Collapse Fragility Development of Electrical Transmission Towers Subjected to Hurricanes

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Abstract

Electrical power systems are critical to the wellbeing of our economy and society. Collapse of electrical transmission towers under hurricanes may result in significant interruptions of power systems. This research proposes a framework for the development of collapse fragility curves of transmission towers subjected to hurricanes. Incremental dynamic analysis (IDA), originally established for earthquake engineering applications, is adapted to model the hurricane induced collapse behavior. For a specific site, a set of hurricane wind speed and direction records are selected from 10,000-year synthetic hurricanes using a combination of autoencoder and k-means clustering. The autoencoder first compresses each wind record into 5 latent features, to which the k-means clustering is applied. Thus, all the collected wind records are divided into 4 clusters. Twenty wind records are picked at random from the 4 clusters and employed to run the IDA analysis, through which the collapse behavior is simulated, incorporating uncertainties in wind loading. The intensity measure of fragility curves is the storm maximum gust wind speed, and therefore the fragility curve is given as the cumulative distribution function (CDF) of the collapse capacity, which is designated as the intensity measure at the onset of collapse. The parameters of a fragility curve are estimated from the simulated data of the collapse capacity using the method of moments. The developed fragility curves are helpful in damage prediction of the electrical power systems under hurricanes.

Keywords: transmission tower; fragility; hurricane; autoencoder; k-means; incremental dynamic analysis

1 Introduction

High wind speeds during hurricanes can severely damage electrical transmission networks. Since the locations of many steel lattice transmission towers may be difficult to access, the failure of these towers often hinders the restoration process [1]. Consequently, severe electric outages can be caused during and after hurricanes. For example, immediately after landfall of Hurricane Rita, more than 500,000 customers lost their power in the state of Louisiana, while in Texas, more than 1,500,000 customers were heavily impacted [1].

The resilience of electrical transmission systems subjected to hurricane loading is critical to ensure rapid recovery in disaster areas. This research aims to conduct robust and comprehensive probabilistic hurricane collapse safety assessments of electrical transmission structures, which can be the foundations for future research on suitable