Abstract:

Analysis and Optimization of Electricity Infrastructure Hardening Measures

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Applied Research Associates (ARA) has performed reliability studies in the Caribbean, the United States, and Canada to evaluate the impacts of high wind events (e.g., hurricanes and tornados) on power transmission systems. The key elements of these studies are:

- Probabilistic wind hazard models, including the effects of spatial and temporal correlation
- Probabilistic vulnerability models for wind damage to transmission lines and towers
- Risk assessment methodologies to determine the probabilities of system failures
    - Duration
    - Geographic extent
    - Financial and social impacts
- Benefit/cost models to evaluate the cost-effectiveness of various design alternatives:
    - Hardening measures
    - Redundancy
    - Maintenance schedules

ARA's probabilistic wind hazard models have been extensively validated and peer-reviewed. Our hurricane storm track model and hurricane windfield model were used to develop the basic design wind speeds in ASCE 7 for the Gulf and Atlantic Coasts of the United States. The model is also used in HAZUS-MH, FEMA's nationally-applicable, hurricane damage and loss estimation tool.

ARA's vulnerability models for electrical transmission and distribution systems have been developed using first principles dynamic load and resistance methodologies. The models properly account for the dynamic wind loads on conductors, ground wires, and support towers. This engineering-based analysis approach is particularly well-suited for analyzing the potential benefits of retrofit methods and new designs. In addition to direct wind damage, we are able to model the probability of tree blowdown impacting above ground distribution lines or the probability of uprooted trees damaging below ground lines. Our existing tree blowdown models are a function of tree type, tree height distribution, and tree density.

ARA has extensive experience in parameterizing the results of detailed damage calculations to produce fast-running damage functions suitable for regional damage and loss modeling. The fast-running damage functions typically depend on peak gust wind speed, local surface roughness, tower type, and tower age (important for wood poles/towers). Key aspects of a system level analysis include the spatial variation of wind loads across the region of interest and the level of redundancy in the network of transmission lines.

Existing databases and models from HAZUS-MH and other tools can be used to estimate the direct economic effects, indirect economic effects, and social impacts of regional power outages. This information can be combined with utility company data on repair and replacement costs, overtime labor costs, and lost revenues to produce a comprehensive understanding of the future losses that can be avoided through various potential hardening measures. The future savings and differences in maintenance costs are discounted back to present value and compared to the increased initial cost of construction to determine a benefit/cost ratio or rate of return for each hardening method.