CRITICAL INFRASTRUCTURE FOR CRITICAL TIMES

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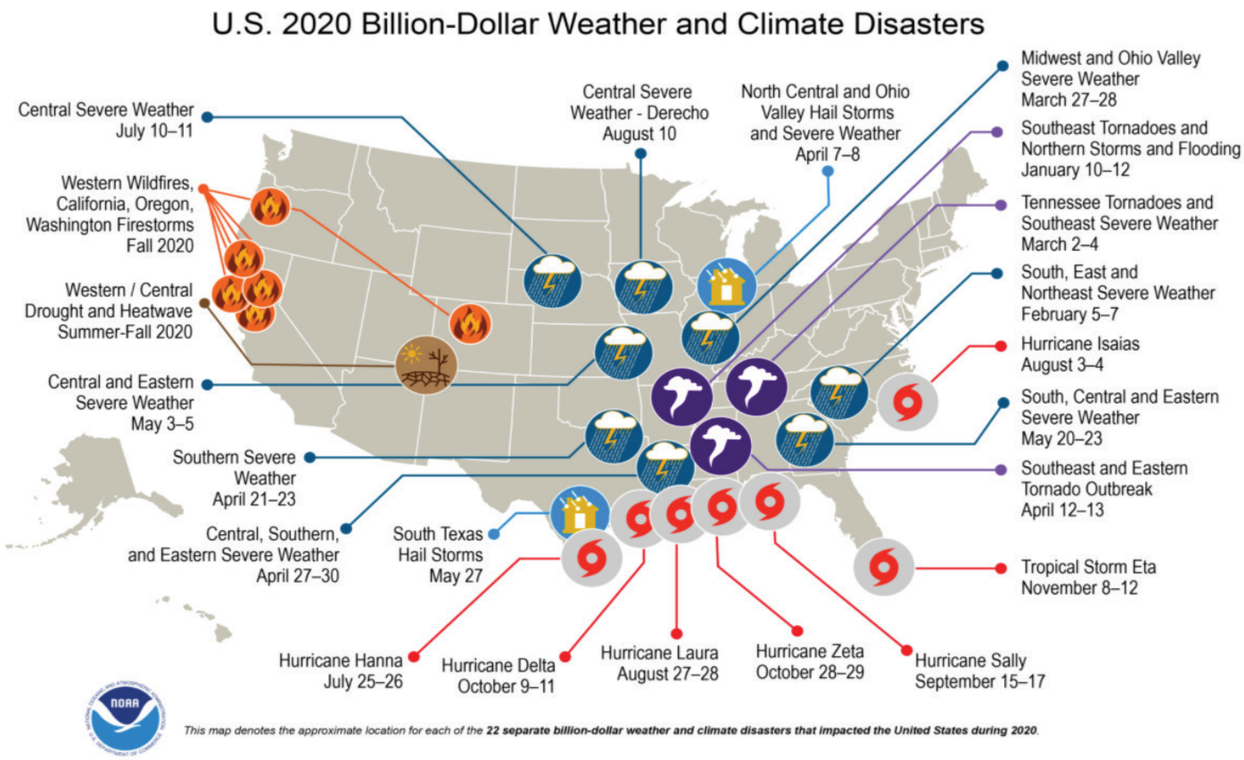
Customers without electricity for days or weeks? Does that happen in the United States of America in the 21st Century? Increasingly, the answer is yes. Wildfires, hurricanes, ice storms, floods and more seem to come more frequently and with greater intensity.

It is well past time to accept these devasting and life-threatening outcomes and pursue new approaches to resiliency to protect our communities from high-impact, low-frequency (HILF) or “Black Sky Hazard“ events.

Electricity is fundamental to the health, safety, and economic vitality of our country. It is the fundamental critical infrastructure that must operate for other critical infrastructure to function. Communications, water purification and distribution, wastewater systems, fuels, transportation, medical services, financial systems, and physical security do not function when impacted from HILF events without a resilient electric system.

According to the National Oceanic and Atmospheric Administration (NOAA), the United States experienced 22 separate billion-dollar weather and climate disasters events in 2020. Significant and major power outages were associated with these events.



NOAA National Centers for Environmental Information "U.S. Billion-Dollar Weather and Climate Disasters: 2020 Events"

The trend in 2021 was not better. The extreme cold weather event in February from Winter Storm Uri wreaked havoc on the Midwest. Texas suffered outages and rolling blackouts for days. The event initiated a FERC-NERC investigation into the impacts and causes. Massive power outages occurred when Hurricane Ida hit landfall in Louisiana in August. New Orleans went black for days when all eight transmission lines into New Orleans were damaged from the hurricane winds and debris. The extent of damage that caused widespread destruction across five states from the recent tornado outbreak and derecho winds from Colorado to Michigan in December is still being determined. Other notable events in recent years include the 2017 Hurricane Harvey flooding in Houston, the 2017 Hurricane Maria devastation in Puerto Rico and the U.S. Virgin Islands, the 2018 Bomb Cyclone that caused severe disruption along the East Coast and Canada, the 2018 Camp Fire that was the deadliest and most destructive wildfire in California history, the 2019 Polar Vortex that created a severe cold wave in the Midwestern United States and Canada, and the increases of wildfires in the west.

The value of critical electric service and critical infrastructure that electricity supports immediately after these high-impact storms and events is immense. Without some level of survival of the electric system lives are lost; local commerce, education and medical care grinds to a halt; and personal safety, security and well-being are at perilous risk. The frequency and magnitude of these HILF events are increasing, and improving the resiliency of our electric grid is therefore imperative, and will be the key to managing an uncertain future of more HILF events.

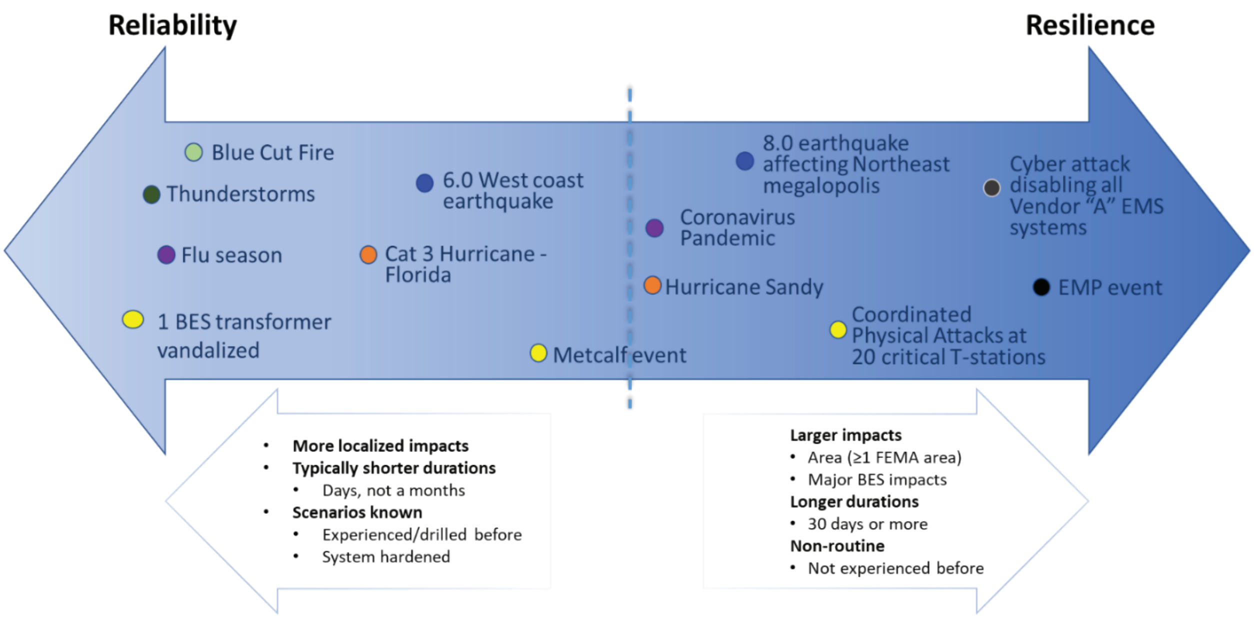
June 2005 wildfire in southwest Phoenix, Arizona area causing outage on six circuits of 500kV, 345kV and 230kV transmission lines.

What is Resiliency?

Many organizations, including the Electric Power Research Institute (EPRI), the North American Electric Reliability Corporation (NERC) and the North American Transmission Forum (NATF), have developed succinct definitions of resiliency in the context of electric infrastructure. In short, resiliency is the ability to reduce the magnitude and/or duration of extreme disruptive events through prevention & preparedness, response, and recovery.

Improving resiliency doesn't mean building everything bigger and stronger: that may not be the most economical choice or the best use of resources. Improved resiliency should prevent a complete loss or collapse of the electric system by prioritizing the survival of key elements of the electric system that support critical infrastructure, with the remaining electric system able to be more readily and rapidly restored building off of the surviving core. A resilient electric system will provide continuity of service to all areas of critical infrastructure as well as targeted and select areas in the community. There may be some failures or losses, but the failures from the HILF events should not lead to a total loss of the system. As a result, the more resilient system can be restored faster, with better triage and restoration time estimates for stakeholders.

There is a gray line between major adverse reliability events and events that are considered extreme catastrophic resiliency events. NATF collaborated with EPRI, U.S. Department of Energy (DOE), and the Pacific Northwest National Laboratory (PNNL) to develop a Transmission Resilience Maturity Model (TRMM). The NATF figure below provides a relative perspective of extreme and catastrophic events on the reliability-resiliency continuum spectrum and the key differentiators that define resiliency events.



Reliability-Resilience Continuum Diagram – NATF "Transmission Resilience Maturity Model (TRMM)" 2021

Improvements made to increase reliability performance during HILF events do not necessarily increase resiliency performance. However, improvements made to increase resiliency during HILF events will improve the reliability performance during major adverse reliability events.

As noted previously, an unfortunate trend is that these major events are adversely impacting the electric system with increased frequency, impacting larger areas, more people, and for longer periods of time. Beyond preparing for natural occurrences (e.g., extreme storms of all types, earthquakes, volcanoes, tsunamis), utilities need to be prepared for a wide range of HILF resiliency events, including cyber attacks, physical security attacks, sabotage, terrorism, communication failures, geomagnetic and electromagnetic disturbances, and systemic software and technology failures. Developing comprehensive resiliency plans for HILF events is under-appreciated but vital. Utilities must do more to strategically plan and enhance the electric grid to survive HILF events and incorporate resiliency as a cornerstone of electric service.

How can we build a better and more resilient electric grid that serves us when we need it most?

A new definition of microgrid is a good start. A new microgrid approach to improved resiliency needs to be holistic with strong integration amongst traditional and renewable generation resources, transmission, distribution, and end users. Utilities need to strategically build microgrids that reduce risks and exposures by initiating long-term investments to achieve high levels of resiliency maturity against HILF events for all stakeholders.

New Microgrids

Microgrids must be planned, designed, and built to provide real resiliency to communities of all sizes. In the past, many have envisioned microgrids as self-sustaining electric islands that can be separated from the grid in times of distress and operate autonomously for extended periods of time relying on distributed generation sources. However, conceptual microgrids do not achieve economic and environmental objectives and, therefore, utilities have not incorporated this approach into their resiliency plans.

An upgraded and hardened substation will be a key
part of a new, reimagined microgrid.

We need to redefine a microgrid. A microgrid should be “reimagined” with the development of electric infrastructure that will provide critical electric service to strategic areas throughout a community during times of greatest distress. This includes targeted hardening and strategic undergrounding of the most critical transmission and distribution lines and upgrading substations to ensure electric service can be provided to other critical infrastructure and areas designated as critical for continuity of communities.

Imagine a select portion of the grid remaining in service after a wide area catastrophic event. The surviving partial system would provide service to multiple small portions of communities across a large metro area. Homes may be out of power, but potable water would still be available. The toilets could be flushed and sanitary systems could still operate. Mobile phones could still operate and customers would still have access to news and emergency information. Phone charging stations could be available and a limited number of grocery stores and gas stations could still operate. Community centers could be available for heating or cooling in extreme weather as well as providing food, water, and shelter.

Reimagined microgrids will survive catastrophic events, remain operational, and provide electric service to multiple small areas (microgrids) of communities across large service territories.

Part of this new approach to incorporate resiliency into the grid is to rethink how the most critical corridors, circuits, stations, and equipment are planned, designed, constructed, and protected. They should be planned, designed, constructed, and protected much the same as black start generation and cranking paths.

Utilities could prioritize these resiliency paths, circuits, stations, or equipment for the different parts of their grid. For resiliency purposes, the portions that should never go down during a HILF event could be designated as “Secure And Functional.” The next highest level would be those lines and stations that would be restored first. They would be designed and constructed such they would sustain much less damage and could be restored more rapidly than other lines. They could be designated as “Prepared For Rapid Restoration.” Lastly, the other parts of the system would be designated as “Standard Construction.”

High quality standards keep utilities focused on average reliability performance and not resiliency. In the past, utilities worked hard to make the electric grid as uniform as possible. This provided consistent training, material inventory, tools, economics, and uniformity across the service territory. Standards assume average life span for normalized events over the depreciation time frame. They do not consider or incorporate HILF events. Typical use of standards blinds utilities from resiliency measures like functional microgrids.

In the future, utilities need to optimize the principles of prevent, respond, and recover into the planning, design, construction, and operation of a more resilient grid.

This important corridor could be designated “Secure & Functional” and have at least one underground circuit to the microgrid.

Common corridors are big resiliency risks. Utilities evaluate multiple circuits on common structures and multiple circuits in a single right-of-way width from a reliability perspective. Detailed analytical studies are based on deterministic and statistical computations for likelihood of occurrence, loss of load probability, and other such approaches. There are reliability standards for common corridors. However, they are not evaluated on a HILF event and resilience basis.

Undergrounding just one transmission line in a common corridor can mitigate the losses from several types of HILF events, such as wind and debris from extreme storms of all types, wildfires, flooding, environmental contamination, physical attacks, and terrorism.

Building Long-term Resiliency

Building for resiliency is comparable to physical financial risk hedging against a HILF event. As there are no financial instruments that can purchase operational physical infrastructure, especially in the aftermath of a catastrophic HILF event, utilities should invest in physical resiliency as the alternative to spending money purchasing risk damage insurance.

Industry groups such as EPRI, NATF, NERC, and others have been advocating for increased resiliency against catastrophic HILF events for over a decade. However, utilities have many current and near-term pressing requirements, such as:

1) Decarbonizing the grid (clean energy conversion at utility scale, DER integration, EV integration, system improvements to manage variable energy resources, interconnection queue);
2) New load/customers;
3) Reliability and operational flexibility improvements;
4) Customer improvements;
5) Normal O&M and storm response; and
6) NERC reliability standards.

But the industry needs to undertake a progressive, strategic investment program to harden critical elements of the grid, including strategically undergrounding select transmission and distribution lines to ensure continuity of service and quick restoration. Resiliency will include a stronger grid, upgraded substations, and newly defined microgrids.

Utility executives and local/state regulators are the initial focal point for ensuring there is a focus on resiliency and plans to achieve it. The boards of utilities should ensure resiliency is addressed in strategic plans and funding initiatives. The business community and community leaders should have conversations with utilities and regulators on the need and value of being prepared for HILF events.

Utilities and regulators need to shift some of the reliability expenditures into resiliency investments. There is a lot of complexity and detail to develop a well-conceived resiliency plan. Resiliency improvements usually have the effect of providing benefits to reliability.

Planning, designing, and building resiliency improvements like new microgrids along with all the other O&M and capital improvements is a tremendous coordination challenge. Only so much work can be done in any given year. These types of resiliency improvements take time and utilities need to develop 5-, 10-, and 20-year plans to achieve resiliency goals.

When considering the costs and benefits of improved resiliency, utilities and regulators must work collaboratively to define the needs for the communities they serve and regulate. Long term plans need to be developed to achieve high levels of resiliency maturity for HILF events. They must identify permanent funding mechanisms to provide certainty to the plans and improvements. One such option can be the development of a small percentage of overall spending specifically dedicated to microgrid resiliency plans. The value of the resiliency improvements should quantify items not normally captured by traditional cost/benefit analysis such as:

- direct cost of losses to homeowners and businesses;
- negative impact on life and property;
- the immediate and near-term economic impact to the community;
- the long-term impact to the economy; and
- the negative impact to the social fabric of the community.

The economic and social impact to communities needs to be incorporated into the overall assessment. The Total Cost of Ownership (TCO) over the life of the asset has been neglected by most of the electric utility industry for decades.

The industry must address Total Cost of Ownership (TCO) over the life of the asset.

Catastrophic HILF events could happen at any time. Utilities always need to be prepared for any type of catastrophic event. A failure to act now means that the scenarios that happened in Texas and New Orleans will be repeated many times in the future. There is a lot of complexity and detail to develop a well-conceived resiliency plan that includes reimagined microgrids.

Resiliency improvements to the electric system must be made as cities and communities develop and implement a strategic program of resiliency so that no metro, urban or rural area is in this situation again.

Conclusions

The value of critical electric service and the critical infrastructure that electricity supports immediately after these high-impact storms and events is immense. Lives are lost; local commerce, education, and medical care grinds to a halt; and personal safety, security and well-being are at heightened risk when the electricity is off. Electricity is critical to protect the vitality of communities, and that pressure increases with the sizes and densities of metro areas.

The challenges for improved resiliency become even greater as electrification of buildings and the transportation sector are considered.

Knowing and having certainty that your community is safe, has access to the basics of life, and that help is on the way allows the community to come together with neighbors helping neighbors.

A well planned, designed, and built resilient electric system will provide continuity of service to all areas of critical infrastructure as well as to targeted and select areas in the community. Improved resiliency does not necessarily require that everything be built bigger and stronger. A resilient electric system with microgrids that serve critical loads will not allow a total loss of the system and everything it serves. Improved resiliency maintains service to critical infrastructure and allows for better triage, better restoration estimates, and more rapid responses on the balance of the system.

This new paradigm of planning, design, and prudent investment in reimagined microgrids with strategic hardening and undergrounding of lines will prepare us for the high impact storms, wildfires, attacks, and other HILF events of the future, and dramatically reduce the negative impacts on life, property, business, the economy, and the community social fabric. Now is the time to start.

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Robert Kondziolka has over 40 years of electric utility experience at Tucson Electric Power Company and Salt River Project. He received a Bachelor of Science in Civil Engineering from the University of Arizona with an emphasis in structural/geotechnical engineering and is a registered Professional Engineer. During his career he has served in, held leadership positions in or received awards from ASCE, CIGRE, EPRI, NSPE, NATF, RMEL and WECC. He is currently a Governing Body member and Vice Chair of the CAISO Western Energy Imbalance Market.

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