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VEGETATION MANAGEMENT

Hardening the System

To identify effective hardening opportunities, a system must be examined from underground facilities to structures, wires and vegetation.

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Following the extensive damage from hurricanes in the early 2000s, regulatory bodies from Florida, Texas and other states asked their utilities to either adopt or investigate hardening options for their systems. In response to this, several utilities have performed hardening studies and implemented hardening measures. Based on these studies, about half of the utilities either have received or are expecting to receive approval to recover some or all of the associated costs through the regulatory process.

System Hardening

After the Atlantic hurricanes of 2004/2005, the Florida Public Service Commission ordered the affected utilities to investigate the types of facilities that failed, determine why they failed in the numbers they did (and whether age had any bearing on the failure) and to look into means to harden their systems against them. Texas, Oklahoma and Kentucky, among other states, also initiated hardening programs.

Hardening programs today include activities that look for ways to protect utility systems against all types of weather events, not just hurricanes. The Los Angeles Department of Water and Power (LADWP) has a comprehensive hardening approach that includes improved designs for wind and fire resistance, anti-corrosion techniques, and the use of upgraded materials and practices that exceed state and local standards.

The National Electrical Safety Code (NESC) is the foundation on which many utility standards are built. Recent damage from hurricanes and wind storms has shown building to NESC requirements alone may suffice for normal weather conditions, but not necessarily for some of the severe weather events that result in catastrophic failures and subsequent extended outages.

Vegetation Management

Tree trimming is a major component of hardening for extreme weather. Revisiting in-place vegetation management programs periodically is vital to minimizing the effects of wind and winter storms on power lines. For vegetation management programs to be effective, it's important to review some of the salient points collected from different wind and winter storms:

- Utility actions typically include the expansion of existing rights-of-way (ROW), clearance of overhang in urban areas, and removal of dead or dying trees (hazard trees).
- Inspections of damage from wind storms and hurricanes have revealed distribution pole failures were principally a consequence of fallen trees (secondary failures) and not due to the impact of the wind on the power delivery system directly (primary failures).
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For distribution systems, a direct correlation exists between the proximity of trees to distribution lines and the vulnerability of the lines to severe wind and winter storms.

- Tree-related failures increase exponentially when wind speeds are more than 60 mph (97 kmph).

- In high-wind situations, risk from airborne debris and from trees outside the ROW can exceed the risk of trees within the ROW by factors as much as 3-to-1 or even 4-to-1.

- Increasing the intensity of the hazard-tree program would not noticeably improve electric system performance during major storm events. Some assessments have shown even if all hazard trees had been removed from areas around power lines, outages could not have been avoided, because sometimes more than half of the trees causing outages have no visible defect and would not be considered hazard trees.

- Line-outage frequency is highly correlated with the number of trees-per-mile edge of the line and weakly correlated with variables such as line and tree heights and clearance between the trees and line.

- Reductions in wind-related outage rates can be achieved by reducing the span length and increasing the number of poles per mile for cases where the majority of damage is due to power line (for example, poles and hardware) failures (primary damage). However, if secondary damage to the power line is more prevalent for most pole failures, then this approach could result in more pole failures rather than fewer, and the time needed to restore service could be prolonged.

Improvements to wind-resistant designs, such as wire size and spacing, are one way LADWP has reduced outages, especially in high fire-hazard areas. The utility also increased its vegetation management inspection cycles to provide better condition-based evaluations.

Flood Hardening

Flooding is the most significant extreme weather event because of the long-term effects of flood water damage on substations and underground electrical services. Floods can be generated by river floods, flash floods and ocean storm surges/tides, with the main difference being the onset of the flooding, with river floods being the slowest building floods. Flash floods are typically associated with heavy downpours that can lead to surges of water turning dry flood plains into raging torrents in minutes. Storm surges are caused by the high winds pushing on the ocean's surface, causing the water "to pile up" as well as the low pressure at the center of a weather system. The water level rise due to the combination of storm surge and the astronomical tide is a storm tide. This rise in water level from the storm tides can cause extreme flooding in coastal areas, particularly when a storm surge coincides with normal high tide, resulting in storm tides reaching up to 15 ft to 20 ft (5 m to 6 m). (The term "storm surge" is often used in a nonscientific way to mean "storm tide.") Hurricanes Sandy (2012), Ike (2008) and Katrina (2005) all caused major coastal flooding. In Sandy, flooding occurred in a matter of minutes or even seconds, according to some eye witnesses.

Flooding affects many aspects of the power system, but it is a major concern to substations. Flooding becomes a problem for substations when the amount of water reaching the drainage network exceeds its capacity. It can cause severe damage to substation equipment and may lead to interruptions in service continuity and widespread outages. Large amounts of water, rust and mud left trapped behind a flood in a substation can make repair of the equipment a sizable and lengthy restoration task.

Hurricane Sandy involved salt water flooding, which creates additional challenges to the infrastructure. Prolonged salt water exposure can damage cables, motors, metal fasteners and the electronic parts, and can cause short circuits. Cleanup from salt water flooding is lengthy and labor intensive, and involves inspecting all the affected areas, evaluating damage, cleaning and repairing damaged equipment. Repairing or replacing some equipment is not always easy as a lot of the equipment is aged (some more than 50 years old) and obsolete. Finally, prolonged salt water exposure is potentially corrosive to concrete and the steel embedded in it, as it contains sodium chloride and magnesium sulfate, among other potentially corrosive elements.

In anticipation of flooding, LADWP did storm-surge analysis for coastal generation plants.

Heat Waves and Dry Spells

LADWP has learned how to prepare for heat waves and summer peaks:

- Inspect substations for peak load readiness and identify load-relief projects with projected overloads
- Identify potential thermal overloads and low voltages
- Develop or update emergency load-transfer and contingency switching plans
- Verify the availability of capacitor banks.

As a precaution, the LADWP changed the specifications and its practices related to distribution transformers and upgrading them before the summer season. Every transformer that experiences a fuse trip during the year is upgraded as required before summer. The utility uses transformers with a 55-degree rise, temperature strips and transformer modeling for better overload capabilities, lower losses and longer life.

Structural Upgrading

The most common hardening practice for electric transmission and distribution systems is upgrading poles and structures with stronger materials. It also may include installing guys and other structural supports. Transmission structures are usually upgraded from aluminum to galvanized-steel lattice or concrete. Materials are typically upgraded to meet certain grade and wind-loading criteria as defined by the NESC. The NESC specifies three grades for pole material strength: B, C and N, of which B is the highest.

Strengthening poles and towers by installing guy wires and upgrading crossarm materials also are common hardening methods. Adding guy wires can increase structure strength without the need for full pole replacement, and upgrading crossarm material allows for the strengthening of a structure with minimal material replacement.

Transmission and distribution poles subject to storm surges and flooding require guying. Costs and procedures for installing guy wires vary according to the height of the pole or structure, soil characteristics, assembly configuration and design wind speed. For example, if lines pass through marshes, it may be necessary to install anchors as much as 100 ft (31 m) deep, substantially increasing cost. The most expensive guying involves pole installation in sand and silt soils.

Tougher California state standards for pole-loading calculations have led to the use of steel poles for heavier construction instead of traditional wood poles, including construction of 35-kV switch-fuse combination poles. The LADWP uses silicone overhead insulators exclusively for 34.5-kV overhead construction because of anti-tracking, weight and brittleness considerations. The LADWP commonly uses fiberglass cross-arms for longevity and strength.

Undergrounding

Placing utility lines underground eliminates their susceptibility to wind, ice and lightning damage. In the U.S., undergrounding has been proposed many times as a way of hardening, but it's often been set aside as a serious solution because of the cost. Though undergrounding of existing overhead infrastructure is not economically feasible, some utilities have considered targeted undergrounding projects, especially for lines serving critical infrastructure and selected backbone circuits.

Though mostly immune to wind-related damage, undergrounding facilities are prone to flooding. Undergrounding also presents significant challenges, namely longer repair time and much higher repair costs; damage to underground facilities from Sandy reinforced that. Investor-owned utilities in North Carolina compared five years of underground and overhead reliability data and found the frequency of outages on underground systems was 50% less than for overhead systems, but the average duration of an underground outage was 58% longer.

Span/Wire Change

Sometimes shortening the span length can improve the storm-withstand capability of distribution lines. The span length can be shortened by adding more poles to an existing line. The number of attachments cannot be reduced on existing lines, at least not without high cost.

Some older distribution lines have old small copper wire (for example, #6 and #4 Cu) or copper-clad wire and aluminum wire with a corroded steel core. Replacement of the old wire with larger-sized wire could avoid some outages during major storms. Small wire replacement is currently part of the electrical hardening initiative at a several U.S. utilities, including LADWP, which uses copper wire instead of aluminum conductor steel-reinforced or aluminum wire as an anti-corrosion technique for overhead construction near the ocean.

Smart Grid

The promises of the smart grid may offer some significant advantages in reducing the footprint of weather-related outages, as well as enhancing and speeding up restoration efforts. The improved robustness of the smart grid, as compared to older grid systems, makes it better equipped to detect and correct supply problems in extreme weather. The smart grid enables the detection and pinpointing of disruptions and facilitates actions (automatic or manual) to correct them. Where severe weather events themselves create safety and security problems, smart grid sensors, communication and automated operation can rectify the issue considerably.

Evolving Concepts

Two strategic hardening concepts are evolving as utilities and regulators consider how best to handle the effects of storms while holding costs at justifiable levels. The first concept involves circuits that would be designated for special hardening attention. Often, the aftermath of a storm with a widespread impact is particularly hard on the surrounding community because basic required services are not available for days after a storm. For example, gasoline stations have no power to pump gas, people cannot buy ice to throw into refrigerators and pharmacies cannot open. This was a frequent complaint in Florida following the catastrophic 2005 hurricane season. Recently, this was a major concern throughout New Jersey and New York City in the wake of Hurricane Sandy.

Here, substantial consideration is given to hardening societally critical circuits, those serving important areas of a community that provide necessary basic services. The cost of making special preparations on these circuits would be permitted to be apportioned over the entire customer base. After a particularly violent storm, homeowners as well as some offices and businesses might be without power, but the community as a whole would have access to needed basic goods and services.

The second evolving strategic concept has to do with designing the system for quick restoration. This more pragmatic approach admits upfront that no amount of reinforcement and preparation will completely avoid damage from certain events, be they Category 4 hurricanes or F5 tornadoes. Economic steps can be taken to make key elements of the system, particularly the societally critical circuits, faster to repair and restore when downed:

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Relocate switching and overhead equipment to minimize possible damage and make it more accessible for quick repair.

- Use more and better-placed lateral fusing to reduce cascading outages from fallen lines and the like. This is common where higher-than-normal tree outages can be minimized to a specific branch or lateral instead of the entire circuit.

- Conduct general reexamination of circuit arrangement and locations with an eye toward making it easy and quick to repair if lines are downed and equipment is ruined.

- Limit the number of customers affected by a line outage through circuit configuration.

- Minimize long overhead line exposure. Shorter overhead circuits tend to have fewer outages than those with long overhead exposure because of less exposure to trees, vehicles, wind and other factors that cause outages.

Every year, the LADWP identifies its worst-performing circuits based on reliability statistics and develops a plan to mitigate the specific causes of outages. Doing this provides a significant improvement to overall system reliability. This hardening measure is even more important in areas of the nation subject to severe weather.

Perspective

Study is needed to develop a hardening initiative. While some initiatives may be common to many different utilities, others are utility specific. Each utility must analyze the performance of its assets during extreme events and perform cost-benefit analysis for hardening the system for future extreme events. Both capital and operations and management costs need to be included in such analysis. Hardening alternatives also should be prioritized to ensure the measures provide the greatest benefit.

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Select Storm-Hardening Programs

Focus area	Florida	Texas	Kentucky
Start date	2007	2010	2009
Vegetation management	x	x	x
Construction standards	x	x	x
Undergrounding	x		x
Forensic inspections	x	x	x
Expanded reliability reporting	x		x
Third-party pole attachments	x		x

NESC Construction-Grade Descriptions

Grade	Description
B	More conservative installation with higher safety factors and lower potential load applied to the structure. Highest grade typically corresponds to crossings (highway and railroad) and lines carrying variable voltage levels.
C	Less conservative installation with lower safety factors and higher potential load applied to the structure. Lower than grade B and typical for power or joint telecommunications/power distribution pole applications.
N	Lowest grade of construction; typically used in telecommunications applications.

Companies mentioned:

Florida Public Service Commission | www.psc.state.fl.us

Los Angeles Department of Water and Power
www.ladwp.com

Quanta Technology | www.quanta-technology.com
