The 2020 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM20)
GECE, Seoul, Korea, August 25 - 28, 2020

Keynote Paper

A System Approach to Predict the Progressive Failure of an Entire Transmission Line System under Extreme Wind Events

Ashraf El Damatty[1)]

[1)] *Department of Civil and Environmental Engineering, University of Western Ontario, London, Ontario, Canada*

ABSTRACT

Downbursts and tornadoes belong to a category of windstorms called High Intensity Wind (HIW). It is reported in the literature that about 90% of weather-related transmission line failures worldwide are due to HIW. A large research program was initiated more than fifteen years ago at the University of Western Ontario, Canada, to assess the performance of transmission line structures under HIW. In this research program, computational fluid dynamics (CFD) simulations were used to characterize the wind fields. A structural analysis numerical model was developed in-house in which the HIW wind fields were incorporated and coupled with finite element modeling for the towers and the conductors. The numerical model considers the variability in the size and location of the HIW relative to the studied tower and is capable of predicting the downburst and tornado positions leading to peak internal forces in all members of a transmission tower. All components of this development were validated using unique experiments conducted at the Wind Engineering Environment and Energy (WindEEE) testing facility. The research progressed to the development of loading provisions simulating the critical effects of downbursts and tornadoes on transmission towers. Those provisions will be incorporated in the new version of the ASCE guidelines for transmission lines loading. The outcomes of the above-described research provided means for analyzing and designing new structures. However, a different approach needs to be developed for existing transmission lines. In those lines, a system approach should be adopted since failure of one or more towers might be unavoidable. The acceptable performance of a line depends on its importance and the level redundancy existing in the system. Also, failure might be affordable if it is contained within a limited number of towers. As such, a novel numerical tool was developed and its application for downburst analysis is described in this presentation. The numerical model considers a segment of a line including multiple towers and the in-between conductors. It identifies the most critical location of a downburst event that will trigger failure for one of the towers. Once a mechanism is formed in the failed tower, the movement of the failed segment leads to an increase in the conductor tension leading eventually to a new equilibrium state for the tower. The prediction of this behavior

[1)] Professor, E-mail: damatty@uwo.ca

required the development of a three-dimensional catenary analytical model for the conductors that was incorporated into the numerical model. A such, the numerical model is capable of predicting the failure location, the failure mode and the new post-failure equilibrium state. The failure of one tower will trigger unbalanced tension on the adjacent towers and a net longitudinal force which together with the downburst forces can result in failure of those towers. The analysis progresses incrementally through the time history of the downburst event predicting the progressive behavior of all towers of the considered line segment. Such a powerful numerical tool provides means to assess existing lines and also to conduct performance-based design for new lines taking into account safety, desired performance and economics.