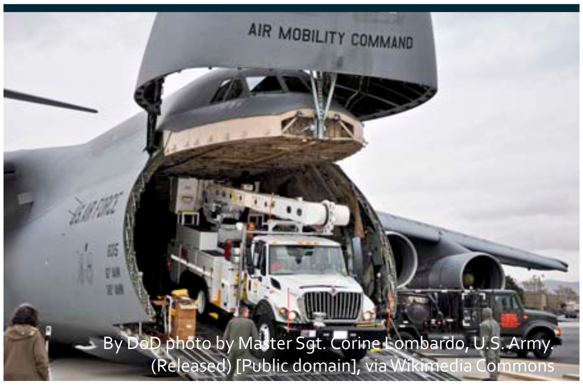
Recommendation: Utilities should include guidelines for responding to VLSEs in their strategic plans. In particular, guidelines should provide the types of coordination and communications mechanisms and interoperable technologies that will ensure necessary resources are available, ready to be deployed, and better positioned to restore power as quickly as possible during a VLSE. Utilities should leverage and expand grid modernization capabilities to improve emergency management coordination and collaboration at the federal, regional, state, and local levels.

Recommendation: The National Institute of Standards and Technology (NIST) should facilitate the development of new interoperability standards for key utility systems. Within the context of the existing NIST Framework, working through the Smart Grid Interoperability Panel (SGIP), a set of new interoperability standards should be developed to better integrate and manage mutual assistance resources during VLSEs. Key needs include work management and mobile data terminal applications and data feeds from external sources (e.g., surveillance videos, Global Positioning System (GPS) tagged photos or videos, and other infrastructure-provider data feeds).

2.3 Develop and Conduct Joint Exercises of Emergency Response Plans to Improve Coordination Among Infrastructure Sectors and Government

VLSEs often affect multiple interdependent infrastructures (e.g., ICT and water) and several states and/or regions. Thus, planning for an event of this magnitude must involve coordination and collaboration at the federal, regional, state, and local levels, and between the public and private sectors, to address the breadth and inter-related nature of these potential impacts. Such efforts also must integrate people, technologies, and processes to maximize preparedness.

Local, state, and federal government entities, critical infrastructure providers, and electric and other utilities must collaborate to effectively integrate and leverage available grid modernization technologies. Improved regional collaboration, to the extent feasible, will enhance emergency plans and procedures for responding to VLSEs.



By DoD photo by Master Sgt. Corine Lombardo, U.S. Army. (Released) [Public domain], via Wikimedia Commons

Recommendation: The U.S. Department of Energy (DOE), in conjunction with other agencies, should develop plans that leverage available technology capabilities across multiple infrastructure provider and first responder groups. At a minimum, stakeholders should include emergency responders, including police and fire departments and emergency medical technicians, as well as telephone and cable TV providers), and electric utilities.

Recommendation: State and federal emergency management offices should conduct annual joint simulations, drills, and related "pre-event" scenario planning efforts at the local, state, and regional levels to test their plans and strengthen their ability to collectively respond to VLSEs.

2.4 Institutionalize Streamlined Emergency Response Procedures Employed During the Response to Superstorm Sandy

During Superstorm Sandy, the federal government provided significant support to the restoration efforts and temporarily streamlined or lifted bureaucratic barriers that could have hampered restoration efforts and extended Sandy's impacts (e.g., utility vehicles and other critical equipment and fuel were transported to New York and New Jersey to help address some of the most immediate, critical needs in those areas).

Recommendation: The federal government (e.g., the Federal Emergency Management Agency, the Federal Communications Commission (FCC), DOE, and other agencies that could be involved in emergency response efforts) should ensure that these types of streamlined emergency procedures (that were implemented during Superstorm Sandy) become standard practice during future VLSEs, to the extent necessary and practicable, to help facilitate emergency response processes and procedures.

3. ICT Infrastructures Should Be More Resilient, Reliable, and Secure

Information and communication technology infrastructures, which are key components of grid modernization capabilities, are critical to communications with field resources during VLSE restoration efforts. Workshop participants noted a need to increase resilience and redundancy in these support infrastructures as well as the need for enhanced or new processes to fully leverage the capabilities these infrastructures can provide. For example, during Hurricane Katrina restoration, texting proved much more effective than voice calls due to lower bandwidth requirements and the "store and forward" capability, which enabled text messages to get through busy cellular networks. Primary and backup communication paths to key control and monitoring points on the grid could be provided in multiple forms (e.g., private and public networks paired together or public cellular networks paired with satellite networks).

3.1 Plan and Test Primary and Backup Systems That Monitor and Control Key Points on the Grid to Increase ICT Resilience for Restoration Operations During VLSEs

The ICT infrastructure that overlays the grid is composed of multiple interconnected systems that often are owned and operated by multiple parties, including the electric utilities themselves. Understanding the potential failure modes and risk of these interconnected systems and their relationship to key monitoring and control points on the grid are essential to ensuring operation during VLSEs. Introducing redundancies into these systems adds another layer of complexity. Having a clear definition/map of these related system dependencies and testing the "fail over" (i.e., the process of switching from normal to backup) capabilities are critical, particularly when there are multiple owners and operators of the components.

Workshop participants suggested that granting "first responder" status to electric utility personnel would markedly improve communications and coordination efforts during VLSE responses.

Recommendation: Electric utilities, in conjunction with service providers, must collaborate to plan and test primary and backup communications capabilities to key control and monitoring points on the grid.

3.2 Grant Electric Utility Resources "First Responder" Status and Establish Electric System Communications Capabilities as Priorities to Ensure Reliable Access to Field Resources

During VLSEs, the public communications networks become congested. For systems and restoration resources that need to have fast and reliable access to these systems, having "first responder" status and priority access are critical to speed restoration and ensure safe operations. Granting utility personnel and key monitoring and control systems priority status will speed restoration and enhance safety during VLSEs.

Recommendation: Federal agencies responsible for emergency preparedness and response planning processes should provide the necessary authorities to help expedite power restorations. These considerations include the following:

- The appropriate federal agencies should grant electric utility personnel "first responder" status.
- FCC should provide prioritized access for electric utilities to use public networks, wired and wireless, for personnel communications and the monitoring and control of electrical grid systems and components during VLSEs.
- FCC should allocate and protect communications spectrum for utility and first responders' use.

4. Systems, Capabilities, and Processes Can Be Leveraged to Improve Communications and Speed Restoration of Power

As utilities integrate digital technologies into their system operations they receive more information. Such technologies and associated processes enable utilities to provide the public and other stakeholders with more accurate and consistent information during VLSEs, including more accurate estimated times of restoration (ETRs), when power outages do occur. Further, such capabilities enhance public safety, security, and preparedness, by enabling people to remain in safe locations until they have been informed that their power has been restored, and by providing the public with greater confidence that they will receive such information as rapidly and accurately as possible.

Such capabilities also can be leveraged to help utilities more accurately and rapidly assess the condition of physical assets, and pinpoint power outages, when they do occur. For example, tying images received from social media feeds or other means (e.g., via emergency responder or security surveillance cameras) to a physical asset or piece of equipment, so that the image can be used to identify steps to resolve actual or potential problems, and help estimate the restoration time, requires utilities to ensure they have appropriate grid modernization technologies in place, personnel trained to properly use these technologies, and that they plan for and execute appropriate systems integration.

These grid modernization and related communications capabilities would enable a utility to determine whether there is a need to immediately dispatch crews where an unsafe or emergency condition exists; use this information in prioritizing its restoration efforts; and ascertain if a response is not needed (e.g., when a wire is not an electric utility wire) which would thereby free up resources for other vital restoration activities. That same information could help optimize restoration efforts by helping to assess the damage to a given asset or piece of infrastructure and helping to ensure that crews, vehicles, equipment and supplies are dispatched as needed.

To date, none of the electric utilities that participated in the Workshop have incorporated social media or video surveillance feeds of field condition data into their systems. Many noted a need for a significant increase in the accuracy of their asset data to ensure electric system models reflect the actual configuration and equipment during a VLSE. At the same time, operators must prepare to use automated data feeds to ensure they appropriately respond to very dynamic grid conditions. Furthermore, a utility could leverage these new sources of field intelligence to help stakeholders understand efforts to restore service in a consistent and timely manner.

4.1 Integrate Field Intelligence Processes, Tools, and Data to Rapidly and Accurately Pinpoint Outages and Assess the Condition of Physical Assets

Electric utilities must examine ways to leverage information gained from non-utility systems to improve their situational awareness, assess any damage to electrical infrastructure, and dispatch the appropriate resources (i.e. crews, equipment, materials) to expedite power restoration efforts. Incorporating information from social media and/or emergency responders or telephone or cable TV providers, (e.g., smartphone video and GPS-tagged photo images submitted via social media) can help assess the condition and operating status of their physical assets.

Recommendation: Multiple service providers should integrate their systems to enable information sharing during VSLEs to assess the condition of each other's physical assets, to rapidly and accurately pinpoint outages and damaged physical assets. To enable such data sharing, the following opportunities deserve further exploration:

- Establish open protocols and enhanced coordination and technologies to enable police or other entities to share video surveillance (i.e., fixed or aerial) with utilities to assist in rapidly and accurately pinpointing causes of power outages.
- Establish open protocols to enable cable TV and telephone companies to share information on power outages identified through their systems with electric utilities.
- Develop methods to integrate power outage information from customer premise equipment (e.g., telephone, cable TV and demand response).
- Develop methods to share video or photo information regarding outage-related damage captured by restoration resources or the public on mobile devices.
- Integrate applications such as Google Earth with utility GIS to help pinpoint damage and facilitate power restoration.
- Develop methods, processes, and tools to effectively identify asset owners for downed wires (e.g., electric utility, telephone and cable TV providers) to reduce hazards to the public and speed restoration efforts while reducing the need for public officials, such as police or fire officials, to remain on site until a trained utility repair line worker arrives to determine whether it is a live electrical wire, a de-energized electrical wire, or non-electrical (e.g., telephone and cable TV) wire.

4.2 Fully Leverage AMI Capabilities to Facilitate Power Restoration and Improve Communications

Many utilities have installed AMI or "smart meters," but have not integrated those meters with more sophisticated outage restoration processes to maximize their value during VLSEs. Workshop stakeholders shared that, in situations where AMI had been deployed and effectively integrated to automatically feed the utility's OMS, operators were better able to identify the location of outages (which also was made easier when certain smaller outages were "nested" within larger outages) and verify when power was restored.

Workshop participants estimated that integrating AMI meters with restoration processes shaved 2–3 days off the time it would have taken to completely restore power; a 10–15 percent improvement in speed of restoration.

This information was useful in prioritizing work and dispatching crews, as well as in informing restoration crews of the need to remain in an area to finish restoration efforts—when they might otherwise assume repair work was completed while a second (or third or fourth) outage of a smaller scale than the first remained in a given area. Using these tools during storm events reduced multiple and repeat repair visits (i.e., truck rolls) to the same area allowing for better deployment of critical restoration resources and restoring service to customers more quickly. One utility reported that this saved more than 6,000 truck rolls during Superstorm Sandy. This resulted in savings of at least one million dollars in restoration costs and other substantial societal cost savings as referenced earlier in this Report.

While utilities were able to access some AMI communications infrastructure during storm restoration, this system became much less valuable when the AMI infrastructure failed due to limited battery backup of communication access points, repeaters, or data collection systems.

The AMI communications and data management infrastructure is primarily deployed to support energy usage collection and is not always designed with grid communications systems resilience in mind. Making this infrastructure more resilient is required to take full advantage of AMI systems in VLSE response.

Recommendation: Electric utilities that have invested in AMI should fully leverage the capabilities of these systems to increase situational awareness and improve communications with customers and other key stakeholders during VLSEs.

4.3 Deploy and Utilize Existing Remote Sensing and Control Capabilities to Proactively Address Outage-Causing Issues

One of the key benefits of investments made in grid modernization has been to increase utilities' situational awareness, thereby enabling them to minimize power outages during VLSEs and smaller events. For example, increased awareness through remote monitoring (i.e., one type of grid modernization technology) allows a utility to make decisions to protect critical assets when needed with preemptive switching and isolation.

One utility reported that their distribution automation capabilities significantly reduced the duration of outages during VLSEs. During Tropical Storm Irene, nearly one-half of its power interruptions, affecting more than 500,000 customers, were restored in less than one hour.

Utilities that have made these investments are now able to obtain sophisticated new information (e.g., images from NASA), which allows them to proactively target their outage-prevention efforts. For instance, emerging "vegetation management" issues (i.e., tree branches overhanging or in proximity to power lines) that cause momentary outages can now be identified and corrected to prevent sustained outages. In high-wind events, vegetation that comes in contact with overhead lines can trigger wildfires or lead to "downed" poles and wires, thereby disrupting power. Capabilities to obtain such sophisticated information are particularly important to help prevent widespread outages during these types of events.

Distribution SCADA systems enable utilities to assess damage sooner and more accurately, and minimize power outages during VLSEs and smaller events. In some experiences, analytics-based assessments reduced the time to restore power by hours if not days. Automatic updating of computer-based physical models would be helpful so less field verification would be needed as conditions change. Utilities that widely deployed SCADA were able to remotely de-energize critical equipment during flooding to prevent catastrophic damage that could require weeks to repair or replace. Grid modernization capabilities that were available to control room operators extended SCADA beyond the substations to include circuit sectionalizing, isolation, and automation or remote circuit reconfiguration. This reduced the number of customers affected and the duration of the outages.

However, some of these new grid modernization capabilities could not be fully utilized during recent major events, due to the extent of damage or not being completely integrated into business processes and lack of operator training. Several operations managers who participated in the Workshop noted the need for a significant increase in the accuracy of their GIS and asset data to ensure these accurately reflect the system configurations and equipment, so this information can be effectively integrated with their system. Many of the utilities that participated in the Workshop have not fully installed distribution SCADA and, therefore, have limited or no real-time visibility into what is happening on their distribution systems.

Recommendation: Electric utilities should use grid modernization technologies and capabilities such as SCADA, automated switching, and remote control of equipment to identify and proactively address outage-causing issues to prevent outages and reduce damage to equipment in VLSEs.

4.4 Link Information From Grid Automation Technologies into Business Processes and Operator Training to Facilitate Appropriate Response to VLSEs

While technology integration is important, Workshop participants underscored the importance of enhancing or changing business processes and properly training or re-training utility workforces and other first responders to use these technologies. A large amount of automated data feeds inundating a control room as a result of a VLSE is of little use if operators are ill-prepared to receive and appropriately respond to such a volume of incoming information. Systems with which the data feeds are integrated can be overwhelmed and result in inaccuracies. Automated technologies also are of little use if operators override the system and revert to manual processes because they are overwhelmed. Such situations occur because utilities, even if they have installed updated technologies, have not included responding to VLSEs in their planning, design, and implementation of such projects.

Recommendation: Electric utilities should better manage information by training their workforce personnel to leverage grid automation technologies and processes to enhance situational awareness, facilitate appropriate responses to evolving operating conditions, and reduce the impacts of power outages during major events. Utilities, communities, states, and regions must integrate technology with people and processes.

4.5 Leverage Traditional and Grid Modernization Communications Channels and Capabilities to Increase Accuracy and Timeliness of ETRs

Incoming and outgoing communications before, during, and after a VLSE are vital. This is increasingly true given the interconnected nature of utilities' critical infrastructure systems. Fortunately, technology is enabling enhanced communications capabilities. Multiple utilities conducted proactive public awareness/ communications campaigns focusing on restoration prioritization (e.g., critical infrastructure first, followed by broader restoration), ways in which to prepare for VLSEs, and steps to be taken in the event of power outages to keep the public safe and speed restoration.

During sustained power outages, people want to know if they need to seek alternate shelter or make other plans to ensure their safety and security, based on estimated times of restoration. Inaccurate information in such instances can be costly and frustrating to customers.

Electric utilities provide information to customers based on the current situation in the field, which is very dynamic during VLSEs. Thus, consistent messaging across all communication channels remains challenging at best. At the same time, a wide array of stakeholders needs information from their utility to help them understand power restoration progress. Timely and accurate ETRs will help these stakeholders navigate and respond to a VLSE.

In the past, electric utilities almost exclusively communicated with the public through mass media, such as TV and radio. They are increasingly able to tailor status updates to target audiences through individualized channels during a major outage event. For example, multiple communication channels are available for utilities to share restoration notifications with a customer's personal device (e.g., cell phones, Twitter, Facebook, email). Such notifications typically consist of recommended precautionary steps to take to plan for extended outages. Utility Internet sites and automated messages can provide updates regarding future and completed restorations. AMI has enabled utilities to "ping" meters and inform customers when their power has been restored, so that individuals in emergency shelters do not have to risk traveling to check their homes.

Customized "portals" that contain tailored information on a secure web page for emergency services personnel, community leaders, and first responders can provide more effective community responses to a VLSE. Portals that are automatically or manually refreshed at regular intervals can provide up to date information that can be used to facilitate restoration and disaster assistance efforts. For example, the American Red Cross can use this type of information to determine how long staff will need to operate an emergency shelter.

Recommendation: Electric utilities should create internal and external communication messaging protocols and processes, leveraging grid modernization technologies to reduce conflicting messages during a major power outage event. To enhance preparedness, these protocols and processes should be documented in a utility's storm response plan.

Recommendation: Electric utilities should leverage grid modernization technologies to effectively communicate with public officials, their customers and the media during VLSEs. Regular communications should provide consistent and timely updates on restoration efforts and ETRs. Secure portals should be deployed to provide public officials, community leaders and emergency responders with key information to assist in their responses to VSLEs.

5. Distributed Generation Technologies Such as Microgrids and Mobile Generators Can Enhance the Resilience of Electric Infrastructure Serving Critical Loads

Microgrids—distributed electric generation resources incorporating storage, load control, and energy management systems—are able to operate independently of the grid, though they normally are integrated with the grid. They are used primarily as backup power sources or to help manage peak load reductions. Microgrids are frequently mentioned as a key component to improved grid resilience and security.

Dual feeds—a common service offering by utilities for customers with critical loads—provide a customer with a normal source and a back-up source of power. Dual feeds may not eliminate outages if both feeds are disrupted or damaged, but dramatically reduce the likelihood of an outage, even during a VLSE. They also provide for alternative restoration strategies. For example, a critical customer served by two different circuits from different substations (which is a common occurrence for data centers), would give system operators greater flexibility in prioritizing crews for repairs. During a VLSE, damage to both electrical feeds could, of course, occur. The concept of dual feeds can be applied beyond electricity. Thus, it is important that other infrastructure feeds be made—and remain—resilient. For example, redundant communication feeds could help with monitoring and controls.

5.1 Define and Update Existing and Emerging Critical Load Requirements to Develop Pre-Event Plans for Replacement Power to Critical Loads

Hospitals, water systems, and emergency services facilities and associated shelters have always been high priorities for utilities in their power supply and restoration efforts. Yet new and different priorities also are emerging that can include fueling stations that supply vehicles and backup generators. Grocery stores, banks, and drug stores also critically need to maintain power, or have it restored, to help the affected area from safety, economic, and security perspectives. In our interconnected, networked world, Internet access is indispensable. Alternative power source options

during VLSEs are essential. Vital facilities such as cell towers and critical data centers need to have power restored before their backup generators run out of fuel, or further restoration and emergency services efforts will be compromised.

Recommendation: Electric utilities, infrastructure providers, and local communities need to work more closely together to define and update critical customer and infrastructure demands to minimize societal impacts.

5.2 Enhance Monitoring and Control Capabilities to Effectively Dispatch Distributed Energy Resources (DERs), Generating Electricity as Needed

Increased penetration levels of DERs will require electric utilities to employ new approaches to balancing load and generation while maintaining system safety and reliability. Advanced control and monitoring systems that can dynamically respond to electric system changes will enable safe and reliable restoration responses to major power outage events.

Remote monitoring and control capabilities can also help utilities to prioritize restoration efforts and target problem areas during a VLSE. A mobile generator could be quickly connected to provide replacement power to critical or isolated loads. With advanced planning, utility-owned emergency generators with quick connections at critical or isolated points on the grid have restored power in less than two hours.

Recommendation: Electric utilities should increase the use of mobile generators to provide temporary power during a VLSE. During emergency planning processes, and well in advance of VLSEs, utilities should establish locations where generators can be easily connected and integrated into the grid. Similarly, they should upgrade and enhance control and monitoring systems to increase situational awareness and support the safe and reliable dispatch of DERs during VLSEs.

5.3 Identify Policy and Regulatory Issues That Inhibit the Integration and Management of DERs During Emergencies

Princeton University, a good example of a successful microgrid, isolated itself from the grid during Superstorm Sandy and relied on its combined heat and power facility to supply electricity and heat. Key to the effectiveness of this solution was the ability to manage the supply and demand on the isolated microgrid, which a single customer like Princeton has the capability to accomplish.

As the effects of extreme weather events and other threats to the grid increase and resilience becomes more important, additional microgrids will need to be deployed. New critical loads must be served during VLSEs; for example, a multi-customer microgrid comprised of a grocery store, gas station, and bank. However, current regulations and capabilities do not provide for these types of installations during VLSEs.

Recommendation: State and federal policy makers should establish a framework to increase the use of DERs (e.g., microgrids, storage, solar and fuel cells) to enhance resilience and avoid power outages during major events.

5.4 Establish Emergency Operational Agreements with Critical Customers to Facilitate the Use of DERs

Customer owned generation can be used to serve additional load outside their needs. Many facilities with on-site generation capabilities, such as manufacturing, most likely will not maintain normal operations during a VLSE. These facilities could establish emergency contractual agreements with other facilities or perhaps with their local utility to use the facility's power supply to help maintain critical loads in exchange for compensation. This would require regular testing of these generators to ensure they are operational when needed.

In addition, individual customers, who may deem themselves as needing a greater degree of resilience, might invest in microgrids, dual feeds, or other DERs.

Recommendation: Utilities should establish collaborative arrangements with critical customers to leverage the customers' technologies and also to operate the resulting integrated DER systems as effectively as possible.

5.5 Identify and Explore Potential Solutions to Regulatory and Policy Barriers Associated with Multi-Customer Microgrids

Workshop attendees cited experiences with microgrids and dual feeds as helpful in serving critical loads, but more can be done. Participants discussed lessons learned and raised questions that should be considered for improvements to better serve critical loads during VLSEs. Some of the issues they identified included:

- Backup generators can run out of fuel; how will fuel supplies be obtained and ensured?
- Backup generators can be rendered inoperable due to flooding; are there ways in which to protect these assets from flooding?
- Renewable energy (e.g., rooftop solar) still requires an operational grid to supply local loads; how can the system supply these loads without grid power?
- Multi-customer microgrids have diverse operating requirements; who balances supply and demand on multi-customer microgrids?
- Some states prohibit third party sales of electricity; how will that affect the viability of multi-customer microgrids?
- Microgrids are becoming more prevalent; will utilities be allowed to own and/or manage microgrids?
- Regarding ways in which to integrate and tie multi-customer microgrids to the utility grid: what new rules, if any, are needed?

Recommendation: GWA should form a working group to identify and explore potential solutions to regulatory and policy barriers associated with multi-customer microgrids.

Conclusion

Today, many grid-related technologies exist to prevent and minimize the worst potential impacts of a major weather event, like Superstorm Sandy, or a cybersecurity threat to the electric grid. Much has been learned in the past few years alone about ways in which to use these grid modernization technologies to the greatest extent possible, both to prevent outages as well as to minimize outages when they do occur, and speed power restoration during outages.

Our digital economy is increasingly dependent on electric power. Preventing outages altogether or reducing the duration of outages by hours or days when they do occur, results in dramatic benefits to society.

Importantly, there have been significant developments in the technologies themselves that enables such advances. When properly incorporated into planning and response processes, and used by a workforce that has been trained to apply these tools, the capabilities of these technologies can be highly effective in VLSEs.

There are no "silver bullets" to address grid resilience; rather it will take a multi-pronged approach.

Utilities and leaders at the local, state, regional and federal levels must work collaboratively toward developing and implementing solutions which include, but are not limited to, the following solutions:

- Integrate and leverage grid modernization technologies to prevent outages and decrease projected impacts.
- Enhance emergency response planning processes to improve deployment coordination of human and other resources.
- Improve the resilience, reliability, and security of ICT infrastructures.
- Leverage systems, capabilities, and processes to improve communications and speed restoration of power.
- Increase the use of distributed generation technologies, such as microgrids and mobile generators, to enhance the resilience of electric infrastructure serving critical loads.

The GridWise Alliance looks forward to working with policy leaders and other key stakeholders to move our nation toward a twenty-first century electric grid that will meet the needs of our ever more power-dependent economy, especially during VLSEs.

Recent State Initiatives in Response to Superstorm Sandy:

Recent examples from New York and New Jersey reinforce the recommendations of GWA:

The New York State 2100 Commission, convened in November 2012 by Governor Cuomo, recommended several steps to improve the resilience of infrastructure serving New York State after experiencing several weather-related events culminating in Superstorm Sandy. These areas include transportation, land use, insurance, finance, and energy. In the area of energy, five recommendations are summarized below.

- Strengthen critical energy infrastructure—physical hardening of facilities
- Accelerate the modernization of the electrical system to improve flexibility
- Design rate structures and create incentives to encourage distributed generation and grid modernization investments
- Diversify fuel supply, reduce demand for energy, and create redundancies
- Develop long-term career training and a skilled energy workforce

An order by the New Jersey Board of Public Utilities (BPU) issued January 23, 2013 in the wake of several regional storm events, directs the electric distribution companies to improve 103 measures, in communications with stakeholders, physical hardening, extensive emergency response plans, and other areas similar to the scope of the GridWise Alliance's Workshop and this Report. The BPU has not completed its review of Superstorm Sandy, thus more findings are possible.

Sources: http://www.governor.ny.gov/assets/documents/NYS2100.pdf
http://www.nj.gov/bpu/newsroom/announcements/pdf/20130123.pdf
http://www.nj.gov/bpu/pdf/boardorders/2013/20130123/1-23-13-6B.pdf

Appendix A. Participating Companies

The GridWise Alliance wishes to thank IBM for hosting the Workshop that brought together more than 60 utility and vendor experts. We are especially grateful to those individuals and companies who participated in the Workshop and provided invaluable follow-up feedback to support the creation of this Report including:

Alstom

Arizona Public Service

CenterPoint Energy

Con Edison

DNV KEMA

Dominion

Duke Energy

Ernst & Young

Florida Power & Light

GE

IBM

ITC Holdings

Landis & Gyr

New West Technologies

NYS SmartGrid Consortium

Oncor

Orange & Rockland

Pepco Holdings, Inc.

Pacific Gas & Electric

PJM

Portland General Electric

PSEG

Quanta Technology

RockPort Capital

SAIC

Southern California Edison

Schneider Electric

Sempra Energy

Silver Spring Networks

SMUD

Tollgrade Communications

Vermont Electric Power Company

Verizon

Appendix B. List of Acronyms

AMI	advanced metering infrastructure
CIS	customer information system
DER	distributed energy resource
DMS	distribution management systems
DOE	U.S. Department of Energy
EMS	Energy management systems
ETR	estimated time of restoration
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
GIS	geographic information systems
GPS	Global Positioning System
GWA	GridWise Alliance
ICT	Information and Communications Technology
ISO	Independent System Operator
NIST	National Institute of Standards and Technology
OMS	outage management systems
PMU	phasor measurement unit
RTO	Regional Transmission Organization
SCADA	Supervisory control and data acquisition
SGIP	Smart Grid Interoperability Panel
TV	television
VLSE	very large scale event
WMS	work management systems

Appendix C. Glossary of Terms

Advanced meter infrastructure (AMI): Electricity meters that use two-way communications to collect electricity usage and related information from customers and to deliver information to customers. (SmartGrid.gov 2013)

Distribution management systems (DMS): A utility IT system capable of collecting, organizing, displaying and analyzing real-time distribution system information. A DMS can help plan and execute distribution system operations to increase system efficiency, optimize power flows, and prevent overloads. A DMS can interface with other applications such as GIS, OMS, and customer information systems (CIS) for a full view of distribution operations. (SmartGrid.gov 2013)

Energy management systems (EMS): A device in the customer's premises, including hardware and software, designed to control the operation of other energy devices according to customer preferences and objectives such as reducing energy costs, or maintaining comfort or convenience. Controlled devices could include, but are not limited to, thermostats, lighting, and smart appliances. Among other control inputs, an energy management device can accept energy pricing signals from a utility or third party energy services provider. (SmartGrid.gov 2013)

Work management system (WMS): The WMS generates and tracks work-related activities. The WMS is often integrated with (i) the AMI for managing work related to setting, replacing and retiring meters, (ii) the CIS for managing service or construction work, and (iii) the OMS for managing outage restoration. The enhanced automated mobile work management system locates crews and equipment and logs job completions. (MultiSpeak 2013)

Information and Communications Technology (ICT): ICT is often used as an extended synonym for information technology, but is a more specific term that stresses the role of unified and the integration of telephone and cable TV lines and wireless signals, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information. (FOLDOC 2013)

Line sensors and smart relays: Devices that monitor voltages, currents and frequencies in the electrical system and send control signals to circuit breakers or switches. Smart relays can store measurement data and process the data to provide utilities with information about system conditions. The settings of smart relays can be adjusted automatically or remotely in response to changing conditions and control instructions. Some smart relays include synchrophasor technology and can act as phasor measurement units (PMUs). (SmartGrid.gov 2013)

Outage management systems (OMS): A software application that can process outage reports from a variety of utility operational systems including SCADA, AMI, and customer phone calls, and display outage information to utility operators. The OMS can help a utility interpret outage information and determine where the likely cause of an outage may be. It can also help the utility optimize its service restoration resources. (SmartGrid.gov 2013)

Phasor measurement units (PMUs): Monitors that take observations at high speed (typically 30 observations per second—compared to one every 4 seconds using conventional technology). Each measurement is time-stamped according to a common time reference. Time stamping allows synchrophasors from different utilities to be time-aligned (or "synchronized") and combined together providing a precise and comprehensive view of the entire interconnection. (NASPI 2013)

Supervisory control and data acquisition (SCADA): A system of remote control and telemetry used to monitor and control transmission and distribution systems. (SmartGrid.gov 2013)

Synchrophasors: Precise grid measurements now available from monitors called PMUs. Synchrophasors enable a better indication of grid stress, and can be used to trigger corrective actions to maintain reliability. (NASPI 2013)

Appendix D. References

Free On-Line Dictionary of Computing (FOLDOC). 2013. "Information and Communication Technology." Imperial College Department of Computing. Accessed May 28. *http://foldoc.org/Information+and+Communication+Technology*

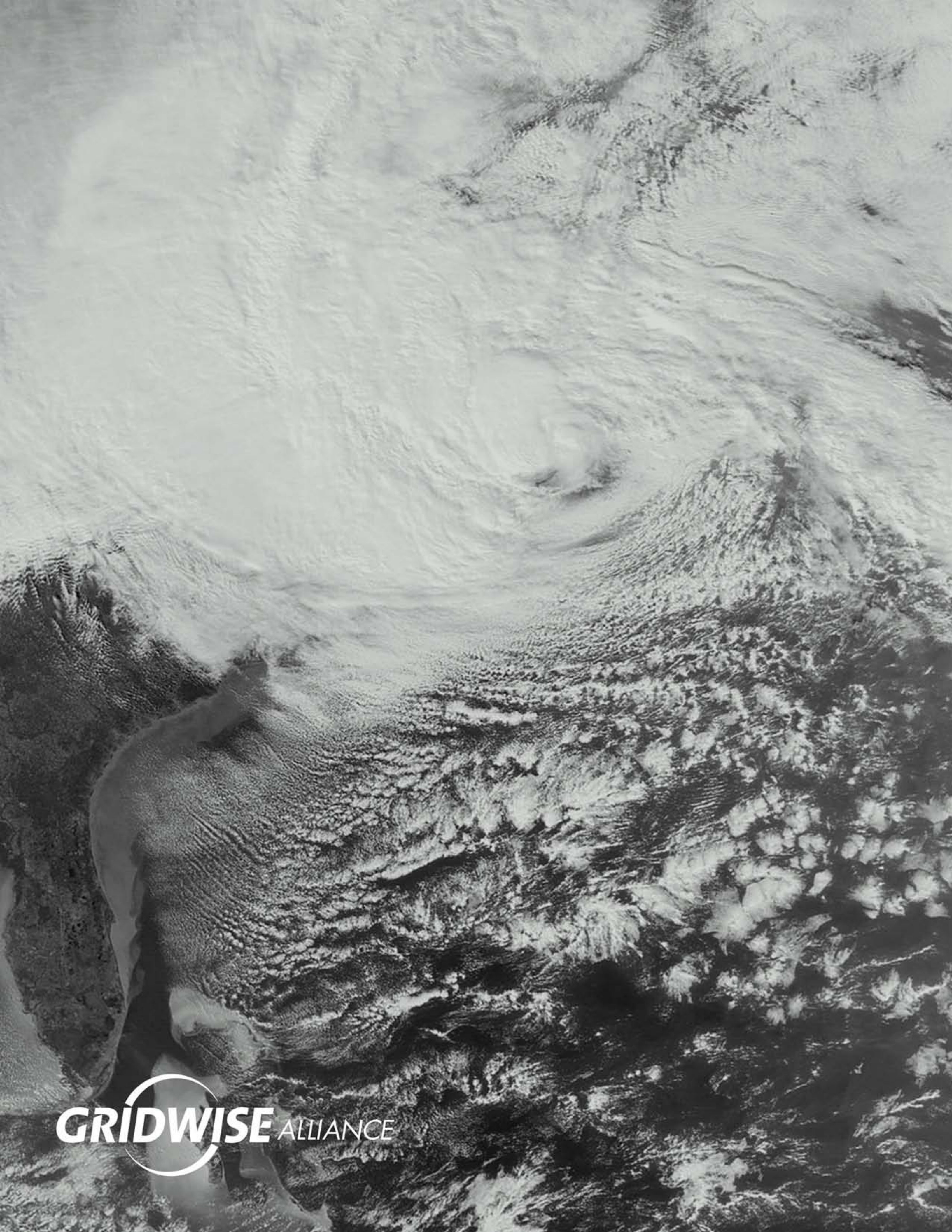
MultiSpeak. 2013. "MultiSpeak and the NIST Smart Grid." National Rural Electric Cooperative Association. Accessed May 28. *http://www.multispeak.org/about/SmartGrid/Pages/MultiSpeakandtheNISTSmartGrid.aspx*.

North American SynchroPhasor Initiative (NASPI). 2013. NASPI Homepage. Accessed May 24. *https://www.naspi.org/home*.

SmartGrid.gov. 2013. "Smart Grid Technology Glossary." U.S. Department of Energy. Accessed May 22. *http://www.smartgrid.gov/glossary/6/lettera*.

AIR M
U.S. AIR FORCE
6015
60TH AMW
349TH AMW


OBILITY COMMAND
FLAMMABLE
NO SMOKING
WITHIN 50 FT
CARGO FIRE AVOID WATER
JET FUEL JP-8 F-34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