Grid Hardening and Resiliency

By Alyson Rossini and Jeffrey Richard
Problem: Severe Weather Combined with Aging Infrastructure Increase Likelihood of Outages and Costs

Hurricanes, floods, snow/ice storms, and other weather events don’t merely impact the environment. They have a significant effect on utility operations and are the leading cause of power outages in the United States. According to the U.S. Department of Energy, between 2003 and 2012 weather events caused nearly 680 power outages, each affecting at least 50,000 customers. With more than one hundred and fifty-four million electric utility customers in the United States, severe weather events are a concern for every utility company that services them. In today’s digital age, customers demand reliable power. Any outage, especially widespread or extended outages like those caused by extreme weather, can decrease customer satisfaction ratings.

Customer service is a vital part of any utility’s business strategy and is not the only reason why utilities are concerned with severe weather events. Most transmission and distribution (T&D) lines in service today were constructed during the 1950s and 1960s and were not originally engineered to meet today’s demand or withstand severe weather. This aging infrastructure raises concerns of congestion, distribution, reliability, and cost of service. If one feeder goes out, will another feeder be able to handle the additional load? If not, will overloading the feeder actually cause more damage to the system? Developing a grid hardening strategy could be the best opportunity to prevent structural failure of an aging infrastructure, significantly reduce restoration times, and allow for better coordination.

Outages due to aging infrastructure coupled with severe weather can be a massive expense for utilities. Depending on the number of customers without power, a single storm can cost between $500,000 to more than $1 billion. In a study of FERC Form 1 data from investor-owned utilities across North America, Leidos identified increases in capital T&D spending during years of major storms. The spikes in historical spend in years 2005, 2008, and 2012 correlate with some of the country’s most significant storms—Hurricane Katrina, Hurricane Ike, and Superstorm Sandy respectively. In order to lower the risk of unpredictable outages and operation and maintenance (O&M) expenses, utilities should consider spending capital dollars on grid hardening and modernization measures, especially if they can include these costs in a rate case.
State commissions and local government have put pressure on utilities to increase reliability before, during, and after storms, which is driving a more urgent need for grid hardening. Some state officials and public utility commissions have gone as far as initiating investigations into utility practices and standards after significant weather events. Now, state commissions are realizing regulatory frameworks must change to allow for greater incentives and flexibility to recover the costs incurred for the massive repairs. In most cases, costs are recovered through a rate case, which could take years, but some states have allowed utilities to defer storm-related costs or implement a surcharge to target infrequent and/or volatile costs. Other regulators have introduced state mandates with performance-based metrics and the potential for penalties.

Cost recovery from rates is not always a given, especially when state commissions have the authority to determine the amount and extent of how storm-related costs are recovered. Hardening the grid to make it more resilient and less vulnerable to extreme weather events must be part of future plans. While the goal is straightforward, the plan is highly complex and requires careful consideration of various factors. 

![IOU Capital Spend Trends](chart)
complex to execute, and what may be necessary today, could be obsolete tomorrow. There must be a balance in protecting the infrastructure, hardening components, reducing the impact of storms, and expediting repairs.

Solution: Grid Hardening – What is it?
Grid hardening is physically changing the infrastructure to make it less susceptible to extreme wind, flooding, or flying debris. Hardening efforts protect facilities against weather events by making it easier to withstand significant damage.

Grid modernization is a supplement to hardening. It involves upgrading the system to use cutting-edge technology or newer components that are often linked to each other through advanced communication or automated systems.

Resiliency is the continued operability and functionality of the facility despite damage and the ability to restore customers quickly after damage has occurred to the system. It means being ready for what might come. This readiness can be defined by two categories: general readiness and storm-related readiness.

› General readiness by electric utilities might include improving communications and preparedness training, regular power line inspection and maintenance, and vegetation management to remove tree limbs posing a risk for outages during a storm. It also includes proactively identifying the worst performing feeders, reviewing circuit configuration and back up, and replacing assets at the end of their useful life.

› Storm-related readiness focuses on ensuring that emergency measures are ready to deploy in the immediate aftermath of a storm. It might involve establishing fuel contracts for vehicles, pre-staging materials, developing a plan for crews, or developing a storm restoration or response app for smart phones. When considering the “grid of tomorrow”, microgrids may be a solution in the near future to reduce the duration of outages and ensure public safety, especially in areas where feeder back up is not an option. They have been evolving from a diesel generator to restore power to a single customer to smart systems that may incorporate renewables and battery storage.

Therefore, grid hardening is a combined system of actions to strengthen infrastructure, ranging from the physical structures and equipment to communications and effective documentation. As part of grid hardening, utilities should consider network data, asset record systems, and the
processes used to maintain an accurate view of their systems. Often assets do not have adequate documentation if they were not updated after construction. In order to lower response times after a storm, data management and geographical information systems (GIS) should be properly maintained so crews can quickly identify and locate problem areas.

**Implementing a Program**

An Edison Electric Institute report on grid hardening states, “There is no one solution to hardening the infrastructure or creating a more resilient system. Rather, utilities and their regulators must look at the full menu of options and decide the most cost-effective measures to strengthening the grid and responding to storm damages and outages.”

Each utility must identify hardening techniques specific to its needs, but there are typically three major categories of approach:

1. Prioritize and target options to reduce the impact
2. Harden the components of the system to withstand impact
3. Implement innovative response measures

To reduce the impact, utilities often move overhead lines underground, increase vegetation management efforts and tree trimming, and implement flood barriers or walls. Pole line location and design can also play a critical role. Utilities typically try to optimize structure pole and line design and improve line access to minimize the storm’s impact. Other measures can include voltage conversions, installation of arresters at regular intervals, and relocation of critical devices to accessible locations.

To harden system components, many utilities rely on a minimum grade B National Electrical Safety Code (NESC) construction or investigate new pole materials, like steel, concrete, or composite poles with fiberglass arms. Hydrophobic coating and submersible switches are also effective for waterproofing and hardening efforts. Other techniques include tree wire and spacer cable configuration, storm guying, and conductor replacement.

Innovative response measures include smart grid technology upgrades. The system can identify issues and re-route power while alerting system operators to the location of the issue therefore avoiding outages. Some manufacturers have automatic transfer switches sensitive enough to detect frequency changes before the system operator in some cases. The use of pole-mounted reclosers with a five-second reclosing time interval are a good option for lines with many customers or heavily vegetated areas since they reduce the number of temporary faults that could cause a long-term outage.
Smart grid technologies have been present in the industry for many years, but the technology is becoming more efficient and wide ranging to allow for better data. Advanced Metering Infrastructure (AMI) can relay information back to the operator in near real time and present an opportunity to create a better plan for the next storm.

Conversation Voltage Reduction (CVR) and Volt/VAR Optimization (VVO) technologies have also been present in the industry for many years, but the technology continues to improve. During a major storm, CVR is used to slightly reduce the end-use or service voltage of the customers who still have power to reduce the overall load on the system. VVO is the use of advanced sensors, equipment, and software to achieve more efficient grid operation by managing voltage regulating and VAR control devices. These technologies provide a higher level of visibility into system operating parameters and allow for greater control over equipment to optimize within its parameters, even when running with limitations.

We are in a period of significant innovation and development of new technologies. When it comes to the electric system, the core principles of safety, reliability, and affordability still guide the decisions regarding the generation, transmission, and delivery of electricity. In this era of transformation, these core principles remain guideposts for decision-making even as the ability to satisfy those principles becomes more complex.

To meet this goal, utilities need the right mix of hardening measures and state-of-the-art tools. The aim of such tools is simple and straightforward: to help utilities continue to deliver reliable power. The best of these tools enable utility field teams, as well as engineers and operators, to manage the impacts of disruptions even before they occur—preparing before extreme weather arrives on the scene.

**Begin with a Comprehensive Plan**

To be successful, utilities should carefully consider a mix of hardening and resiliency measures that will address their specific weather events and potential vulnerabilities. To start the process, begin with the basic questions: Where are the problems? What is causing the most concern? What are the vulnerabilities?

First, a utility should consider its demand and weather models to understand how and when the different types of weather might impact its system. This should help in recognizing the system needs and prioritizing the grid hardening investment.
Developing a grid hardening plan can be a considerable undertaking, and the path may not necessarily be a direct line. A utility may need to balance the ability to handle a major storm event with the ability to quickly and effectively recover from difficulties. It might even determine a thorough evaluation of the entire electrical grid is prudent and take the opportunity to include other critical O&M programs, such as pole inspection and thermal imaging/hot spots, or implement GIS-based systems.

Partnering with a consultant that has experience in all grid hardening approaches and has worked with utilities in varying regions can help focus on the best path forward. Leidos has helped utilities across the country determine, prioritize, and implement effective hardening measures. We have developed customized tools and applied advanced technologies to help utilities meet their grid hardening goals.

**Innovation Improves Program Success**

Leidos defines innovation as the implementation of new ideas with business impact. Using advanced technologies, automated tools, and targeted approaches provide utilities with the means to not only harden existing infrastructure using technology but also improve performance by transforming processes.

Innovative tools and techniques can be grouped into two categories: automation and data analytics.

1. Automating existing processes improves the quality, performance, and efficiency of a hardening program. It builds quality into the program up-front.

2. Data analytics provides insight into system characteristics and helps shape an approach for a changing and growing grid. It provides applications for better data, and improves team coordination and communication.

With automation and data analytics, Leidos has been successful in creating customized solutions for a client-focused approach.

For example, Leidos developed a custom field data collection system to help one utility capture field data in a digital format. For information collection to be made really useful, it must be made readily accessible. The system not only made the information easily accessible and transferable, but also standardized the data and displayed it geographically in Google Earth. For the first time, all data was transferred electronically across utility functions and accessible in real time.
This approach proved more efficient than traditional data collection methods by reducing human errors. It helped prevent information loss by automating the data-entry process, which translated into eliminating budget-eating delays and providing for a better-engineered design.

From the field to the central office, the utility found several ways to leverage the new data handling. For example, rapid analysis and reporting could be used to identify system-wide issues, such as unbalanced phase loading and excessive spans. In addition, personnel could quickly identify and locate electrical facilities, like underground cable and fuse sizes, when necessary.

Using a collaborative learning approach, Leidos also developed a series of quality control tools to facilitate utility-specific processes and check the accuracy of designs. The unique automated quality checker standardizes designs and checks for inconsistencies across deliverables. Full quality reviews involve a substantial time investment, but quality control can be built into the engineering designs up-front with automated tools and processes. The quality checker provides standards and templates to allow work to be done consistently. These tools were instrumental in enabling Leidos to meet the utility’s delivery schedules and have since been provided to the utility for use by its staff members.
To enable utilities to improve and monitor performance, Leidos developed a unique scorecard supported by proven design methods and automated tools. Each of which can be used by utility managers to keep track of the execution of activities by their staff, and to monitor all of the many and varied consequences which emerge from these activities. The report can also be used to measure and score the quality of the engineering design.

About Leidos

Leidos is a global science and technology solutions and services leader working to solve the world's toughest challenges in the defense, intelligence, homeland security, civil, and health markets. The company's 32,000 employees support vital missions for government and commercial customers. Headquartered in Reston, Virginia, Leidos reported annual revenues of approximately $7.04 billion for the fiscal year ended December 30, 2016.

Author Bios

Jeffrey Richard is an electrical engineer with experience working on a variety of distribution projects, including in-depth assessments and engineering reviews. His efforts help to alleviate voltage problems on distribution infrastructure. He also leads a team of engineers in engineering system improvements to maintain and improve infrastructure. He earned his Masters of Engineering in Power Systems Engineering from Worcester Polytechnic Institute and his Bachelors of Science in Electrical Engineering, University of Massachusetts.

Alyson Rossini, PMP, has project management and distribution system design experience working as a consultant in the utility and energy industry. She trains, supervises, and leads a team of distribution engineers, and she develops and implements program processes and performance metrics. She has managed strategic sourcing projects for various materials and services used in power generation, transmission, and distribution. She earned her Bachelors of Science in Industrial Engineering from Northeastern University.

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