DISTRIBUTION GRID RESILIENCY – NORTH AMERICA

Matthew G Olearczyk
EPRI – USA
molearcz@epri.com

ABSTRACT

When hurricanes, ice storms, and other significant weather events occur, the electric distribution system is vulnerable to damage and outages. The impacts and costs of these storms can be exorbitant, given the critical nature of electric power systems and their interdependency with other critical infrastructures, such as natural gas and oil, water supply systems, banking and finance, transportation, and others. The frequency and severity of recent storms has focused industry attention on the need to enhance the resiliency of the distribution system so that it will experience less damage during these events. Distribution resiliency improvements can include changes in design standards, construction practices, maintenance and inspection practices, and restoration practices. A significant challenge for utilities is to determine the optimal set of distribution improvements that are acceptable within their regulatory framework, address their particular system parameters and weather characteristics, improve reliability, enhance resiliency, and enable more rapid recovery during and after extreme events..

INTRODUCTION

In response to this challenge, EPRI gathered input and feedback from utility experts from North America, and based on this direction, established a three-year research project on grid resiliency. The overall goal of this research is to create actionable information that utilities can apply to enhance the resiliency of their distribution systems to major weather events. Resiliency can encompass the following forms:

- *Damage prevention* – Hardening of overhead lines to resist damage, undergrounding, and vegetation management.
- *Easier repair* – Maintenance, retrofits, or new designs to facilitate damage repair; limit pole damage and cascading failures.
- *Isolation and reconfiguration* – Isolation of damage to minimize the number of customers affected.
- *Recovery* – Improved technologies and processes to accelerate restoration.
- *Community sustainability* – Improved communications with customers and the community (e.g., estimated restoration times); maintaining electric supply to critical infrastructure such as traffic signals, prisons, hospitals, and cell towers.

GENERAL

Aerial Structure Resiliency

The overall objective of this research is to identify strategies for improving the resiliency of overhead distribution infrastructure via hardening, graceful degradation, and ease of repair. Field testing revealed that the stresses associated with simulated tree impacts find the system's weakest spot, such as splices, cross arms, or pole tops, and highlighted the importance of inspection and maintenance programs to identify and bolster these weak points. Preliminary testing of various classes of poles revealed that specification of a minimum pole top circumference may be more important than the class of pole in minimizing pole breakage. Other preliminary successes were conductor ties designed to enable slip, to prevent damage to costlier structures, and breakaway conductors, which are especially well suited to poles with critical or expensive equipment.

Field and full scale laboratory testing of overhead system infrastructure comprised the majority of the research. This testing provides data to quantify the performance of components individually and in combination to determine optimal designs for storm resiliency.

In full scale field testing, a large pole was dropped against a decommissioned line to simulate the impact of a downed tree to test the pole's performance, analyze how it failed, and determine methods to improve its resiliency. This field test revealed that failures occurred far from the impact point, and that the impact's stress finds the system's weak spot, such as splices, cross arms, or pole tops. These findings point to the need for more resilient structures, highlight the importance of inspection and maintenance programs to identify weak points, and provide direction for further testing in a laboratory setting.

In the laboratory, EPRI conducted component-level testing on individual equipment such as poles, conductor ties, and cross arms to evaluate strength and resiliency characteristics. Installing larger, heavier class poles is an effective but expensive method of hardening an overhead system. EPRI conducted destructive testing of five classes of poles to better quantify their resiliency characteristics. A key finding is that specification of a minimum pole top circumference may be more important than the class of pole; in some cases, this may enable utilities to gain the strength of a higher class pole at the price of a lower class pole if the latter pole has a minimum pole top circumference. Chemical wood preservative treatments were also examined, with preliminary results indicating that chromated copper arsenate (CCA) can compromise pole strength, compared with pentachlorophenol (Penta). Another key component to overhead line resiliency is conductor ties. A tie designed to be the first component to fail in the event of an impact, yet strong enough to perform under normal conditions, can prevent damage to costlier structures such as insulators, cross arms, and poles. EPRI has compared hand ties, preformed ties, and other tying methods to determine their relative strengths and failure rates. In addition, entire pole top assemblies – conductors, conductor ties, insulators, insulator pins, and cross arms mounted on a pole – were tested to examine the performance of the components as a system and provide guidelines to coordinate the strength of different materials to help utilities design more resilient structures.

EPRI is also building on past work to test breakaway conductors, with preliminary success. The advantage of this type of conductor is that it is rigged to fail rather than the pole, protecting the pole from damage and enabling a relatively easy repair. This arrangement is particularly well suited to poles that support critical and/or expensive equipment such as reclosers and automated switches.

Vegetation Management

The overall objectives of this research are to better understand the mechanisms of vegetation-caused damage to distribution infrastructure during storms; gather and document utility practices related to vegetation management (VM) programs, specifically related to storm damage; and determine if there are new options for VM programs that could result in less system damage during major storms. The research is focusing on selected VM processes deemed a priority during a series of 2012 industry workshops. Specifically, the research intends to focus on evaluation of results from previous storms; characterization of tree program specifications and contract attributes; correlation between trim specifications and actual damage; identification of customer outreach programs that materially change tree exposure to smaller or more wind resistant tree species; use of tree growth restrictors; and identification of emerging trimming practices that help limit tree damage during major weather events.

Research conducted in 2014 revealed that most utilities' approach to VM to maintain day-to-day reliability differs from their approach to major storm resiliency only in degree. If a utility's reliability practices include a five-year trim cycle, it may choose to reduce the cycle to four years to improve resiliency in selected areas. Other current resiliency practices include widening the standard trim corridor around the pole line; enhanced tree trimming (ETT), also known as blue sky trimming, which removes all vegetation above a power line; and Hazard or Risk Tree Programs, which look outside of the trim corridor to identify weak, decaying, or dead trees with the potential to fall across the distribution line in storm conditions. Overall, tree trimming practices to prevent rapid regrowth have become more sophisticated, and most utilities follow tree trimming guidelines provided by the International Society of Arboriculture and ANSI.

In 2015 an industry survey revealed that utilities are moving toward a more-risk based approach in their VM programs, especially in determining the optimal deployment of resources to protect critical infrastructure. To enhance risk analysis, some utilities are using advanced technology to provide quality data. Current leading practices include incorporating Geographic Information System (GIS) data, weather information, and smart phone/tablet technology into the development and execution of VM strategies. Many utilities currently use GIS data in their VM programs for information such as location of poles, trim dates, trees identified for removal, areas for mowing and herbicide application, etc., while a few utilities are beginning to use GIS in conjunction with OMS, pictometry, and LiDAR data to improve their VM strategies. Overall, the adoption of these technologies to date has been limited, but opportunity exists for utilities to embrace these innovations to improve their grid resiliency efforts.

Integrated Vegetation Management (IVM) is now emerging as an approach that determines appropriate VM strategies through extensive data analysis. While IVM is a promising approach, its adoption throughout the industry has been slow, most likely due to cost of program development, especially in the areas of data acquisition and the length of time to realize benefits.

Undergrounding to Enhance Resiliency

EPRI's purpose in this research is to compile representative cost data on the undergrounding of distribution infrastructure so that utilities may better assess this strategy for improving distribution grid resiliency in major storms, such as wind and ice storms. In terms of traditional measures of reliability, underground systems outperform overhead systems; for example, the frequency of underground system outages is about one tenth that of overhead systems. Certainly, in major storms, underground distribution is far less susceptible to damage than is overhead distribution. However, undergrounding can be costly, and those costs can vary greatly from utility to utility. The ultimate goals of this research is to enable utilities to identify optimal selected applications for undergrounding to enhance resiliency, identify ways to narrow the cost gap between underground and overhead systems, and enable utilities to conduct cost/benefit comparisons between undergrounding and other strategies for enhancing resiliency.

For this research, EPRI identified three focus areas to investigate the cost of undergrounding. In the first area, EPRI is examining the components that increase that cost, and specifically, is determining which components are driving the cost differences from utility to utility. In a second focus area, EPRI is identifying applications in which undergrounding may provide sufficient benefits to justify the cost compared to overhead systems. In the third area, EPRI plans to explore opportunities for applying new technologies that lower the cost difference between underground and overhead solutions.

In interviews, utility project participants have stressed that the representative cost data resulting from this Research needs to be fully documented and supported so that utilities can adjust pricing according to their circumstances.

Grid Modernization

The overall goals of this research are to document the challenges and opportunities that key grid modernization technologies present with respect to distribution grid resiliency; gather and document utility practices intended to manage these challenges, and identify and communicate opportunities that can be exploited for the benefit of the industry; and identify and scope specific proposals for EPRI research to overcome difficult-to-manage challenges, or further exploit high value opportunities. The research is focusing on grid modernization issues identified during industry exchange workshops, including configuration and operation of outage management systems (OMS) and distribution automation (DA)/automated restoration systems during severe impact storms, and hardening of key grid modernization poles to mitigate/prevent damage to these expensive assets. Additional issues include design standards and hardening of grid modernization communications assets to maximize their effectiveness during severe impact storms, and use of advanced metering infrastructure (AMI) for outage and restoration detection.

Protecting critical DA/AMI backhaul poles during a storm event is one key to maintaining grid functionality. At EPRI's Lenox, Massachusetts laboratory, the team has developed and tested break-away connectors designed to disengage wires from poles when impacted by falling trees or other large storm debris, protecting the DA/AMI backhaul poles from the large stresses that might cause them to break. Break-away connectors were proven to successfully protect DA/AMI poles from simulated downed trees. Further research will aim to identify the best break-away connector, fine tune the break-away force, test potential damage to the DA switch from the break-away stresses, and quantify the connector's costs and benefits.

Another area of potential improvement for maintaining functionality during storm events is in DA switch power management. Currently, a DA switch, controller, and communications device rely on batteries as a backup power source during an outage, when local power from the circuit is de-energized. Under normal conditions, these batteries need to be replaced every 3-4 years. During large storms, depending on their innate functionality and how they are configured, they may drain to the point where they cannot be recharged, requiring utilities to replace all of their DA batteries after restoration, at significant expense of dollars and time. To date, the team has characterized how most of the commercially available DA switch controllers operate. Further research will develop a specific set of requirements for backup power, and then explore battery alternatives such as supercapacitors or hybrid batteries. Also planned are studies to quantify the costs and benefits of retrofitting existing controllers or specifying new controllers with different battery technologies that improve resiliency, and to address the post-storm costs of reassembling these systems after the batteries have been exhausted and must be replaced.

In the area of enhancing functionality, the team has explored using pole down/wire down sensors originally developed by EPRI's Transmission and Substations Group on critical wires and poles. The sensors detect when their angle has been changed. Deployed strategically on poles and lines, they can report on whether a pole is leaning or the pole is down. One key opportunity for deployment of wire down sensors is on spacer cable (Hendrix wire) where covered conductor is deployed to prevent incidental tree contact from causing an outage. A potential adverse side effect of this design is an increase in the potential of high impedance faults, due to the conductor cover increasing the fault impedance, which could be quickly detected by a wire down sensor. Early identification of poles/wires down could improve the damage assessment process and enhance safety. Continuing research in this area includes identifying specific requirements for this application (e.g., sensing, internal logic, packaging, and communications needs) and developing and testing prototypes to cost-optimize the sensor. A cost benefits analysis will include deploying the sensor alone or in conjunction with the breakaway connection installations. Another exploration in the area of enhancing functionality is deploying DA Automated Restoration (aka FLISR, FDIR, etc.) solutions that can continue to operate beyond the first contingency. During severe impact storms, multiple faults commonly occur. Many existing DA automated restoration solutions are only able to operate for the first fault, and beyond that they are unable to continue to restore service. During the Lenox Summit, utilities demonstrated more sophisticated Automated Restoration technologies that can handle second or even additional contingencies. Continuing research in this area will focus on documenting the specific requirements, safety concerns, costs, and benefits of multiple contingency automated restoration.

Prioritization of Resiliency Investments

In this Research, EPRI aims to provide utility decision makers the data they need to prioritize investments in the grid resiliency improvement strategies identified in the other distribution grid resiliency (DGR) project research. Most utilities already have tools and processes in place to prioritize investments. However, EPRI interviews with Research participants have found that utility decision makers need performance, cost, and benefits *data* to support the decision-making process. This Research leverages information obtained from the five other DGR areas to provide this data, which utilities can then use to prioritize DGR investments.

In work completed to date, a literature review, industry survey, and series of interviews with utility subject matter experts revealed that utilities have effective processes in place for managing assets, managing risk, and prioritizing investments. These processes define and often weight attributes, as well as employ a project “scoring” approach. These approaches generally seek to address how well the strategies support various goals such as safety, reliability, financial performance, customer service, environmental impact, and increasingly, resiliency. However, utilities lack the credible supporting data needed to accurately characterize resiliency investments.

To meet this data need, EPRI is currently assembling matrices of data that list strategies for improving DGR, application guidance, cost data, and benefits data. Strategies cover a broad range, including, for example, the following:

- Stronger wood poles and breakaway conductors on poles
- Expanded vegetation management right-of-way width,
- Undergrounding services
- Implementing expanded distribution automation algorithms that can handle second contingencies
- Streamlined, rapid storm damage assessment methodologies that enable effective restoration plans

The application guidance that EPRI is providing can be segregated into two types: 1) ongoing strategies that provide benefits over a long period of time (e.g., by changing new construction standards), and 2) targeted strategies that retrofit changes to facilitate benefits in the short term.

For a given strategy, cost can vary considerably from one utility to another. For example, underground costs can vary due to soil conditions, underground design methods, and labor rates. EPRI is adopting the approach of using “representative” costs that enable comparisons between various strategies, while enabling individual utilities to modify these costs, as appropriate. EPRI is also investigating the use of various stratifications of costs (e.g., high, medium, and low costs that may represent urban, suburban, and rural projects) to provide a range of choices for utility use. Normalization of the units of the cost data (e.g., per mile or per circuit) will also increase the usefulness and scalability of the data.

EPRI is evaluating various measures of benefits that reflect a more resilient system, as well. Traditional measures, such as SAIFI and CAIDI have some usefulness, but other measures specific to major events are being evaluated as well. The latter include overall event duration, trouble cases per mile (or per circuit) and estimated time to restoration (ETR) accuracy. One measure with promise is average damage of a particular type per mile or per circuit, where “damage” can include multiple elements such as the number of broken poles, number of spans down, and number of services down.

References:

Distribution Grid Resiliency: EPRI, Palo Alto, CA: 2015, 3002006688

~END~