Making Distribution Grids Stronger, More Resilient

Three-Year Research Project Looks at Pole-Top Components, Vegetation Management, and More

By Phil Zahodiakin

Electric utilities have sharpened their focus on resiliency following widespread outages from an unprecedented series of superstorms including Hurricanes Katrina, Rita, and Sandy and the Halloween Nor'easter of 2011.

"Those and other storms brought a focus on aging infrastructure and what we could do to prevent widespread outages," said Chuck Talley, manager of Distribution Engineering Services at American Electric Power (AEP).

In 2015, EPRI concluded its three-year Distribution Grid Resiliency Project with 27 utilities, which evaluated options for strengthening electric distribution systems and provided a solid foundation for future research while informing utility investment to improve resiliency.

Holding Utilities to a Higher Standard

The superstorm outages made clear that society as a whole had grown profoundly more dependent on the Internet, Wi-Fi, and smart phones. "We've seen a major change in residential customers' expectations of electricity providers," said Heather Adams, director of Electric Distribution and Standards for New York–based Central Hudson Gas & Electric.

"In just a three-year period, we experienced the four worst storms in our company's history in terms of customers impacted," said Adams. "Our customers and the media were judging our response to those storms much more critically than they would have 30 years ago."

"Utilities and regulators are very attentive to reliability scores such as SAIDI, but those are misleading metrics because they often exclude data on prolonged outages," said Mark McGranaghan, EPRI vice president for distribution and energy utilization. "Now utilities are expanding resiliency investments to address longer-term weather events."

Where the Research Focused

EPRI and participating utilities focused on current resiliency practices and improvements with respect to overhead structures, vegetation management, undergrounding, grid modernization, and storm response practices.

“When we framed the initiative, we kept the definition of ‘resiliency’ broad,” said EPRI Technical Executive John Tripolitis. “Our focus was grid performance in severe weather conditions.”

According to EPRI’s McGranaghan, overhead structures and vegetation management are priorities for resiliency enhancements.

Overhead Structures: Traditional Approaches and New Technologies

In field tests, researchers intentionally toppled trees across decommissioned power line spans volunteered by PPL Electric Utilities, Xcel Energy, and AEP. They observed that damage occurred at weak spots many spans away—such as cracks in crossarms and poles, and corrosion in conductors—confirming the importance of inspection and maintenance.

EPRI also conducted stress tests on utility poles and overhead components at its Lenox, Massachusetts laboratory.

Findings from field and laboratory tests include:

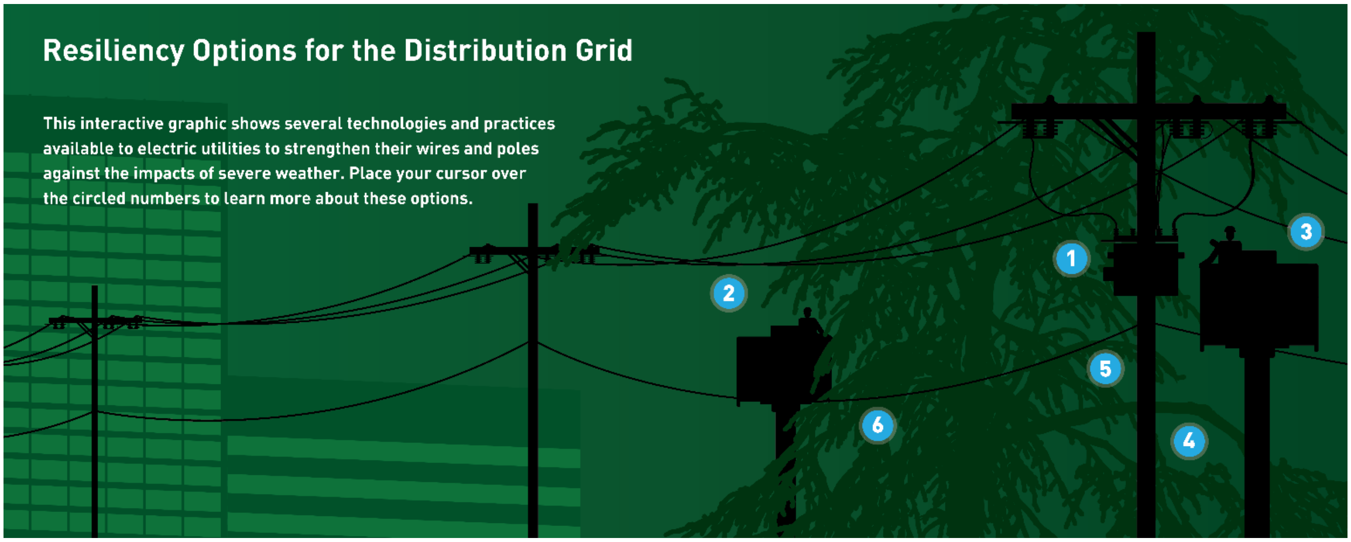
- When upgrading wooden poles, choosing replacements with a greater pole-top circumference may be more cost-effective than replacing them with steel or fiberglass poles. Pole-top strength is more important than base strength.
- When upgrading poles that carry automated switches, reclosers, and other critical components, it may be cost-effective to also upgrade adjacent poles, which can help absorb forces from tree impacts.
- Spacer cables can potentially reduce tree impact–related outages.

According to Tripolitis, collaborative research efforts into hardening overhead structures should continue to focus on open questions related to traditional resiliency approaches. These include data gaps regarding predictions for spacer cable performance as well as benefits of replacing wooden crossarms with stronger fiberglass versions.

“Our standards engineers are especially interested in the EPRI project data on fiberglass crossarms,” said Central Hudson’s Adams. “We currently apply wooden crossarms except in places where they have to withstand the greatest tension. When a tree hits the distribution line or pole, the impact forces must be absorbed somewhere. If they can’t be absorbed sufficiently, the weakest component will break. This may be the pole top, for example, which would require a more complex, lengthy repair than a crossarm. These are some of the scenarios we’ll be considering as we comb through the research results.”

Researchers looked at designing weak spots into the system to minimize damage. For example, conductor ties can enable conductors to slip through when they are struck by trees, reducing the forces on poles and pole-top components. According to EPRI Senior Technical Executive Tom Short, these devices have not yet been proven in the field. “We haven’t figured out the optimal slip resistance to prevent conductors from slipping out of their insulators many spans away,” he said.

Also under investigation were “breakaway” conductors designed to break when trees fall on them, potentially protecting poles from damage and enabling easy repairs. As with ties, Short said that more field work is needed to validate the performance of these devices.



The interactive graphic shows several technologies and practices available to electric utilities to strengthen their wires and poles against the impacts of severe weather.

Vegetation Management: From Tree-Trimming to LIDAR

Tripolitis points to vegetation management as critical. Falling trees and branches are usually the leading cause of damage in severe weather. Because such programs are costly, utilities must weigh carefully their benefits relative to other resiliency investments. As part of EPRI's resiliency project, participants identified the industry's best vegetation management practices.

"Traditional vegetation management programs are designed to deliver reliability in normal weather," said Tripolitis. "But in severe weather you have trees falling into power lines from outside cleared corridors. So, we looked at tree trimming that can help prevent excessive damage during severe storms."

Particularly valuable is trimming above conductors so that fewer branches fall on them, preventing faults and outages. Other helpful practices include using the following:

- Geographic information systems to record pole locations, trim dates, trees targeted for removal, property boundaries, and more
- Sonic scanning to determine which trees are most likely to collapse in a storm
- LIDAR to measure the height of tree canopies to assess risks of trees falling into power line corridors

Going Underground

Underground circuits often are built in densely populated areas for increased reliability, safety, and aesthetic considerations. Elsewhere, underground lines support reliable electricity service to hospitals, airports, and other critical facilities during severe weather.

In major storms, underground distribution lines are far less susceptible to damage than overhead distribution. Outages can result, however, if the circuit's substation is knocked out or if underground equipment is damaged.

Utilities must evaluate many factors when considering burying lines. Are corridors for overhead lines prone to floods? Are hospitals and airports served by redundant circuits? How long can such facilities function with backup generators?

When examining the costs of various types of undergrounding projects, EPRI found that they vary widely among utilities and can be three to four times higher than those of overhead systems of equal length. Researchers also examined historical performance of various underground distribution systems in storms to identify cost-effective applications.

Grid Modernization

For grid modernization, research participants examined traditional approaches such as hardening poles and installing automated switches, along with emerging technologies such as sensors that indicate when poles and lines are down.

They concluded that the use of steel poles—even in areas with frequent severe weather—is not necessarily worth the investment. "We learned that Florida had a surprising number of steel poles fail during some big hurricanes in the early 2000s," said EPRI's Short.

Replacing wood poles with larger wood poles may or may not be a good option because "the survival of wood poles in severe weather seems to depend on the strength of the pole's overhead components," he added.

Advanced metering infrastructure offers promise for detecting outages and restoration. When service to a meter is interrupted, "it sends out a 'last gasp,'" said AEP's Talley. "So, depending on a utility's outage management software, those pings could be interpreted as a possible outage."

Possible, but not definite: EPRI concluded that outage-and-restoration detection with meters is not yet well-supported by field experience.

Utilities are deploying automated switches, which have been proven to work effectively under normal grid operating conditions. But in severe weather their reliability is questionable because they may not operate if their circuits are de-energized or their control system batteries have failed. Moreover, during a major event, the switches' communications with central operations centers could fail if the systems were overloaded. EPRI recommends additional research, particularly on more effective batteries for the switch controls.

Storm Response

EPRI and the utility participants compiled large data sets on the industry's many approaches to emergency planning, drills and training, weather forecasting, damage assessment, incident management, personnel strategies, and communications with customers.

Conclusions and recommendations include:

- In major storms, decentralize responsibilities for power restoration to those utility regional operations centers near outages to ease the burden on the main operations center and to more effectively manage restoration activities.
- In the largest weather events, utility personnel who don't routinely perform restoration duties may be called upon to serve. As a result, it is important to develop, document, and implement procedures (and related training) for key restoration activities such as addressing fallen conductors.
- Communicate estimated restoration times to customers after completing an initial damage assessment, and update customers with more granular estimates as restoration progresses.

In a separate project, EPRI is researching storm damage assessment with unmanned aircraft systems. The Federal Aviation Administration is developing regulations that will make it easier for utilities to deploy these systems for storm response.

Prioritizing Resiliency Dollars

Participants in EPRI's project developed a model to help utilities prioritize resiliency investments, building on a method developed by AEP. AEP's Talley said that the project "elevated our tool to beta 2.0" by incorporating methods to score the benefits of potential investments.

"For each distribution circuit, you input customer profiles and circuit characteristics, such as vegetation density, performance data, and the circuit's age," said Talley. "Then you input resiliency options, and the tool gives you cost-benefit scores. Currently, the tool must be run by individual circuit. If you have 6,000 circuits, you would run the tool 6,000 times. What's coming next is the ability to run it for groups of circuits and to drill down into sections of very long circuits."

Transferring Results from the Field

The next step for utility participants is to apply the project's findings and recommendations to resiliency efforts in their service territories.

"One of the greatest aspects of this project was the ability of our engineers to observe various concepts tested in a field scenario," said Central Hudson's Adams. "Seeing the concepts demonstrated on lines that replicate real distribution systems will help all our engineers to better apply the designs and conclusions from the project."

EPRI Tackles Electromagnetic Pulses

In 2016, EPRI launched research to help protect the U.S. transmission grid against electromagnetic pulses (EMP).

Part of EPRI's Transmission Grid Resiliency project, this EMP research will evaluate grid vulnerabilities and the costs and benefits of mitigation options.

"Industry participation in the research has been tremendous and is growing every day," said Rob Manning, EPRI's vice president of transmission research. "The issue is getting more attention in government circles because of the potential impact of an electromagnetic pulse on the entire power grid."

The Transmission Grid Resiliency project is looking at other threats as well. For instance, with the North American Electric Reliability Corporation, EPRI has developed tools to assess the potential impacts of geomagnetic disturbances. EPRI also recently completed a guide to help power companies assess severe weather threats.

EPRI Examines Metrics and Cost-Benefit Frameworks for Climate Resiliency

Recent extreme weather and natural disasters are heightening vulnerabilities of electricity infrastructure and operations. Drought, heat waves, hurricanes, wildfires, flooding, and severe winter storms have resulted in costly disruptions and damage to power systems. Increasingly, strategies to address climate change are focused not only on greenhouse gas mitigation but also climate resilience. For example, the U.S. Climate Action Plan of 2013 emphasizes climate preparedness and resiliency alongside domestic carbon reductions and international climate action.

To enhance climate resilience, electric utilities can assess vulnerable infrastructure, evaluate risks, and identify opportunities to harden assets and operations. To prioritize among investment options and support recovery of costs, utilities are often required by regulators to demonstrate that projects would yield net benefits for their customers. However, without metrics specific to resilience, the benefits of resiliency measures are being estimated with metrics traditionally used for reliability planning.

"While there are commonalities between resiliency and reliability, there are critical differences related to the type of hazards and their 'low-probability, high-consequence' nature," said EPRI Senior Technical Leader Delavane Diaz. "As a result, reliability metrics such as average service interruption indices and outage cost estimates are not well-suited for characterizing resilience."

To address this gap, EPRI is conducting a technical assessment of resiliency metrics and analytical frameworks and facilitating a collaborative forum for electric companies to discuss the merits and limitations of those approaches.

Key EPRI Technical Experts

John Tripolitis, Matt Olearczyk, Tom Short