

WHITE PAPER / FLOOD LOADING AND ELECTRICAL DISTRIBUTION

BUILDING HARDENED, FUTURE-READY ELECTRICAL INFRASTRUCTURE

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Hurricanes and flooding can cause extended power outages and lead to major financial losses. Upgrading equipment and constructing robust infrastructure can help in delivering continuous service to customers, saving millions of dollars otherwise lost during flooding events.



Reliability is essential to all electrical utility customers, from residential to commercial and beyond. Utilities are increasingly required by regulators and local jurisdictions to enact measures to improve resiliency. Prolonged power interruptions can cause huge economic losses, so utilities must identify challenges that can disrupt their systems. Utilities operating in coastal flood zones and areas subject to wind-borne debris must pay special attention to storm hardening of their distribution equipment, electrical substations and other transmission assets.

LONG-TERM BENEFITS OF STORM HARDENING

Utilities typically set aside reserves of equipment and capital for disasters. These reserves can be utilized to rapidly respond in emergency situations and restore service as soon as possible. A targeted, detailed storm-hardening plan can help utilities reduce the amount of capital reserves and idle spare equipment while being prepared to maintain a continuous supply of power during severe weather events and natural disasters.

Utilities must proactively identify asset locations that are vulnerable to flooding, storm surge and wind-borne debris and implement storm-hardening programs. Performing a vulnerability assessment helps in needed critical upgrades that will strengthen the infrastructure.

100-YEAR FLOOD

The term “100-year flood” is often used colloquially to mean an event that should only happen precisely once per century. This is a common misconception and does not mean 100 years should pass between floods of equal or greater magnitude. Rather, it refers to an event that has a 1% probability of occurring in any given year. A common misconception is that elevating equipment above the 100-year flood elevation on the Flood Insurance Rate Map (FIRM) provides adequate protection from flooding events. However, that may not be sufficient in all cases and locations.

SUBSTATION DESIGN CRITERIA AND MEASURES

To maintain operation of substations during or immediately after a major flood event, an important design measure is to raise all critical equipment above the Design Flood Elevation (DFE). This can be easier said than done.

For greenfield installations, this might require raising the substation site, potentially requiring substantial amounts of fill. This solution may not be ideal, as it could increase the flood risk for adjacent properties. Alternatively, elevating equipment on taller supports may be a prudent solution. Either of these approaches could introduce additional costs to a project. However, it is important to keep in mind the resulting benefits in reliability and risk reduction. Depending on what design phase the project is in, it might even be prudent to consider an alternative site in a lower-risk area that may have lower overall costs once flood mitigation measures are factored in.

For brownfield installations, raising critical equipment above the DFE can be accomplished through retrofits of existing structures.

Beyond adjusting the elevation of facilities due to flood risk, utilities should consider designing for conditions associated with floods, such as buoyancy loads, hydrostatic and hydrodynamic loads, debris impact, soil instability and scour, as well as other local considerations. These can have a significant effect on the structural design, and in-depth knowledge of these effects is needed to determine the appropriate design criteria and methods.

For installations that are in need of retrofit but have not been addressed yet, temporary flood barriers have been successfully used by utilities for rapid response to flooding events.

APPROPRIATE DESIGN FLOOD ELEVATION

Elevation must be a top consideration for flood-resistant construction. While there are multiple national and local sources for flood risk information that prescribe and define risk zones and design elevations, designers must ultimately determine the appropriate equipment elevation for their specific project locations.

The most common design resource used to determine flood risk and flood elevation is the Flood Insurance Rate Map (FIRM), published by the Federal Emergency Management Agency (FEMA). A FIRM depicts the boundaries of flood hazard areas (flood zones) as well as the Base Flood Elevation (BFE). These maps are created using the best available data at the time the map is created, but they do not account for incremental changes in topography, weather patterns, mean water levels or study methodology that could shift the extents of the risk zone boundaries or the BFEs in the future. As flood insurance studies (FIS) and FIRMs are updated periodically, the flood risk for a particular site may change.

When determining a DFE for setting equipment elevation, the designer must take into consideration the current BFE, wave height and storm surge elevation, as well as the appropriate margin of separation above these quantitatively determined values. Given the limitations of FIRMs, when determining an appropriate design margin for a facility that is expected to have a significant service life, it is important to consider possible future changes in risk that could require expensive retrofits to mitigate. It is also important to note that flooding can occur at even more significant levels than the 100-year flood, and thus a utility may want to consider designing for a more significant event to reduce the risk of damage.

A thorough assessment of the site will help quantify these additional considerations and aid in determining an appropriate DFE. This can be an enormous challenge for utilities. Partnering with specialists for this assessment can help in developing a site-specific, risk-informed design.

GOVERNING DESIGN DOCUMENTS

The following documents provide information about design and building requirements for constructing or retrofitting infrastructure in general, as well as flood-resistant design, construction and more:

- **American Society of Civil Engineers (ASCE) 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures:** This standard is an integral part of U.S. codes. It describes the means for establishing soil, flood, tsunami, snow, rain, atmospheric ice, earthquake and wind loads and their combinations for structural design.
- **ASCE 24, Flood Resistant Design and Construction:** This standard is referenced by ASCE 7 and describes minimum requirements for flood-resistant design and construction of structures in flood hazard areas.
- **FEMA 55, Coastal Construction Manual:** This manual describes principles and practices of planning, siting, designing, constructing and maintaining residential buildings in coastal areas. It contains a wealth of information regarding accepted design practices that can improve performance during a flooding event.

FLOOD DESIGN CLASSES

Designing is not merely about floods or wind speeds; safety is equally important. For example, a school or hospital will have design criteria that are more stringent than a house or a restaurant. Flood design classes, which define how important the facility is to the health and welfare of the public, help delineate which requirements should be applied to different facilities. A higher flood design class will have more stringent design requirements.



Flood Design Class	Buildings and Structures
1	That are uninhabited and pose negligible risk to the public or minimum disruption to the community if they are damaged or fail due to flooding.
2	That pose a moderate risk to the public or moderate disruption to the community if they are damaged or fail due to flooding.
3	That pose a high risk to the public or substantial disruption to the community if they are damaged, incapable of performing their expected functions after flooding, or fail due to flooding.
4	That are essential facilities; their services are necessary for emergency response and recovery and would pose a substantial risk to the community at large in the event of failure, disruption of function or damage by flooding.

While a substation is generally unoccupied and therefore does not generally present a direct risk to health and safety, power delivery is critical for the health and welfare of the public. Thus, a flood design class of 3 or 4 is likely appropriate for many substation designs. Transmission and distribution systems are large, interconnected networks typically having multiple redundant paths to service customers. Additionally, the effects of temporary or extended outages have varying effects on the health and safety of the general public or a specific customer. Therefore, perhaps a lower flood design class can be justified if a thorough evaluation of criticality is performed.

CONCLUSION

Assessing and retrofitting existing infrastructure, especially in high-risk flood areas, can help electric utilities meet customer expectations and comply with evolving

regulatory requirements. There is no one-size-fits-all approach to storm hardening, nor are there off-the-shelf solutions that can be implemented. Each utility's challenges are different and ever-changing, and the solutions will vary accordingly. Handling and executing programs of this magnitude can pose several challenges, delay projects and increase expenses. Collaborating with storm-hardening specialists can ease pressures, improve site and regulatory assessments, build robust structures and enhance the customer experience.

BIOGRAPHIES

ANDREW HARPER, PE, is a substation department manager at Burns & McDonnell. He has more than 10 years of experience in seismic analysis and design, substation design, steel design, concrete anchorage and more. He supervises a multidisciplinary team of engineers, designers and drafters who execute substation design projects for a wide range of clients. Andrew earned a Bachelor of Science in civil engineering from Washington University in St. Louis.

ALEX KLADIVA, PE, SE, is a senior structural engineer at Burns & McDonnell. He has more than 10 years of experience in structural analysis, design, specification preparation, coordination with contractors and fabricators, construction administration, field investigation, and project management. He specializes in structural design of substations ranging from 12.5-kV to 345-kV. Alex has also performed forensic investigations of commercial and residential structures to determine the cause of structural damage and has designed new commercial and industrial buildings, as well as building additions and repairs. Alex is an active member of the ASCE 113 committee on substation structures, is secretary of the IEEE 605 committee on bus design in air-insulated substations, and is a member of the ASCE Committee on Transmission and Substation Foundations.