14 Dec 2017 | 14:00 GMT

How to Build a More Resilient Power Grid

During big storms, falling trees cause more damage to power grids than strong winds

By **David Wagman**

Photo: REUTERS/Eduardo Munoz

After Superstorm Sandy hit New York City in October 2012, the city's famous skyline was mostly dark.

Special Report: Puerto Rico After the Storm

North America's electric transmission may be an engineering marvel, but that doesn't make it immune to failure, sometimes in spectacular fashion. For proof, just mention some dates and names to Nicholas Abi-Samra and wait for his reply.

Abi-Samra has more than 35 years of experience in power generation, transmission, distribution, retail, and end-use energy applications. He is president of Electric Power & Energy Consulting and an adjunct professor with UC San Diego. He also is the author of a new book: *Power Grid Resiliency for Adverse Conditions* (Artech House, 2017).

The book is part technical reference guide and part history lesson. In it, Abi-Samra describes the impacts of heat waves, ice storms, and hurricanes on grid operations through case studies from North America, Europe, and Asia.

Start with the 1965 Northeast blackout. It cascaded from Ontario and upper New York State through Manhattan, leaving millions of New Yorkers in the dark. That incident offered the first large-scale evidence of the vulnerability of North America's interconnected grid. It also led to the creation of the Electric Power Research Institute (EPRI), Abi-Samra says, and its mission to enhance grid reliability through research and cooperation across the industry.

Mention the 2003 Northeast blackout and Abi-Samra links it to a realization that the grid's operating conditions were not visible enough. Remedies included technologies like synchophasors and operational strategies like load shedding.

Synchophasors measure the instantaneous voltage, current, and frequency at specific locations on the grid, offering operators a near-real-time picture of what's happening on the system, which lets them take action to prevent power outages.

Load shedding involves the short-term interruption of power to one or more end users to allow the grid to rebalance itself. Many industrial-scale power users trade off the occasional loss of power for lower power prices, known as "interruptible rates."

The early 2000s were also marked by hurricanes that hit Florida and Louisiana particularly hard. Widespread loss of transmission and distribution poles led to efforts to replace wooden poles with steel and concrete. Further hardening came after Hurricane Katrina devastated substations, leading to investments to elevate them above storm surge levels.

Superstorm Sandy in 2012 exposed storm vulnerabilities in the Northeast, particularly the near-impossibility of insulating a system from damage in the face of fearsome winds and flooding.

The idea that resulted from Sandy was to "allow the system to fail, but in such a way that it could quickly recover," Abi-Samra says. This illustrates another lesson: Efforts intended merely to harden infrastructure are not enough—the grid also needs to be resilient.

Hardening and resiliency are different concepts, Abi-Samra says. Resiliency refers to characteristics of the infrastructure and operations such as strength and the ability to make a fast recovery, which help utilities minimize or altogether avoid disruptions during and after an extreme weather event.

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Abi-Samra says that making the power distribution system more resilient starts with design changes. It may be advantageous, for example, to split up a large network into smaller circuits, and to reexamine circuit arrangements to enhance the speed of repair.

Greater deployment of smart grid technology can also help. With it, when an outage occurs, intelligent switches can detect a short circuit, block power flows to the affected area, communicate with nearby switches to reroute power around the problem, and keep as many users energized as possible.

And because these intelligent switches do this automatically, they can reduce the time it takes to restore power to just a few minutes, Abi-Samra says.

For example, when Hurricane Harvey hit Texas in August, local utility CenterPoint operated more than 250 intelligent switches on its network. The effort saved more than 40 million outage minutes, Abi-Samra says. The utility also used smart meters to remotely disconnect customers. Both measures helped to minimize the storm's impact and speed up restoration efforts.

Abi-Samra is a proponent of distributed generation resources and microgrids. Indeed, microgrids are part of a 10-year, $17 billion plan to rebuild and modernize Puerto Rico's electric system, which was largely destroyed by Hurricane Maria in September. The combination of distributed energy resources like rooftop solar, battery energy storage, and microgrids could better protect hospitals and government buildings, large employers, and vulnerable communities.

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But such approaches are not a panacea to preventing grid failures, he says, and the interconnected grid still has a lot to offer.

When an area is hit by severe weather, adjoining utilities can offer support by supplying power and ancillary services. That value may be best demonstrated during summer heat waves, when generating resources from across a region are summoned to meet soaring demand for air-conditioning in businesses and homes.

But when it comes to the massive destruction suffered by Puerto Rico, Abi-Samra says the biggest lessons may involve nothing more technical than a chainsaw and a bucket truck.

In part, he says, Puerto Rico's grid disaster is the story of a financially struggling utility that deferred maintenance, limped along with a shortage of maintenance workers, and let slide seemingly mundane tasks like tree trimming.

Because as much as 45 percent of reliability incidents are due to vegetation, efforts to harden Puerto Rico's electric system could benefit from simply revisiting its vegetation management strategy, Abi-Samra says.

"Flying debris such as roofs and road signs and vegetation such as falling trees and limbs are the primary causes of distribution-pole damage during a storm, not strong winds themselves," he says.

What's more, the risk of airborne debris coming from trees outside of the right-of-way can exceed the risk from trees inside the right-of-way by a factor of as much as four to one. "Vegetation management on the right-of-way only is not enough," he says.

Hurricane Maria in September and Superstorm Sandy in 2012 both showed that no amount of reinforcement and preparation can completely eliminate damage.

Abi-Samra says that structurally hardening the distribution system should focus on two objectives: hardening circuits that feed critical loads and load centers, and designing systems to allow for quick restoration.

"A cost-effective hardening approach should start with substations, feeders, and circuits which serve critical infrastructure such as hospitals," he says. Once that is complete, the remaining feeders can then be prioritized.

The most common hardening practices include replacing wooden utility poles with poles made of steel, concrete, or a composite material; upgrading transmission towers from aluminum to galvanized-steel lattice or concrete; and installing guy wires and other structural supports.

In the end, Abi-Samra says it's unrealistic to think that damage to the grid can be avoided when severe storms or other events occur. Instead, he says the goal should be to minimize any adverse impacts. Microgrids, distributed generation resources, smart grid technologies, and operational analytics all can enhance resiliency.

"Put intelligence on top of that," he says, "and you can make life better for the public."