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ASSESSEMENT OF STRUCTURAL CAPACITY OF AN OVERHEAD POWER TRANSMISSION LINE TOWER UNDER WIND LOADING

Sudhan Banik[†], Hanping Hong[*], and Gregory A. Kopp[†]

[†] Boundary Layer Wind Tunnel Laboratory
University of Western Ontario, London, Ontario N6A 5B9 Canada
e-mails: sbanik@uwo.ca, gak@blwtl.uwo.ca

[*] Department of Civil and Environmental Engineering
University of Western Ontario, London, Ontario N6A 5B9 Canada
e-mail: hongh@eng.uwo.ca

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1 INTRODUCTION

Wind related failures of overhead power transmission line towers are fairly common. Predicting failure loads or establishing collapse criteria under wind loads for transmission towers are usually done using the results from full-scale tower tests. However, the test results are only valid for a particular tower and loading conditions where static loads are normally applied. These tests may not predict exactly how the tower may behave under different static and dynamic loading conditions. As an alternative, nonlinear analysis techniques such as nonlinear static pushover analysis (NSP) Ref. [1] and incremental dynamic analysis (IDA) Ref. [2], which are routinely used for characterization of capacity curves for structures under seismic excitations, can be employed for predicting the load-deformation behaviour of a transmission line tower. Application of NSP in wind engineering is not common and to the authors' knowledge the use of IDA for structures under wind load has not been investigated yet. This perhaps is partly due to the fact that the seismic design philosophy allows the structures to undergo a permanent inelastic deformation under severe seismic excitations and the design for wind actions requires the structures to remain in the elastic range.

In this paper, the NSP and IDA procedures are adopted for assessing the capacity of an example transmission tower under wind loading. A brief description of the methods along with the adopted procedure for wind loading are presented first. This is followed by the description of the example tower and calculation of the wind load on that tower. The analysis results are presented next followed by the conclusions.

2 EVALUATION OF STRUCTURAL CAPACITY UNDER WIND LOADING

2.1 Use of nonlinear static pushover procedure

The nonlinear static pushover (NSP) analysis method is a popular and routinely used method for seismic performance evaluation of buildings. The analysis results can be used to assess the structural capacity or to characterize the load-deformation curve by monotonically increasing the lateral loads with a predefined height wise lateral load distribution. The method is adequate if the response of a multi-degree-of-freedom system is dominated by its first-mode since the analysis assumes that the structural vibration mode remains unchanged and independent of its deformed shape. The NSP analysis ignores duration of loads, effects due to cyclic loads and progressive changes in the dynamic properties after yielding of a structure.

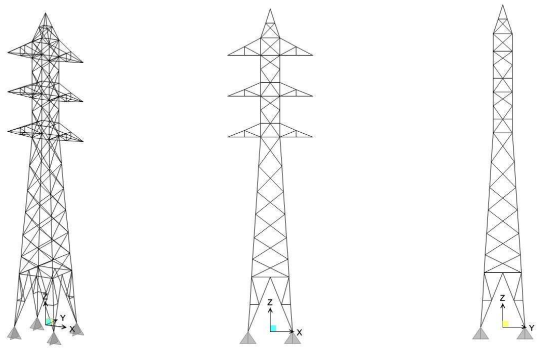
The NSP analysis or the structural analysis considering material nonlinearity are rarely employed in the literature for assessing the structural capacity under wind loading. If the NSP is adopted for assessing the capacity of the transmission tower, the first issue needs to be considered is the height wise lateral load distribution pattern. In this study, three possible load distribution patterns, namely the rectangular pattern, inverted triangular pattern and the pattern obtained from the application of the codified design wind load on the tower. Using one of these considered load distribution patterns, and the structural analysis is carried out for monotonic increase horizontal force. The results of the analysis are then employed to define the capacity curves in terms of total horizontal force (or total reacting base shear force) versus the displacement at the top of the transmission tower. The incipient of collapse may be defined by the point where there is no convergence for an increased lateral load.

2.2 Use of incremental dynamic analysis procedure

To overcome some of the drawbacks of NSP mentioned previously, the incremental dynamic analysis (IDA) may be employed to characterize the capacity of the transmission tower. The IDA is a powerful tool to assess the global behaviour of a structure from its elastic response to global dynamic instability through yielding and nonlinear response. The IDA procedure requires a series of linear and nonlinear dynamic analyses to be carried out for a few selected strong ground motion records that are scaled using an intensity measure. The results obtained are then employed to characterize the capacity curve in terms of an intensity measure or base shear versus lateral displacement or drift ratio. Note that although the IDA is only used for structures under earthquake loading in the literature, it could be adopted for evaluating the structural capacity under wind loading too. In order to apply the IDA to structures under wind loading, we note that unlike the seismic loading which consists of zero mean stochastic excitations, the along wind velocity causes the drag force that can be represented as a non-zero mean loading due to the mean wind speed and a fluctuating stochastic excitations. The fluctuating part of the wind load can be generated using a suitable wind spectrum and a coherence function incorporated using the Auto Regressive Moving Average Method similar to that described by Ref. [3].

2 EXAMPLE TRANSMISSION LINE TOWER

In the present study, a 110-KV tangent type steel lattice tower shown in Figure 1 is taken as an example. The tower has a height of 25.25 m and 3.52 m × 3.52 m square base area. It has a total of 316 members and 111 joints. All members of the tower are taken as equal-legged angle sections. The members are modeled as three dimensional frame elements.



a. 3D view   b. XZ projection   c. YZ projection

Figure 1. Example transmission tower

4 PRELIMINARY RESULTS

4.1 Static pushover case

In the present study, the capacity evaluation of the example transmission tower is carried out using the NSP for its YZ and XZ planar projections. Commercial software SAP 2000 is used for this purpose. Two nonlinear hinges are assigned in each member of the modeled tower to capture the interaction of axial and flexural stresses. These hinges are placed on both ends of the member. Wind loads from longitudinal and transverse directions are considered in the analysis. Longitudinal and transverse wind loads are applied on the YZ and XZ projections of the tower, respectively. Figure 2 summarizes the results obtained from NSP analyses for the different loading types. The results are plotted as the base force in the dominant wind direction versus the displacement at the top of the tower in the same direction. The base force is the total reaction component from all supports in the dominant wind direction.

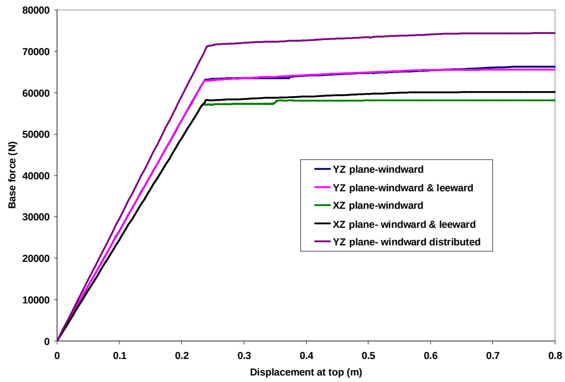


Figure 2.   Capacity curves for different projections of the example tower.

4.2 Incremental dynamic analysis case

The incremental dynamic analysis (IDA) is carried out in SAP 2000 for the planar projection of the example tower only in YZ plane. The analysis is only conducted for the longitudinal wind loading. The curves are plotted in figure 3 using the maximum displacement and maximum base shear force obtained in each analysis. Figure 3 also includes the NSP curve obtained for same planar projection for comparison purpose.

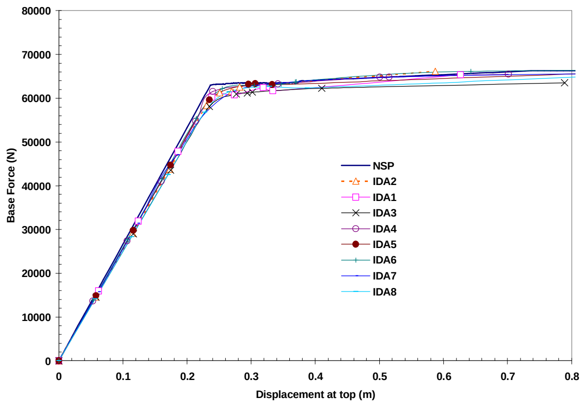


Figure 3. Capacity curves for the YZ projection of the example tower

It is apparent from figure 3 that the capacity curves resulted from IDA do not have significant variations in the inelastic region, which was expected at the beginning of the analysis and results in a similar curve obtained from the NSP analysis.

5. CONCLUSIONS

From the preliminary results, it is observed that the capacity curves obtained using NSP and IDA procedures show a bilinear load-deformation relationship for the transmission tower under wind loads. It is also observed that there is no significant difference between the capacity curves obtained from these procedures. In the full paper, the effect of height wise load distribution pattern and the duration of wind loads on the capacity curve will be discussed along with these preliminary results and the implications of these results will be given.

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