I.3. Recommendations of Resilience and System Hardening Practices

3.1 Introduction

Resilience has received increasing public attention and has become an increasingly important factor in understanding priorities and investments in modernizing the grid. Natural hazards, including extreme weather conditions have induced additional challenges in the design and operation of transmission facilities. Natural hazards in the PJM region could include hurricanes, tornados, flooding, polar vortexes, earthquakes, landslides, tsunamis, heat waves, and other extreme weather scenarios such as heavy ice conditions. Social events could induce resilience challenges as well. Utilities have gained extensive experience through system hardening post natural disasters and preventive measures on transmission facilities in preparation of the future resilience events (Ref. [1]). In this section, good practices of system hardening in PJM regions are highlighted below.

Although this document does not specifically address cyber and physical security requirements, it is important to recognize the cyber security requirements for these infrastructure systems should be robust enough to prevent cascading events due to cyber or physical attacks (Ref. [2,3]).

3.2 Recommendation on designs

In this section, natural hazard is a natural phenomenon that if properly prepared for can prevent severe damage to transmission infrastructure. When natural hazards occur, the 3-R philosophy of "Repair-Restore-Rebuild" is a common practice in the industry, where special design criteria and new materials may be applied beyond the normal design standards.

3.2.1Transmission Lines

The following factors need to be considered when hardening a transmission circuit:

- Enhance the design due to potential or anticipated disasters (for example, hurricane levels, and/or wind loading during storms, special foundation design, etc.)
- Determine the service restoration requirements and priorities due to natural hazards and establish preventive hardening recommendations
- Determine the required structural enhancements needed to meet the service restoration requirements during natural hazards
- Determine applicable site specific design standards/references for enhanced circuit design, (including updated ASCE Stds., wind maps, flood maps, etc.)

- Recommend materials and structure design for the site specific disaster areas(For example, pole and tower materials and designs, insulator selection, conductor selection, overhead vs. underground installations, etc.).
- Cost and constructability review
- Spare strategies, for example, spare equipment and materials for rebuilding most vulnerable circuit segments to applicable standards in lieu of immediate rebuild of the entire circuit to those standards.
- Other common design criteria of transmission line hardening
    - Longevity/Life span of the structure (for example, steel structures vs. wood structures)
    - Line structure recommendations (for example, lattice towers vs. steel monopoles)
    - Foundations types need to be reviewed/specified at each location to meet the overall resilience/hardening goal, if requirements are beyond the normal reliability design standards (for example, direct embedded, vibratory caisson, drilled pier concrete anchor bolt, etc.)
    - Safety (for example, road side transmission lines, etc.) and Social impacts (for example, visual impact, etc.)
    - Other regulatory issues, including environmental, electric fields (EF), electro-magnetic fields (EMF), RFI, FAA, and local regulations.
    - Applicable special design consideration for critical service paths

3.2.2 Substations

Factors need to be considered when hardening a substation:

- Environmental parameter impacts:
    - Evaluated/changed environmental consideration of aging infrastructures
    - Site location considerations: sea level rise, flood plain, wild fires, and federal, state, and local regulatory changes
    - Storm patterns and category changes for weather events – understand the geographic extent of the storm impact
    - Space weather hazard measure (GMD protection)

- Special grounding issues, if applicable to the hardening site. For example, life of the ground conductor needs to be considered in conditions such as salt water exposure or other natural hazard conditions.

- Aging infrastructure replacement at existing facilities, for example, applying indoor installations, metal-clad switchgear, Gas Insulated Switchgear (GIS)/Gas Insulated Line (GIL), compact substation design, etc.

- Special consideration on raising substation foundation for hardening as needed, for example, when the flood waters rose above the doors of the control houses at many of the coastal substations during Hurricane Sandy, FEMA proposed new standards to require those utilities to raise equipment in the substations.

- Critical load/services may require redundancy beyond conventional reliability design criteria.

- Safety, social, and aesthetic impacts

- Physical Security and Cyber Security

- New technologies, such as compact substation design, metal-clad switchgear, GIS/GIL, digital substation, etc. may help to improve resilience performance.

- Design and O&M support for protection and communication (carrier relay vs. fiber)

3.2.3 Other resilience and system hardening design related issues

- Extreme Low/High temperature operation requirement

    - Applicable design and operation methods on severe conductor de-icing conditions would need further investigation.

        1. For new breaker that would operate down to -40^{o}C, include heaters for the gas systems;
        2. Legacy breakers may need to be outfitted with heaters for control cabinets and air handling systems;
        3. Winter readiness consists of draining all air systems of accumulated water, checking the operation of all thermostats and heaters, checking the condition of air piping and accumulating breaker weatherization items (spare heaters, thermostats, compressor maintenance kits, etc.)

    - Applicable design and operation methods on severe hot weather conditions would need further investigation, for example, transformer cooling systems and control building HVAC, etc.

    - Developing reliable rating method for facilities operating at extreme low/high temperature.

- Design substation control building with easy social distance availability for O&M activities in response to abnormal operation environment such as pandemics.

References:

1. IEEE Technical Report 83 "***Resilience Framework, Methods, and Metrics for the Electricity Sector***", https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR83_ITSLC_102920.html
2. NERC CIP Standard on ***Physical Security***, https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-1.pdf
3. NERC CIP Standard on ***Cyber Security - Supply Chain Risk Management,*** https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-013-1.pdf