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Dynamic response due to cable rupture in a transmission lines guyed towers

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Abstract

The design of guyed lattice steel structures used in transmission lines (TL) is generally accomplished by static analysis, in order to simplify the dynamic actions, which are represented by "equivalent static loads". However, the static response to this type of structure is not always sufficient for design purposes, since such structures are lightweight, slender and that are always subject to dynamic nature action, except the own weight. Therefore, a dynamic analysis is critical to get a more precise result in terms of stresses on the bars and nodal displacements. In this context, this paper deals with the static and dynamic response evaluation of guyed lattice steel towers of TLs submitted to dynamic action of rupture cable. For this purpose, numerical models of isolated tower and completed stretch of TL were developed, including all components. The models are subjected to static analysis through "equivalent static loads" application coming from the rupture cable and dynamic analysis, in the time domain, using the Direct Integration Method (DIM) of equations of motion explicitly, with central finite differences for the problem solution. Finally, the results of static and dynamic analysis are compared, specifically the peak and final values (after the structure stops vibrating) with the static response values, in order to verify the dynamic amplification generated in the most realistic model against the results obtained from the model used in the usual design practice.

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Keywords: Guyed towers; transmission lines towers; dynamic analysis; cable rupture.

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1. Introduction

The main actions on transmission line structures (TL) are dynamic in nature, such as wind and cable rupture. Cable rupture, although occurring less frequently, is one of the actions that can lead the tower to collapse, including triggering the phenomenon known as the "cascade effect," in which many towers collapse in sequence. The rupture of a cable, or bundle of cables, generates forces in the towers that are longitudinal to the TL, whereas in the action of the wind, the forces in the towers can be longitudinal or transverse. In the design of a tower, these actions should be considered as dynamic actions, however, for simplicity, they are usually considered as "equivalent static". Currently, this is no longer justified because of the great advances in numerical and computational methods, making it possible to obtain the structure response through a dynamic analysis, which would lead to more realistic results and consequently the design of a more efficient and economical structure. The mechanical behavior of TL towers is usually is evaluated through a static and linear analysis. Determining the effects of the dynamic nature actions on TL towers is a complex task, given the range of variables involved and their randomness. The use of methods that result in more proximity to reality is essential to design the towers safely, seeking to maintain the efficiency and economy in their design. Thus, a dynamic numerical model for a careful evaluation of TL segments, which guarantees accurate results at element level, becomes necessary.

This research presents an numerical investigation on dynamic response in a transmission lines guyed towers subjected to cable rupture. The main purpose was to determine the dynamic response of lattice towers of guyed TLs subjected to cable rupture in terms of stress amplification in the discrete elements of the dynamic model versus the results obtained in the elements of the static model.

2. Cable rupture analysis

The response of a guyed tower, called S1E2, subjected to the cable rupture hypothesis, is obtained through two types of analysis: static and dynamic in the time domain. The methods defined for static and dynamic analysis are detailed below.

2.1. Static analysis

The static analysis was performed in the finite element program ANSYS© [1], considering a model with an isolated guyed tower. A hypothetical span of 500m in relation to the supposed adjacent towers was considered. In order to evaluate the static response of the isolated tower, "equivalent static loads" were used in order to simulate the rupture of a conductor cable or a lightning rod, according to the procedures prescribed in the NBR 5422 [2]. The "equivalent static loads", directly on the arms of the suspended guyed tower are as follows:

- A horizontal load, in the longitudinal direction to the TL, applied to the arm of the tower where the cable to be rupture is located, with a value equal to the traction in EDS (Every Day Stress) condition of the cable. The value to be taken for a conductor cable, equivalent to the static residual stress after rupture, is 16% of that of its Ultimate Tension Stress (UTS). For a lightning rod of the guyed tower studied, the value adopted for the horizontal load is of 11.75% of the UTS of this cable.
- Vertical loads applied on the tower arms to consider the weight of insulator chains, conductive cables and lightning rods.
- Self-weight of the structure, which is considered in the ANSYS© [1] program by applying a vertical acceleration of 1g ($g = 9.81$ m / s²). The structure, consisting of steel profiles, has a specific mass $\rho = 7850$ kg / m³. In this way, the program calculates the bars self-weight and distributes them to the nodes of the structure.

The loads are considered in the model as concentrated vertical forces (Y direction) applied to the cable suspension nodes, located at the ends of the tower arms, as shown in Fig. 1. It should be noted that the vertical force of the conductor cables applied to the tower arms is the sum of the weight of these cables with the weight of the insulators chain, which is 1350 N. The vertical load applied at the point of suspension adjacent to the ruptured cable was halved, as there is no self-weight in the span with the ruptured cable. The S1E2 tower is analyzed for two different cable rupture hypotheses. The first, called H1, simulates the rupture of the conductor cable suspended by