Preventing Damage and Exposure of Energy Infrastructure Through PEER Strategies

Evolving Trends for Efficiency, Reliability and Resiliency

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Abstract
Power is a basic necessity for every human being, if lost or interrupted causes a huge discomfort. Often these interruptions are caused due to external damages and exposure to the environment. In recent times, cities all over the world are facing big challenges due to climate change causing unprecedented rainfall / hurricane leading to flood. During such catastrophic events, communication networks and power supply is essential to keep oneself protected, safe and reach-out for emergency support. Apart from these extreme weather conditions, interruption in grid network is also happening due to tree contact, animal contact, accident due to vehicles or human interference and fire. All these events can cause a significant human & revenue loss if unprepared. Under these circumstances, it is critical we build resilient & reliable grid systems that help us during natural disaster, human error & threats.

The damage that power interruption events caused from a practical and economic standpoint is a key concern for customers. Measuring, reporting, trending, and benchmarking these metrics will assist with identifying poor performance and provide the justification for investment to reduce sustained interruptions and improve reliability. Performance Excellence in Electricity Renewal (PEER) is an effective framework that looks comprehensively on Reliability & Resiliency with specific focus towards damage and exposure prevention. The credit implies on the project to focus on the identification of external threats and measures to mitigate them. It also specifically mention about the hardening of power systems from floods and storms, references to be considered while designing or retrofit, thus reducing the likelihood of equipment failures due to any external & physical threats.

Keywords – External damages, natural disaster, power system hardening, reliability, safety, threats.

1. Introduction

Cities and communities around the world are utilizing new and innovative grid technology to address natural and man-made threats. Often energy infrastructure is tested by blackouts, natural disasters, and an increasing number of cyber-threats, such as the Hurricane Harvey & Irma which damaged the U.S. grid infrastructure in 2017 and the December 2015 cyber attack that took down the Ukraine power grid. While there have been significant strides in some respects, grid inefficiencies and risks are costly, having a multiplier effect and are likely to increase in future. According to NOAA's National Centers for Environmental Information, the United States has suffered 212 weather and climate disasters since 1980 that have cost more than $1 billion, totaling $1.2 trillion[1]. Power interruptions cost European Union businesses €150 billion each year[2]. In India, at Tamilnadu, during the Vardah cyclone in 2016 the state utility, Tamilnadu Generation and Distribution Corporation (TANGEDCO), lost 10,000 electric poles and 800 transformers were damaged causing a loss of more than 1,000 crores[3]. Apart from natural disasters causing damage to energy infrastructure, there are other threats, such as tree falling, animal or vegetation intrusion and human interference that can also cause outages locally. A recent EU study found that €4 billion could be saved annually from using smart grid technologies, such as Advanced Metering Infrastructure (AMI), Undergrounding etc.

This paper talks about how by leveraging damage and exposure preventions strategies in PEER (Performance Excellence in Electricity Renewal) these challenges can be better planned and managed across campuses, communities and cities. PEER is a certification program that measures and improves power system performance and electricity infrastructure.

The comprehensive credit based program is classified under four main categories;

- Reliability & Resiliency
- Energy Efficiency and Environment
- Operations, Management & Safety
- Grid Services

2. Common risks and threats

Common risks and infrequent threats are conditions that occurred in historical data disrupting the quality of electricity delivery such as voltage swings, faulted lines or blown fuse caused due to tree or animal contact, extreme weather or human interference, etc. These types of events can realistically be expected to occur periodically in the region where the project grid is located; for example, cyclones are historically recorded in Balasore, Nellore, but not in Hyderabad. Hence, by doing this assessment, the grid operator can make meaningful decisions to design or make improvements to modernize the electricity grid.

PEER defines the following as common risks and threats that can affect the reliability performance of a grid infrastructure.

- Supply interruptions—originating from;
  - Tree or branch interference
  - Vines causing short circuits
- Unintentional damage to equipment—including damage from;
  - Animal interference
  - Traffic accidents
  - Unintended public exposure
- Extreme weather—depending on the location of the project grid this may include;
  - Flooding / Rainfall
  - Windstorms, Sandstorms, Ice storms
  - Earthquakes

The key objective is to support projects with considerations for common risks and threats, and raise awareness of strategies and measures that can be used to improve reliability by reducing the damages to grid infrastructure.

3. Damage and exposure prevention strategies

Projects around the world are often looking for advanced technologies and innovative solutions to mitigate common risks and threats through prevention of external damages and exposure to the environment. PEER proposes the following techniques or strategies to prevent external damages and threats:

OPTION 1. External damage prevention

A. **Prevention from Tree Contact:**

It is observed that a relatively high percentage of cable failures were caused by tree fall during bad weather. Tree management near distribution lines is an important adaptation action needed to reduce risks of power distribution system outages. The objective here is to prevent cables and power systems from contact with trees.

Tree damage can be organized into five categories:

- Broken branches
- Trunk bending
- Splitting of main or co-dominant stems
- Complete trunk failure
- Tipping or up-rooting

The following are two prevention techniques for avoiding contact between cables and power systems and trees:

1. *Up gradation of overhead distribution lines*
   Upgrading overhead distribution equipment can make the system more resilient against damage from downed trees and limbs. Redesigning wires can also provide better protection from falling tree limbs, and allow them to more easily detach when force on the wire is more extreme to reduce the likelihood of damage to poles and other pole-top equipment. Creating greater tree clearances around distribution facilities near substations and critical infrastructure is also encouraged.

2. *Hazard Tree program and vegetation management*
   Identify trees that are tall enough to contact the overhead distribution system and are also dead, declining, diseased, or otherwise structurally unsound. Some of the important programs in hazard tree management program include:
   - Designating responsible individuals;
   - Identifying and prioritizing the sites to be examined;
   - Performing and documenting the inspection;
   - Performing the necessary actions to reduce the hazards (e.g. vegetation management);
   - Maintaining the records of inspection & actions taken; and
   - Recording tree failures. The program should be compatible with available resources (e.g. personnel and funding).

B. **Prevention from Animal/Bird Contact:**

Animals, such as squirrels, monkeys and birds, such as crows, sparrows are one of the most common causes of distribution faults. Below is a list of grid infrastructure problems caused by animals/birds:

- Animals in substations cause a variety of problems, such as faults, which can result in power outages, reduced equipment life, or severely damaged equipment;
- Squirrels, raccoons, snakes and other creatures that climb fences, structures and equipment may eventually come into contact with energized parts of equipment;
- Rodents chewing through power and control cable insulation can also cause outages and damage.
- Birds build nests in substation structures and equipment;
- Some birds have wingspans that can bridge phase-to-phase distance and cause an outage; and
- Bird droppings can also cause issues.

Some of the mitigating methods include:

- **Fence barriers** – To deny animals access at the fence line for an outdoor substation requires consideration of possible access paths over, through, and under the fence[4].
- **Fake predatory animals** – Plastic owls, snakes, falcons or other objects can be placed conspicuously in the substation structure or on top of an enclosure.
- **Disturbing noises** – Various types of disturbing noises can be generated to drive off animals. They consist of ultrasonic, loud or danger signal noises.
- **Chemical repellents** – Chemical repellents and additives can be used to treat the food supply, or as baits in traps to kill animals if they enter or live within the substation.
- **Perching and climbing deterrents** – Anti-perching features or conductor covers to prevent birds from perching, nesting and shorting exposed overheard conductors. A common deterrent involves the use of a sticky gel. This gel can be applied as a deterrent to surfaces where birds perch, such as structures, incoming wires and guy wires.
- **Screened nesting locations** – Deterrence of birds and other animals from the general area can be accomplished if access to the preferred nesting sites within the substation is denied.

C. **Prevention from Human interference:**

Substations and transmission lines that are close to the highway or on the adjacent pathway are often prone to human attacks or vehicle accidents. Design requirements should include damage exposure prevention and protection to all potentially exposed major/critical equipment, such as but not limited to:

- Fencing around the structure
- Pad-mounted equipment along roadways, walkways, and bicycle paths
- Transformers (indoor and outdoor type)
- Construction of wall around the structure with secured access.

D. **Prevention from extreme weather conditions:**

Power outages due to severe weather events (e.g. floods, heavy winds, earthquakes, tropical cyclones) have increased over the last decade, many utilities/campus projects sought to reduce weather-related outages by “hardening” the systems to flooding, heavy winds and earthquakes by making the major electrical equipment less susceptible to damage. Considering power system hardening strategies during the initial stages of the project can significantly contribute to reducing the total operational and damage cost incurred from severe weather events.

PEER proposes the following design considerations and/or infrastructure to harden power systems against flooding, storms and other extreme events and maintain continuous availability of power supply:

1. **Flood plain avoidance** – Implement one of the following strategies to prevent damage to electrical equipment and assets (e.g., substations, diesel gensets, transformers, OH cables) and ancillary equipment (e.g., pumps, compressors), based on a 100-year flood mark or flood map. Protect stored fuel to meet or exceed the requirements set by the authority having jurisdiction.
   - Strategy 1: Build a permanent storm water drainage system to protect critical power assets from inundation.
   - Strategy 2: Install standalone pump-to-pump water from low-lying areas around the electrical systems. The pump should be operational in the absence of power supply
   - Strategy 3: Permanently relocate or increase the height of critical power assets in the flood-prone area per local flood zone maps.
2. **Storm protection –** Ensure that the outdoor equipment can withstand three-second wind gusts up to 140 mph or equivalent. This may include electric poles, substations, transformers and over-head lines.
3. **Seismic protection –** Have in place seismic restraint–certified equipment for critical electrical systems and/or install a seismic restraint structural support for critical electrical systems, based on the seismic zone. The critical electrical system would include substation, transformers, poles and other infrastructure depending on the importance of the project.

Apart from this, National Fire Protection Association (NFPA) 1600 standard defines general criteria for organizations to use for developing disaster management programs[5] that focus on the safety measures to be considered during normal and emergency conditions, like an extreme event.

E. **Undergrounding –** One of the oldest strategies of power system hardening is undergrounding. Placing electrical cables underground eliminates their susceptibility to heavy winds, ice and lightning damage. In many countries, undergrounding has been proposed as a solution for hardening the transmission and distribution system.

The graph below derived from European report CEER Benchmarking Report 5.1[6] – CoS demonstrates that undergrounding has a significant positive impact on reducing system outages.

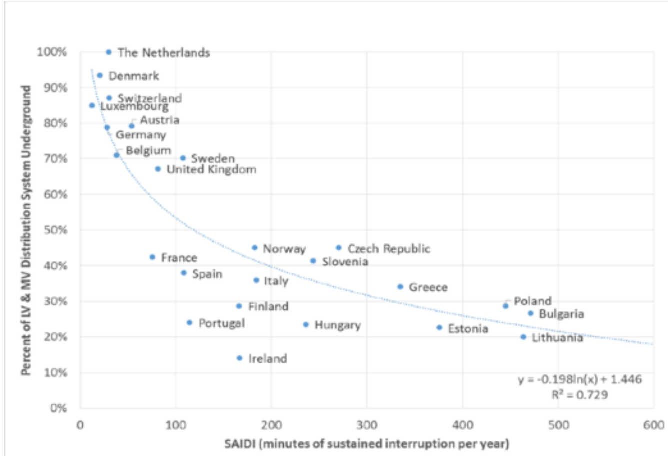

Figure 1: Shows the reduced SAIDI based on increased underground cabling across Europe.

4. Conclusion

Failures of network components could significantly affect the reliability of power systems. Component failures are caused by different factors. Analysis of the causes related to the failure have a practical value and could help power utilities take remedial actions and determine appropriate methods for failure reduction. Damage and exposure prevention design considerations and prevention strategies reduce the likelihood of equipment failures due to external physical and environmental threats.

Over a period of 2003 – 2012, weather-related outages are estimated to have cost the U.S. economy an inflation-adjusted annual average of $18 billion to $33 billion[7]. The costs of outages take various forms including lost output and wages, spoiled inventory, delayed production, inconvenience and damage to the electric grid. Continued investment in grid modernization and resilience will mitigate these costs over time – saving the economy billions of dollars and reducing the hardship experienced by millions of Americans when extreme weather strikes. Thus, power system hardening and prevention from external damages becomes crucial for both developed and developing countries, such as India, which has seen a number of weather-related outages in recent years. Modernizing grid infrastructure to increase resilience will be the need of the hour and through the strategies and techniques explained as part of the PEER program cities, communities and buildings could better prevent external damages and risks.

More information on PEER strategies can be found at peer.gbci.org.

5. References

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