White Paper

Natural Disasters and Improving Community Resiliency: Proactive Energy Approaches

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manage energy better

How can utilities proactively improve resiliency before disaster strikes?

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Restoring power quickly after a disaster can help minimize suffering while helping communities recover more quickly. Utilities should focus on proactively improving resiliency through better design standards, vegetation management, back-up generation, microgrids, and other technologies.

2017 was a banner year for hurricanes, earthquakes, and wildfires, with damages amounting to $306 billion, according to insurance firm Swiss Re — nearly double the losses of 2016.[1] However, the related human suffering was and continues to be far worse than the sheer financial cost.

Hurricane Irma hit the Caribbean in early September and caused extensive damage and destruction. As the damage was being assessed, Hurricane Maria made landfall in Puerto Rico as a Category 5 hurricane. Both Irma and Maria were among the most powerful hurricanes in recorded history, directly affecting 10 million people in the Caribbean and leaving 3.5 million Puerto Rican residents without power and limited supplies of clean water and food.[2] The 2017 hurricane season also included Hurricane Harvey, the wettest storm on record with record-breaking rainfall of 60.54 inches near Groves, Texas.

Although the lack of electricity directly caused suffering, the bigger issues were the impacts on water, sewer, ports, and the distribution of food and fuel. The big lesson from the 2017 natural disasters is that community resiliency is even more important than the resiliency of the electrical grid. Community resiliency can be measured by how fast an area can get basic, life-preserving community functions up and running after a disaster.

The growing impact of increased natural disasters on society is not taken lightly by the public. There is an expectation that modern technological advancements are applied to our critical infrastructure (such as the energy grid) to reduce outage time, increase resiliency, and ultimately limit human suffering. It is critical to focus efforts on enabling a grid that can flexibly adapt to disasters and is able to recover quickly from disruptions — **restoring the critical societal functions that reduce human suffering.**

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The Historical Approach to Electrical Resiliency

Traditionally, the goal following an outage has been to restore electrical service to all customers, as quickly as possible.

Priority has always been given to "critical loads" such as hospitals, emergency shelters, and water/sewer infrastructure. Beyond those loads, electric system resiliency historically centers on:

1. Design standards oriented towards events expected in the service territory
2. Improving the health and reliability of individual grid components
3. Vegetation management to reduce the damage from falling trees
4. Developing increasingly effective recovery processes

Design standards oriented towards events expected in the service territory

Utilities certainly use history to identify which types of events are a more probable concern in their service territory. However, some rare events have such severe consequences that they merit consideration. For example, a service territory may not have experienced a flood in 200 years, but if it did, the restoration time will be extremely long if substations built without regard to flooding are damaged. The challenge is to balance and justify spending for system hardening with the potential risk.

End customers can't afford a system that is 100 percent resilient to every conceivable natural or man-made disaster. For system hardening, good engineering judgement and experience are applied to assess the appropriate level of system design. For ice and wind, the U.S. standards are provided by the National Electrical Safety Code. For flooding, studies assess topography compared to various flood patterns.

A sample of the events that are considered in design standards include:

- Hurricanes (wind and flooding)
- Tornadoes
- Earthquakes
- Wildfires
- Ice storms
- Cyber attacks
- Physical attacks

Typical hardening efforts include:

- Increasing pole size, class, and guying
- Increasing wire size
- Raising the height of equipment and controls
- Protecting generation through design reviews
- Targeted undergrounding of feeders
- Redundancy of feeds

Normally, the end result is a substantial reduction in time required to restore services, however the number of customers that lose service initially is often not substantially improved since one tree limb can still take out a significant number of customers. The big difference comes in how much work is needed to restore the customers after effective hardening — removing a tree limb versus replacing several poles.

Improving the health and reliability of the individual grid components

Even the best designed system will not be resilient without proper maintenance. Poles age, wire corrodes, and both breakers and transformers require regular attention. Improving health and reliability starts with evaluating how each individual component impacts reliability. For example, a fused line serving six residential customers is less critical than a station transformer and breaker serving a feeder for the local hospital. The next step is assessing the likelihood of failure based on asset type, age, condition assessment, and history.

Taken together, each component is assigned a level of reliability and resiliency risk, then prioritized for attention. Follow-up steps could include everything from replacing poles and breaker maintenance to restoring original design integrity.

Vegetation management to reduce the damage from falling trees

Vegetation in the right-of-way is likely the single most important factor in system response to wind and ice events. Certainly maintaining the original design clearance for vegetation is important. However, resiliency studies include seeking greater clearances, where possible, to reduce damage from falling trees. For example, a utility's main lines might receive special treatment to increase clearance from 10 feet to 20 feet, or pole heights might be raised to reduce the likelihood of damage from trees. The return on money spent for vegetation management is often greater than any other initiatives.

Development of increasingly effective planning and recovery processes

In recent years, utilities have done a more effective job of developing processes for major event planning and recovery.

Prior to an event, activities have traditionally included storm damage prediction modeling and detailed emergency response plans for each type of event. Management through the storm allows for adaptation to changing conditions and resource availability. Post-event processes normally include rapid field assessments, communications with communities and end customers, and post-storm analysis to improve future responses.

In addition to effective recovery processes within a utility, major events like hurricanes, ice storms, and fires require extensive coordination with response organizations like fire, police, and other public utilities, such as water.

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The Changing Resiliency Landscape

A new approach to community resiliency includes:

1. A growing awareness that resiliency is primarily about reducing societal suffering
2. An awareness that existing back-up generation has underperformed
3. The improvements in cost and reliability of microgrids
4. Rapid advancement in control technology that balances generation and load at a local level

Resiliency is primarily about reducing societal suffering

The 2017 hurricane season reinforced the importance of primarily approaching resiliency as the ability of a community to recover from events and reduce human suffering. The aftermath of the hurricanes in Texas, Puerto Rico, and Caribbean nations showed that restoring electrical service to all customers was only of secondary importance. The most important issues, for example in Puerto Rico, were restoring clean water, sewer, ports, food distribution, and fuel availability.

In thinking about resiliency in this context, societal risk has three important factors:

- Which electrical loads are most important for the community to maintain essential services?
- What is the likelihood that normal electrical service to the most critical loads will be lost?
- What local back-up options exist and are most reliable for the continued electrical flow to essential services?

These factors can be used to determine which investments can best improve community resiliency and recovery. The resulting complete resiliency approach that includes preparation, response, and prioritization is illustrated below:

Resiliency

PREPARATION	RESPONSE	PRIORITIZATION
Design standards	Storm damage prediction modeling	Load criticality assessment
Pole size	Detailed emergency response	Recovery time for essential services
Wire size	Rapid post-event filed assessments	- Water
Height of controls	Management through the storm	- Sewer
Generation security	Communication	- Fuel dispensing
Undergrounding	Post-storm analysis	- Food sources
Targeted use of DER		- Hospitals
Grid redundancy		- Shelters

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Existing back-up generation has underperformed

On the surface, community resiliency may seem to be a simple matter of having back-up generation for critical loads like water treatment facilities. Proper back-up generation design, maintenance, and inspection with periodic testing are required to ensure these systems will provide power in an emergency situation when needed most.

However, history has shown that local back-up generation often does not have a great success rate, as defined by being operational for the total time required. Because back-up generation is seldom used, the generator becomes unreliable or the old fuel becomes contaminated. (Fuel contamination is a leading cause of failure.) Imagine trying to run your vehicle on fuel that has been sitting in the tank for five years.

In addition, events like hurricanes or ice storms can last for many days, with recovery efforts that stretch into weeks. Even if the back-up generators work, tank size can limit onsite fuel supply, restricting use to the short term. For example, a hospital in Beaumont, Texas, ran its generators for 14 days after 2005's Hurricane Rita. Because of a high water table and local regulations limiting above-ground fuel storage, this hospital required a fuel-delivery truck nearly every day during its generator run.[3] The result has left resiliency planners seeking new approaches and technologies to provide reliable back-up options.

Improvement in the cost and reliability of microgrids

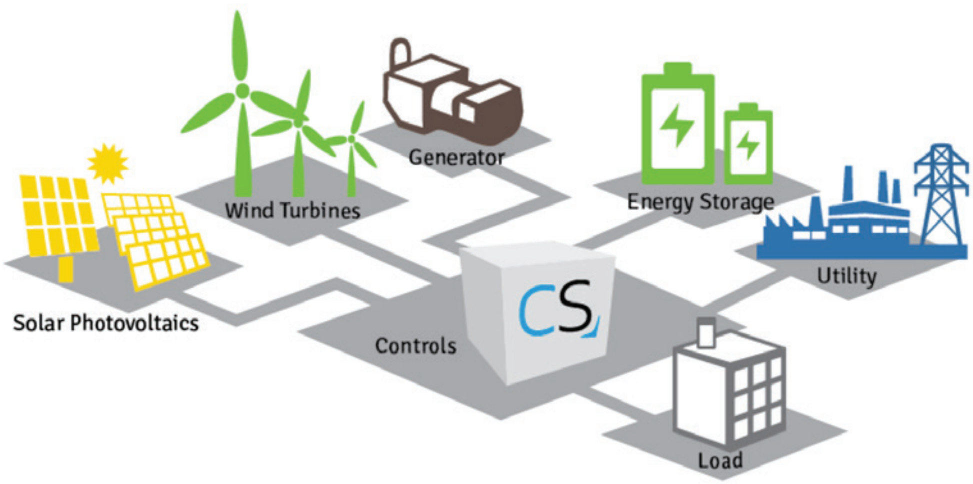
Reducing community suffering and community recovery requires either hardening central generation delivered through lines with little vulnerability or reliable and sustainable generation near critical loads.

Using Puerto Rico as an example, much of the generation is on the coast and quite vulnerable to hurricane damage. Most of this generation is also remote from the loads. Consequently, vulnerable overhead transmission and distribution lines are required to deliver energy to critical loads. The efficacy of hardening the existing system to the point that critical loads are quickly recovered is highly questionable, and comes at a high cost.

As an alternative, microgrids could be developed near the critical loads to avoid the vulnerability of long transmission and distribution lines. José Román Morales, acting chairman of the Puerto Rico Energy Commission, said the island is trying to both restore and transform the damaged power grid. The island needs to, "adopt and implement alternatives that allow greater resilience and faster restoration. Distributed generation technologies, such as microgrids, have the potential for restoring power to unserved areas and providing stability to recently reconnected areas," Morales stated.[4]

A DOE workshop defined a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."[5]

> Distributed generation technologies, such as microgrids, have the potential for **restoring power** to unserved areas and **providing stability** to recently reconnected areas.
>
> **José Román Morales, acting chair of the Puerto Rico Energy Commission**



Microgrids can take many forms, operating in parallel with or independently of the grid.

The microgrids could have one or multiple generators, with components including a fossil fuel-fired generator with a moving shaft, a battery, renewable sources like wind or solar, or fuel cells that use fossil fuels but have no moving shaft.

What makes the microgrid unique is the ability to either operate in parallel with the utility grid or independently of the utility grid. Local microgrids can be interconnected to create a network of microgrids.

Whatever form the microgrid takes, it must be used beyond emergency situations to stay reliable. For example, a fossil fuel-fired generator with a moving shaft operated as a microgrid could have three different modes:

- The microgrid could be a normal part of a generation supply, brought in and out of operation each week as needed. If a hurricane occurs, the fuel would be fresh and the generator would be in good working order.
- The microgrid could be operated and balanced with a local load or a group of loads as needed in an emergency.
- The microgrid could be operated as part of a group of microgrids in a local area to improve reliability and flexibility.

Advance control technology balances generation and load at a local level

Each of the three modes in the microgrid example above requires effectively balancing available generation with the load demands in real-time circumstances. In addition to the control challenges, there is a perhaps a more difficult issue of prioritizing which loads are most critical to serving with the available generation or energy supply.

The control technology in each of the three modes would need to balance load and generation dynamically according to conditions and a hierarchy of community needs. In addition, in non-emergency conditions microgrid usage should be tied into other optimization factors such as reducing environmental impact, reducing cost, the need for power quality, and maintaining reliability.

Achieving the required control necessitates several technologies:

TECHNOLOGY REQUIRED	WHAT IT DOES	IMPORTANCE TO A MICROGRID
Advanced metering	Measures and communicates delivered power and, in some cases, customer-side generation output.	Any electrical supply system must balance generation and load. Advanced metering provides the load and/or customer-side generation in near-real time.
Intelligent load optimization and balancing system	Provides overall orchestration and control of microgrid components according to a defined hierarchy.	Given an understanding of societal priorities, a technical solution is necessary to balance available generation and load.
Switch gear	Provides the controlled connection to the power grid (switch or breaker).	A microgrid needs to be able to operate in parallel with or separate from the main utility grid. A controllable switch is necessary to change from parallel operation to independent operation and back.
Building management system	Provides the ability to prioritize loads in a building to avoid overloading available generation.	In balancing load and generation, the building's entire load may not be a priority under emergency conditions. The "intelligent load optimization and balancing system" needs to reach into a building and prioritize loads to optimize energy use.
Microgrid	Source of energy for feeding loads that may work in coordination with central generation or independently in emergencies.	The microgrid is the local source of energy that gives options for feeding loads.
Intelligent inverter	Connects local direct current sources, like batteries or solar, to the AC utility grid and/or loads.	The intelligent inverter can also provide voltage control and protection functions.
Storage	A device that can absorb, store, and dispatch energy on command.	A storage device can immediately respond to changing loads and generation. Storage also works with renewable generation to mitigate the impact of intermittency.

Landis+Gyr can integrate these technologies into optimized microgrid solutions that can improve both resiliency and normal operations.

Improving Resiliency Through Innovative Technology

The integration of a utility Internet of Things (IoT) platform, intelligent endpoints, and analytics applications can provide robust and reliable tools to proactively manage rapid restoration of community-critical services.

New IoT network platforms are self-healing, so node loss can be overcome while communication between devices is maintained by automated network reconfiguration. Because these networks are robust, utilities can rely on them for critical communication during the initial stages of service restoration. Metering endpoints have "last gasp" functionality that enables utilities to pinpoint, respond, and restore system outages faster and in a more targeted way than traditional manual approaches.

Preparation

Reliability planning solutions are able to analyze distribution system topology along with details of historical outages that occurred during normal days or during storms. This information can be used to suggest reliability improvement solutions to reduce outages.

Such planning tools can recommend vegetation management and/or undergrounding projects. They can even work within the perimeters of a fixed budget and defined reliability goals. Using this information, utilities can better plan their distribution systems to withstand future storms or other similar calamities.

The technology can also optimize placement of fault circuit indicators and automated switching devices in the distribution system to help locate and restore faults more efficiently.

Response

Leveraging leading Distribution Automation (DA) solutions, utilities can quickly and efficiently complete system recovery from major disasters. One example is the automation of switches and reclosers, which allow distribution circuit reconfiguration and help to restore customers faster.

Smart sensors are another effective tool, allowing utilities to pinpoint fault locations and send restoration crews to those specific areas, avoiding time-consuming line patrols to locate faults.

Such innovative sensors can also play a key role in protecting the safety of line crews with their ability to detect change in direction of power flow. This can help identify dangerous back-feeding on a distribution circuit caused by behind the meter Distributed Energy Resource (DER) and distributed generation.

Prioritization

DA, along with DER planning/management solutions, can be useful in community recovery efforts by leveraging behind-the-meter generation to support local critical loads (e.g., hospitals, evacuation centers, etc.). They can also identify opportunities for the addition of utility-owned DER that will both support day-to-day grid operations and smooth outage restoration during major disasters.

Landis+Gyr applies these innovative technologies to improve resiliency and solve other real-world utility challenges —
enabling utilities to manage energy better.

[1] "Preliminary Sigma Estimates for 2017: Global Insured Losses of USD 136 Billion Are Third Highest on Sigma Records." Swiss Re, 20 Dec. 2017, **http://www.swissre.com/media/news_releases/nr20171220_sigma_estimates.html.**

[2] "Hurricane Season 2017." UN OCHA, 29 Oct. 2017, **https://www.unocha.org/hurricane-season-2017.**

[3] "Diesel Generator Failures: Lessons Taught by Hurricanes." Power Engineering, 1 Aug. 2007, **http://www.power-eng.com/articles/print/volume-111/issue-8/departments/dg-update/diesel-generator-failures-lessons-taught-by-hurricanes.html.**

[4] Wood, Elisa. "Puerto Rico Energy Commission Opens Docket on Microgrids and Distributed Generation." 17 Nov. 2017, **https://microgridknowledge.com/microgrids-puerto-rico/.**

[5] Office of Electricity Delivery and Energy Reliability Smart Grid R&D Program. "DOE Microgrid Workshop Report." 30-31 Aug. 2011, **https://energy.gov/sites/prod/files/Microgrid%20Workshop%20Report%20August%202011.pdf.**

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