In the aftermath of Hurricane Maria, the island of Puerto Rico has been devastated with a loss of their electrical power infrastructure and lack of fresh water. The electrical infrastructure efforts are estimated to bring power back to the island in six months.

The Puerto Rico Electric Power Authority (PREPA) is the only power distributor on the island. PREPA’s power plants were 44 years old when Hurricane Maria struck; most industry power plants average 18 years. They burned Venezuelan oil at these aging power plants which needed billions of dollars in overdue repairs and renovation. Puerto Rico being essentially bankrupt did not help. This is a lesson for other governments to make sure their citizens are well protected for typical catastrophes that occur in their region.

The re-building of the power infrastructure

Of course, re-building the power infrastructure must happen as soon as possible, but hardening and resiliency must be built into any such system. Let’s start with the U.S. Department of Energy (DoE) guidelines for this effort. These guidelines were created after the 2005 and 2008 hurricane seasons in the U.S. The document covers refiners, petroleum product pipeline operators, and electric utilities located in the Gulf Coast of the United States.

Definitions

Hardening refers to physically changing the infrastructure to make it less susceptible to damage from extreme wind, flooding, or flying debris. This makes the architectures better able to withstand the impacts of hurricanes and weather events without sustaining major damage.

Resiliency, refers to the ability of an energy facility to recover quickly from damage to any of its components or to any of the external systems on which it depends. These types of measures do not prevent damage; instead they enable energy systems to continue operating despite damage and/or promote a rapid return to normal operations when damages/outages do occur. See Table 1 for a summary of findings from research by the U.S. DoE.

Table 1 A summary of findings for energy hardening and resiliency
Puerto Rico’s gas stations and fuel storage areas were also heavily affected by Hurricane Maria, but we will not cover that aspect of hardening/resiliency here in this article; however, you can see suggestions for that in Table 1.

**A major problem with most electric power utilities**

Most power utilities design and maintain their system architecture around normal weather conditions expected in the area (Maybe hurricanes are a normal condition in Puerto Rico, but their financial situation was not healthy, so PREPA may have had financial concerns or just did not take adequate steps to prepare for such an event as Hurricane Maria).

Power utilities seem to feel that it is not economical to design their systems to handle extreme
weather conditions, but instead focus upon the efficient restoring of power after such a major event. As we saw in Puerto Rico, that thinking did not work out so well.

So, most electrical utilities will design their systems to local National Electrical Safety Codes (the IEEE has the NESC on their website).

**Electric power infrastructure hardening**

**Electric power infrastructure hardening**

![Final Hardening Measures](image)

NYC’s Con Edison storm-hardening strategy after superstorm Sandy hit NY on Oct. 29, 2012 (Image courtesy of Con Edison)

**Wind protection**

A good example of wind hardening is Florida Power and Light (FPL) which has been tracking power distribution pole failures from hurricanes since 1992 along with other equipment failures (Table 2).

**Table 2** Failure rates of power distribution poles for past hurricanes
FPL knows the number of distribution poles which are exposed to hurricane winds. They take this data and couple it with the total number of broken poles to compute pole failure for each hurricane (Note that Andrew was a Category 5). They do not look at overall pole failure rates, but instead those that showed high failure rates to see which ones are more prone to failure. This is still fairly economical since they do not strengthen every single pole that fails. They also investigate if a wooden pole was treated with Creosote or CCA and look to see if that pole is on a main trunk feeder or a lateral branch (Figure 1). It is interesting to note that FPL stopped purchasing Creosote poles in 1978.

To add stronger poles where needed, the best alternatives to wood for strong distribution poles are steel and composite (concrete is usually too heavy for typical digger-derrick trucks). Existing poles can be strengthened with a steel brace mounted at the bottom driven into the ground. Fiberglass wraps are also sometimes a good solution, but is more costly. Guy wires may also be used.
Figure 2 A pole truss shown by the red arrow

Shorter spans between poles can be considered, this helps with the conductor wires having less chance of snapping in a high wind. Conductor sizes with smaller diameters helps increase the extreme wind rating without needing shorter spans or stronger poles depending upon the regions typical weather patterns. Moving pole-mounted transformers to a ground pad mounting scheme can also help harden the utility poles.

Ultimately, underground distribution can be considered in extreme cases such as Puerto Rico and other Caribbean islands. Drawbacks are higher installation cost, flooding, uprooted trees nearby, and longer restoration times for that type of solution if damaged. Consider the six months it will take to get Puerto Rico power back to its residents.

Flood protection

Flood protection
In this scenario, elevating substations may be considered or re-locating to areas less likely to flood. Elevating to a 25-foot level will be for a Category 3 storm. Elevating a substation for a Category 4 or 5 storm has not been a common practice due to much higher costs, until now! Some utilities might consider spare equipment instead.

**Modernization**

Here is an area that Puerto Rico’s PREPA went 44 years without paying much attention to this aspect.

Utilities can now consider implementation of new technology such as improved supervisory control and data acquisition (SCADA) systems, *Geographic Information System* (GIS) systems, and advanced switching mechanisms to self-diagnose and repair problems and promote greater efficiency of the grid.

**Electric power infrastructure resiliency**

Pole maintenance and regular inspections are a common resiliency activity that we often see in our neighborhoods. That, along with Vegetation Management around the poles and wires can be a good general way to improve resiliency.

Utilities can also choose to use mobile transformers and substations to temporarily replace damaged assets. A mobile substation consists of a trailer, switchgear, breakers, emergency power supply, and a transformer with enhanced cooling capability. These units will provide a temporary restoration of grid service while circumventing damaged substation equipment, allowing time to repair grid components. Mobile transformers are capable of restoring substation operations in some cases.
within 12-24 hours.

**Readiness**

An important storm-specific readiness activity that some utilities employ is to secure fuel contracts for post storm recovery needs such as emergency operations and repair vehicles. Most of the companies reported having fuel contracts in place to cover fuel for emergency vehicles and small portable generators, which are necessary to power operations and IT sites. Some companies even have emergency plans to arrange for skid tanks – portable fuel tanks used for refueling vehicles – to be delivered to pre-determined locations following a storm. Puerto Rico has the fuel, but cannot get it to hospitals for their generators or to other areas right now.

**Other solutions: Thinking ‘outside the box’**

Mobile transformer substations can be purchased or leased for temporary substation power in the 10 to 100 MVA range. Mobile substations include the trailer, switchgear, breakers, emergency or station power supply, a compact high-power-density transformer, and enhanced cooling capability. Hospitals and critical services can be up and running inside of 12-24 hours and can run for a while until power can be restored region-by-region.

![Figure 4](image-url) Don’t discount a trailer-mounted mobile transformer team

Let’s get engineers creatively working to make this world a safer and better place to live in. Governments and utility companies need to get funding in place for these safety measures to prevent another occurrence like Puerto Rico’s incredible trial after Hurricane Maria.

Steve Taranovich is a senior technical editor at EDN with 45 years of experience in the electronics industry.

**References**
4. Hurricanes and Power distribution system architecture: Puerto Rico, Planet Analog
5. Storm Hardening the Grid, T&D World Magazine, Paul Maudlin, Oct 1, 2014

Also see:

- Hurricanes and Power distribution system architecture: Puerto Rico
- Power grid blackouts: Are they preventable and predictable?
- Electronics brought to extremes by Sandy
- The Tesla Model S, ultracapacitors, and large energy storage
- How smart is it to deploy smart meters on the smart grid?