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MODELING THE RESILIENCE OF POWER DISTRIBUTION SYSTEMS AGAINST ICE STORMS

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Ice storms cause widespread damage to electric power distribution systems and result in large-scale power outages each year around the world. The frequency and intensity of ice storm events will likely increase because of climate change. In order to build resilient power distribution systems against ice storms, it is necessary to rationally model the resilience and investigate cost-effective resilience enhancement strategies. Currently, studies on resilience modeling of power distribution systems to ice storms are very limited. Two limitations have been identified from existing research: (1) reasonable fragility models of tree damage and tree-induced component failures are lacking; (2) vegetation management strategies modeled are not realistic and economical.

To overcome these limitations, this paper proposes a probabilistic framework for assessing and evaluating the enhancements of the ice storm resilience of power distribution systems. In this framework, based on finite element analysis and Monte Carlo simulation, the fragility of distribution components is thoroughly investigated by considering four different failure modes, including three tree-induced modes overlooked in previous work. An empirical tree damage fragility function developed based on tree damage data in a past ice storm is used to estimate the tree damage probability. Besides upgrading poles, a targeted vegetation management strategy which focuses on hazard trees is used to improve the system resilience.

The proposed framework is demonstrated with a power distribution network in Oklahoma. Results show that system resilience decreases nonlinearly with respect to the increase in the ice storm intensity. It is also found that the effect of wind directions cannot be ignored considering the significant increase in the outage cost caused by the most unfavorable wind direction. For the studied network, vegetation management is found to be more cost-effective than upgrading poles.