ABB

Lessons learned in storm readiness: three areas you should not overlook

- Hardening of substations
- Leveraging your data
- Developing vendor relationships

It has often been said that nothing can make or break a utility like a storm. The 2017 Atlantic hurricane season, which devastated vast swathes of Texas, Florida, Georgia, the Caribbean and Puerto Rico, has raised awareness about what is working – and not working – in efforts to improve grid resiliency in the face of increasingly extreme storms.

Three enormous hurricanes

First came Harvey who stuck around, making landfall multiple times and dumping up to 52 inches of rain, forcing work crews to contend with catastrophic flooding, muddy conditions and mosquitos. Then Irma, a slow-moving storm roughly the size of Texas with winds topping 180 miles per hour for more than 37 hours. And then Maria, the deadliest of the season.

Three enormous hurricanes. Each, in different ways, more devastating than the last – together making up the most active and dangerous hurricane season in U.S. history.

The storm impact varied dramatically – based, in no small part, on storm preparedness. In the Florida Keys, for example, it took five months to clear 2.5 million cubic yards of garbage overhanging the road connecting the Keys to the mainland, but amidst this wreckage, transmission systems and substations emerged relatively unscathed. Hardening efforts in response to earlier storms had done their job. Repair focused on the distribution system.

On the other side of the spectrum, the Puerto Rico Electric Power Authority (PREPA) had let basic maintenance slip. Then came Hurricane Maria, slicing Puerto Rico's fragile grid in half. Approximately 80 percent of the island's grid was damaged, destroyed or compromised, reported the U.S. Army Corps of Engineers. Of 334 substations, for example, nearly 40 percent suffered major harm.

These storms will not be isolated events. A recent RAND report predicts that even the most optimistic projections of sea-level rise, precipitation, and extreme temperatures will expose infrastructure "to more natural hazards of high intensity." The report warns: "exposure to natural hazards is expected to increase – in some cases substantially – across the continental United States." [1]

In this paper, we bring you three areas utilities should not overlook when developing storm readiness plans:

- hardening of substations
- leveraging your data and
- developing vendor relationships/plans to provide the support and resources you need to hit the ground running when disaster strikes

Hurricane Harvey, a Category 4 storm, caused catastrophic flooding

Hardening of substations

Nearly 90 percent of weather-related power outages originate on the distribution system. Because storm response efforts tend to focus on distribution lines, it's what storm crews know, it's their wheelhouse. But anyone who has ever experienced a flooded substation will understand why we are highlighting the hardening of substations, those critical nodes of operation, first on our list of areas not to overlook.

Tony Conte, an ABB storm-hardened first responder, has had his feet on the ground in Florida, the Virgin Islands, Puerto Rico, to name a few, but the storm story he recalls most vividly happened the morning after Sandy ravaged New Jersey. Conte drove through the night to make what should have been a ninety-minute drive. Armed with a strong cup of coffee, he arrived at the Jersey Central Power & Light (JCP&L) headquarters at 6am. FirstEnergy JCP&L's area manager had had a rough night as Sandy took its infamous hard left turn toward an abandoned Atlantic City boardwalk, arriving just in time for high tide.

In all, twelve northeast states impacted by Sandy reported 8.2 million customers without power. New Jersey had the greatest number of outages with 2.8 million peak customer outages, representing 71 percent of customers. [2] Bridges were out, and access was limited, but JCP&L had done a flyover by the light of a full moon. The worst-case scenario was worse than could have been imagined.

The area manager showed Conte a map, "I need you to go here and here and here and here," he said, drawing frantic circles on a map. "I need you to take care of it. I need band aids!"

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01 Over 13 of JCP&L's substations – even those raised on platforms – were flooded. The ABB response team was engaged to evaluate, prioritize, and reconstruct.

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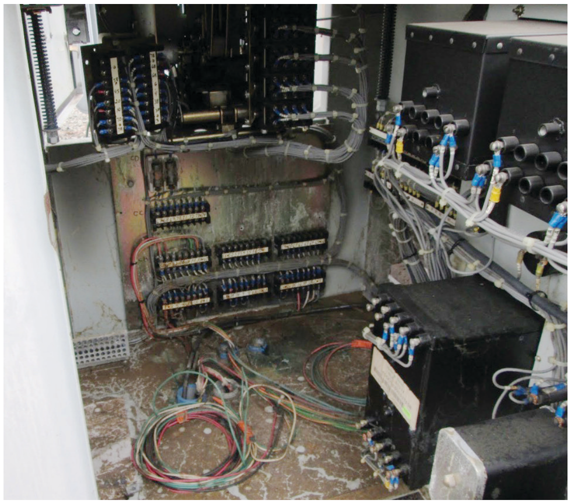
02 The switch gear had not been disengaged, and equipment was damaged.



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03 A water-logged control cabinet is pictured here.

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04 Water ingress posed significant problems. Numerous materials – many of which were obsolete – needed to be replaced or refurbished before power could be restored.

Meanwhile, one state over, Dan Taft, Con Edison's Chief Engineer, Control Systems, was shocked by the damage inflicted by the introduction of salt water to the copper wiring and control wiring of a Manhattan substation. "The corrosion we saw looked like it might have taken decades to occur," he said, "and yet it occurred in a matter of hours."

Determined never to let it happen again, Con Edison replaced its copper wires with a whole new fiber optic communication network that is virtually immune to water damage, part of a $1 billion program to protect New Yorkers from the next major storm. This effort also effectively digitized the substation, giving Con Edison eyes and ears over their entire program.

Superstorm Sandy was a wakeup call for many coastal utilities, not just those directly impacted but those who'd learned what happens when electrical substation equipment never designed to touch water gets inundated with brackish salt water. Since then, coastal utilities have been hardening substations against flood, including building dams and walls, building distributed and elevation adjustable relay panels, and raising transformers, control houses and other major substation components.

According to IEEE, many utilities design substation switchyards and/or control house elevations at the 100-year-flood Elevation, plus 1 foot. [3] IEEE suggests that this approach is practical for inland substations impacted only by rivers, wetlands or waterway flooding, however, IEEE recommends additional steps for substations who face risk from storm surge, tidal cycles, tropical precipitation, hurricane-force winds and tsunamis:

1. Identify all substation switchyard elevations and control house elevations that do not meet flooding industry standards.
2. Evaluate the risk of loss of equipment and/or systems to determine the scope of flood mitigation activities required to maintain acceptable levels of service as per FEMA FIRM maps.
3. Determine the worst-case storm scenario based on history and design accordingly.

Elevating equipment out of projected storm surge or flood levels – an important measure – still leaves substations “outdoors” and, thus, vulnerable. An additional solution for flood-prone substations is “indoor” Gas-insulated switchgear (GIS) in which all primary electrical components are encapsulated. GIS offers unique benefits. It can be safely operated in confined spaces in a significantly reduced footprint. Perhaps more important, according to IEEE, wind and atmospheric contaminates (e.g., dust, salt, industrial pollutants, etc.) cannot impact the substation’s operation, improving reliability, safety and life cycle costs. [3]

That’s aboveground. Then there are underground distribution substations, many of which were installed decades ago. Primary equipment was often designed with open-air electrical connections and multiple circuits, meaning personnel may find themselves working on a de-energized circuit adjacent to energized ones, a significant safety risk.

These designs are becoming increasingly problematic given increasing threat of flooding, among other issues. Submersible apparatus and control systems is one solution. Underground vaults should be designed to operate in floods, incorporating a water level monitor and a working pump and drainage system as well as a local battery system that maintains vault operations if source power is lost.

Warning systems are also gaining adoption. Florida Power and Light (FPL), for example, took a lesson from Sandy and installed 223 flood monitors in flood-prone substations to warn operators to de-energize equipment. Eric Silagy, President of FPL, reported that the monitors performed well during Irma. Silagy said:

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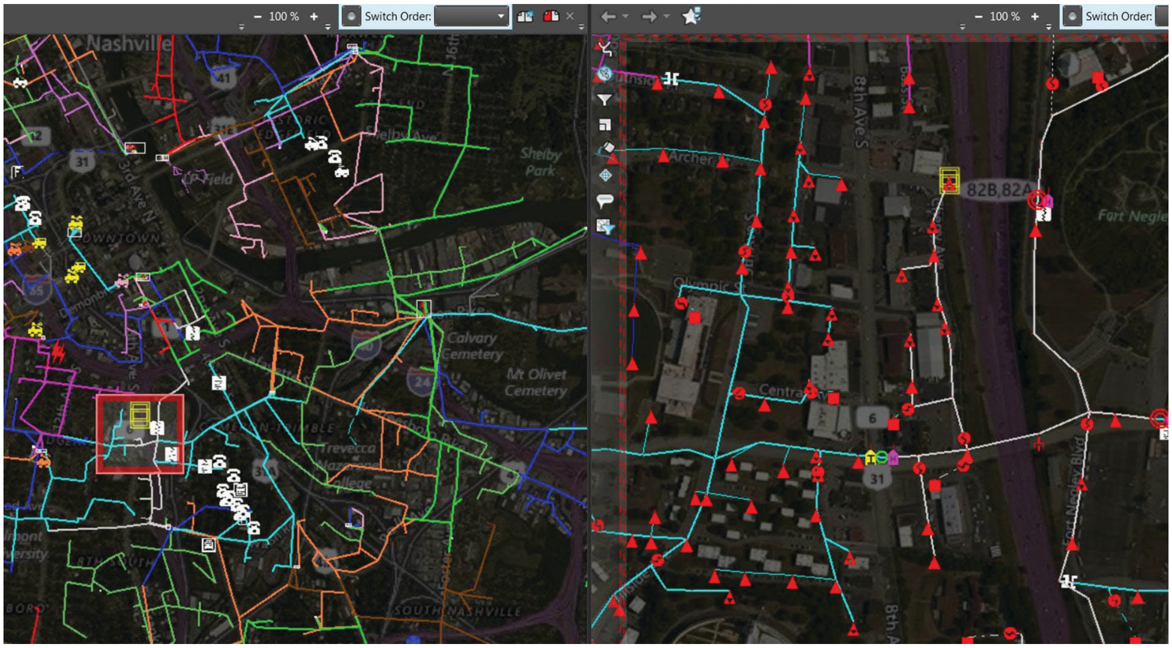
For a landmark substation in Helsinki, an outdoor air-insulated switchgear (AIS) installation was replaced with innovative GIS technology, freeing up 70 percent of the space occupied by the old facility.

“Those flood monitors saved three or four days of work and millions of dollars’ worth of equipment that would have had to be replaced rather than simply re-energized.”[4]

In addition to hardening the substation to protect vulnerable equipment against wind and water, it is important to maintain strategic spare equipment, especially in cases where you have older equipment that is obsolete.

“It is also critical to ensure proper strategic locations of spares,” said Conte who recalls instances where strategic spares were damaged along with the equipment they were designated to replace.”

Optimize Your Data



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Network Manager Advanced Distribution Management System (ADMS)

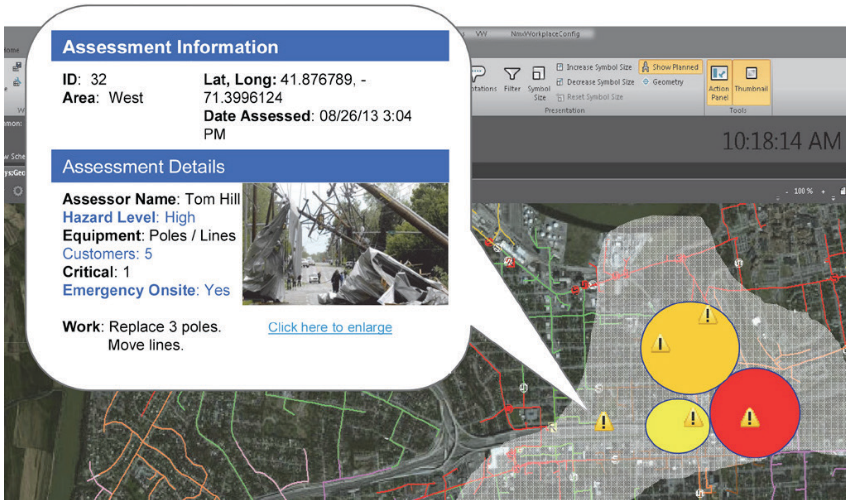
"Every storm makes utilities a little smarter about the weak points on their systems," said Gary Rackliffe, Vice President, Smart Grids North America, ABB. "Utilities can take steps to harden their grids by raising or moving substations, replacing old poles, and installing more resilient breakers, switches, or transformers at critical locations. And now, with the flood of data streaming in from smart grids, utilities are also asking themselves how they can use this technology to manage risk and optimize reliability."

Utilities ask these questions as they not only face the growing threat of extreme weather, but contend with aging infrastructure, the loss of highly experienced workers to retirement, and ever-increasing demand on the grid.

The good news: In our digital age, utilities no longer have to rely on fixed, time-based maintenance schedules and staff judgment to drive maintenance and replacement decisions. According to Greentech Media (GTM): "With widespread communications, low [data] processing costs and continued deployment of intelligent equipment, businesses can collect and analyze far more data from the field than ever before." [5]

Done right, the convergence of information technology (IT) and operational technology (OT) provides actionable intelligence to base asset replacement decisions – called conditioned-based maintenance (CBM) vs. time- or interval-based maintenance. The goal, of course, is to reduce risk of failure and optimize reliability by identifying vulnerabilities – both during normal operations and under the stress of natural disasters while, at the same time, reducing maintenance costs.

The driver is mountains of data – collected and streamed by intelligent sensors and advanced metering infrastructure (AMI). Utilities need tools to unlock and make sense of that data. Advanced Distribution Management Systems (ADMS), with advanced analytics, fulfill this need, performing as the heart of a smart grid.



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ADMS connects the control room to the grid, providing actionable intelligence on the location and extent of damage.

Before a storm, utilities can simulate the potential impact of a future storm to predict likely trouble spots and refine plans to place crews and locate replacement equipment and supplies. Then, during a storm, ADMS can automatically reconfigure grid systems to isolate faults or outages. By giving utilities greater visibility into the farthest reaches of distribution systems – places they couldn't see before – operators or closed loop enterprise software applications can tell when there is a need to proactively operate taps, capacitor banks, DERs, or other devices to keep the grid functioning.

"ADMS has the ability not only to identify the location of a fault along a feeder, but also the exact pieces of protection equipment that operated and the geographic extent of the outage," said John Barnick, Industry Solution Executive, ABB Enterprise Software.

"This allows utilities to dispatch repair crews exactly when and where needed. No consumer phone calls required."

As sensor prices fall and their reliability grows, investment decisions have become easier. The same can be said about the availability of the IP communications networks needed to transmit that data. The upfront investment varies with the scale of the utility and the scope of implementation, but payback comes quickly, typically in two to three years. For example, according to ABB analysis, a catastrophic transformer failure can cost from three to 10 times the price of the equipment itself.

CASE STUDY

CenterPoint Intelligent Self-Healing Grid

Quickly identifies, isolates & restores outages

2.4 million advanced meters and monitoring devices feed data into the system

Powered by ABB's advanced distribution management system **(ADMS) – the heart of the system**

1 Plan

- Library of storm models
- What-if analysis
- Notificaton preferences
- Asset performance management inte-gration

2 Prepare

- Projection model for impending storms
- Assess resource needs
- Prepare for mutual assistance callouts and onboarding

3 Assess & Restore

- Damage assessment & outage analysis in near-real time
- Isolate faults and re-route power (self-healing)
- Prioritize work & dispatch crews
- Notify stakeholders

4 Closeout

- Post event analysis & reports
- Build data for future planning & grid hardening

The Grid in Action

Test #1 – a 200-year spring storm floods Houston in 2016

- 13"+ of rain in 6 hours
- Extreme wind, lightening & catastrophic flooding
- 600 overhead line fuses & 650 transformers out
- Power restored to 90% of 240,000 customers in 27 hours

Hurricane Harvey – a record-breaking hurricane

- 52 inches of rainfall in southeast Texas
- At its peak, one third of Houston was underwater
- 293 circuits and 4,494 fuses out
- Award-wining response
- Restored 1.2 million outages
- Avoided 41 million outage minutes

By the numbers to date

- Reduced outages by 200+ million minutes
- Enabled restoration of 1.5 million outage cases without customer phone calls
- Saved consumers $20-25 million per year
- Saved fuel equivalent to 14,000 tons+ CO_2 emissions

What actions are you taking on the front end of storm season to increase the speed of your post-storm response?

34%
Reported they are partnering with suppliers to ensure material support capabilities

32%
Are working with suppliers to prepare storm response

SOUTHWIRE COMPANY AND UTILITY DIVE BRAND STUDIO SURVEYED MORE THAN 100 INDUSTRY EXECUTIVES. [6]

Vendor relationships
Just as utilities have moved toward formalizing mutual assistance programs, they are also increasingly engaging in advanced storm planning and agreements with vendors. They want the comfort and confidence of knowing that the necessary people, capabilities and resources can be rapidly mobilized when the call comes. These plans may include:

- A single point of contact so it is clear who to call when the time comes
- Defined roles and responsibilities, requirements, estimated scope of work, and manpower
- A blanket PO, typically including a not-to-exceed amount and finalized invoice process for easy flow, sign off, and payment
- Defined work locations (may be vendor or customer or both)
- A safety training plan (may include training in advance and on site to ensure everyone is working to the desired level of safety as determined by the customer's specific safety requirements)

Of course, storms are unpredictable, and some specifics are undeterminable in advance, but laying the groundwork can provide a solid foundation to allow vendors to put resources – from first responders to engineers and technicians to the factories that supply the products – on high alert to respond to specific needs and priorities. The ideal partner is responsive, flexible and prepared to engage at all levels as a member of your extended team.

Acting as an extended part of a team can take many forms. For example, ABB first responder Tony Conte served as JCP&L's single point of contact during ABB's reconstruction of 13 flooded substations after Sandy struck.

"I made the customer feel comfortable and confident that we had the resources to get the job done." Even when needs cropped up that were beyond ABB's usual scope, from painting to portable toilets, Conte stepped up to fill the gap.

> "The customer needed solutions, and he needed them urgently, without delay."

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01 ABB facilities at Warminster and Quakertown were quickly set up as work locations to receive and refurbish damaged equipment. Because some of the equipment was 20-40 years old, replacement parts were difficult to source and match, even with ABB factories providing emergency support. But time was critical, and ABB technicians proved to have the knowledge, ingenuity and tenacity to be up for the challenge.

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02 Example of bus work and insulators that were refurbished to fit into existing frames on site.

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03 Refurbished equipment, including switchgear, transformer and breaker control cabinets and protection and control panels, was then shipped to the field. Technicians worked day and night to complete field testing and verification to put the substations back in operation as quickly as possible.

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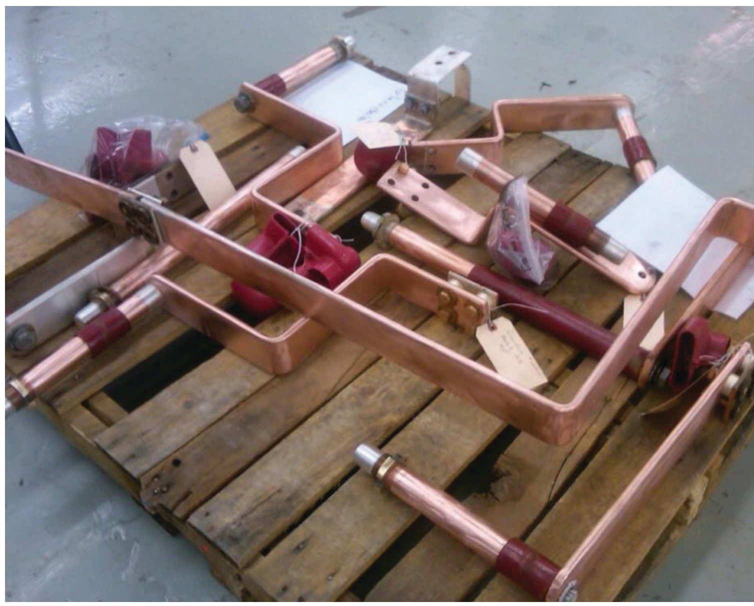

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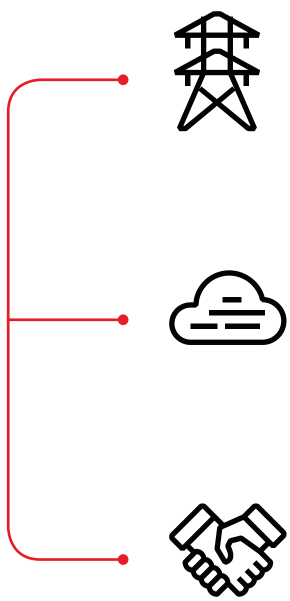
Moving from a reactive to a proactive stance

In the face of changing weather patterns and ferocious storms, utilities are becoming increasingly proactive in their storm preparedness efforts. They are focuing on multiple fronts, taking actions that are:



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Hard to protect infrastructure

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Smart to turn mountains of historical and real-time data into vital intelligence

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Soft to build relationships, plans and agreements to ensure vendors have what they need to hit the ground running when disaster strikes

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