# A Methodology for Transmission Power Line Hardening Using a Machine Learning Approach

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**Background/Objectives.** The power infrastructure in coastal areas is often exposed to extreme wind and precipitation events. Such incidents often have a significant impact on the power transmission infrastructure. A recent example, Hurricane Maria (H-Maria), damaged more than 55% of Puerto Rico's transmission towers leaving the island with almost all of its 2,400 distribution and transmission lines nonoperational. After an event of such massive destruction, the reconstruction of the grid must be a major focus. Moreover, studies that guide the reconstruction process towards increased resiliency of the transmission lines are critical. In such a reconstruction process it is important to quantify how the newly installed infrastructure will compare with what existed previously under extreme weather conditions.

**Approach/Activities.** This machine learning based study addresses this gap by building a model that can predict hurricane-induced damage to the transmission lines. The model is further used to estimate the damage caused by H-Maria in three hardened future power infrastructures scenarios. Utility data on the power towers, material, type, location, and damage after H-Maria was used to find the weakest structures in the transmission lines. Processing the utility data reflected that the wooden structures were found to be more likely to fail. As a result, three hardened infrastructure scenarios were tested: (1) replacing the wood two-poles with a stronger structure, (2) the wood two-poles and three-poles were replaced and (3) the wood two-pole, three-pole and single-poles were all replaced. We utilized a random forest classifier to create the damage prediction model for power towers. H-Maria simulated weather data from a high resolution (1-km) weather and research forecast model (WRF), elevation, and land cover were used along with power tower characteristics to train the model. The damage in the towers (i.e., response variable) is defined as a binary variable, which indicates if the tower failed or not. To begin developing the three scenarios for the future power infrastructure it was determined which structure was optimal to replace the previously found weak ones. To test this concept, a case study of an actual section of a 115 kv line was used, replacing wooden structures with low failure rate towers. The steel self-support pole was found as the best option for the hardening of the line, with a reduction of damaged structures of 40% in that line.

**Results/Lessons Learned.** The hardening with the steel self-support pole was expanded for all the 115 kV transmission lines on the island. The result of the analysis shows a significant decrease in the damaged structures for the three hardening scenarios. The second and the third hardening scenarios have fewer damaged structures across the lines, with a mean reduction in the damaged structures per line of 9% and 10%, respectively. The difference between the mean improvement of the second and third scenarios is not significant. However, the maximum decrease in damaged structures for a single line improves by 6% in the third hardening scenario. As a result, the third scenario, replacement of all wooden poles, was chosen as the best configuration of the infrastructure, with decreases in the damaged towers ranging from 1% to 66% for the 115 kV lines. The hardening methodology will be tested in recent and future extreme weather events to assess effectiveness of hardening post H-Maria.