XLIII CILAMCE
21-25, November, 2022
FOZ DO IGUAÇU - PR - BRAZIL

TRANSMISSION TOWER: COMPUTATIONAL MODELING AND ANALYSIS OF THE SIMULATION OF WIND EFFECTS.

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Abstract. In Brazil there is a great need for electrical transmission towers, due to its large territorial dimensions, as well as the great distances between energy production sites and high consumption centers. In this perspective, the use of this important type of structure tends to be usual. The objective of this work is to perform a graphical and computational modeling of a self-supporting lattice structure. Then, the aerodynamic analysis of these structures is carried out simulating the structural effects of random loads due to wind actions. For the transmission tower model chosen, the finite elements of the truss model were considered, straight, connected by perfect joints. In the simulation, the towers located in the city of Foz do Iguaçu - PR were considered. From this modeling, the wind effects produced bending and torsion in the structure, as well as axial forces in the bracing members, which prevented high horizontal displacements, proving that the adopted model meets the design criteria. It was also evaluated that the structural failure, in an eventual episode of overload due to wind, should occur by buckling of internal elements, where the application of structural reinforcements will be proposed.

Keywords: Transmission tower. Wind effects. Structural analysis.

1 Introduction

Self-supporting transmission towers are lightweight structures that support their own weight and loads due to the components of the transmission line. In addition to static gravitational forces, dynamic loads due to the random effects of natural and human activities act on them. The functionality of the towers in the transmission system is to compose the energy transport route, to keep the cables and components suspended and with safe distances between the wires and obstacles, and to connect generating plants to the substation. The Foz do Iguaçu region is exceptional when it comes to power production, being home to the largest hydroelectric power producer on the continent (ITAIPU, 2018), which connects to importants transmission lines. Foz do Iguaçu is also a region where wind gusts occur among the fastest in Brazil, which can reach a speed of 50m/s on average, according to the isopleth chart (ABNT NBR 6123, 1988). The computational modeling of this structure consists in simulating the structural behavior of the towers using three-dimensional truss bar models. With the model defined, the simulated wind effects on the structure were analyzed, resulting in a detailed analysis of stresses and displacements.

2 Methodology

The methodological process of this study involved the analysis of a self-supporting truss transmission tower model, proposed by the authors, based on the usual models for an adopted transmission voltage of 137 kV. The structure was modeled considering the local conditions of the city Foz do Iguaçu - PR, with the support of data obtained in standard ABNT NBR 6123/88, such as the basic wind speeds and factors of topography, neighborhood, and importance of the structure. In the model, 4 different sections of structural profiles was adopted, and are listed in Tab. 1.

Table 1. Model components

Element type	Use	Material	Dimensions (mm)	Loads
L profile	Bracing and secondary horizontal lock	ASTM A36	76 x 76 x 7,3	87.90 N/m
L profile	Horizontal lock	ASTM A36	102 x 102 x 12,2	191.50 N/m
L profile	Bracing	ASTM A36	152 x 152 x 22,2	265.14 N/m
L profile	Columns	ASTM A36	203 x 203 x 19,1	285.20 N/m
Conductor cable	transmission cables	ACCR 1117 T13	Diameter = 32.9	17.88 N/m
Column type insulator	Support for conductor cables	Steel / Ceramic	Diameter = 226	540.10 N

During the modeling process, we sought to approach the real model for a structure of the type, as shown in Fig. 1 and Fig. 2. The profiles were pre-dimensioned by an estimation process, then applied in the simulation. The dead load of the structural elements was considered according to the material used, and in total 4 cases of analysis were generated, product of the combination of dead load with dynamic effects of the wind, in the main evaluated directions, in relation to the reference axes.

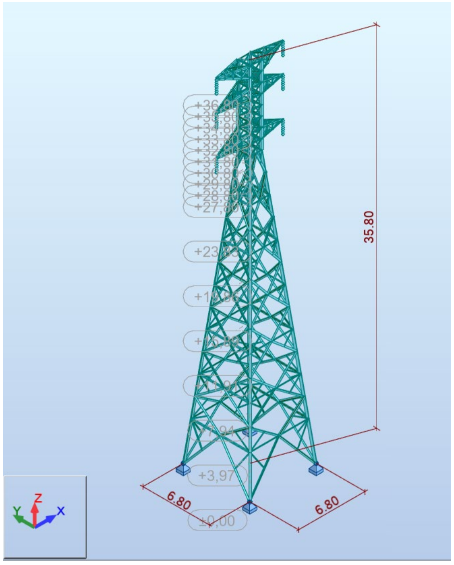


Figure 1. Model perspective view (meters).

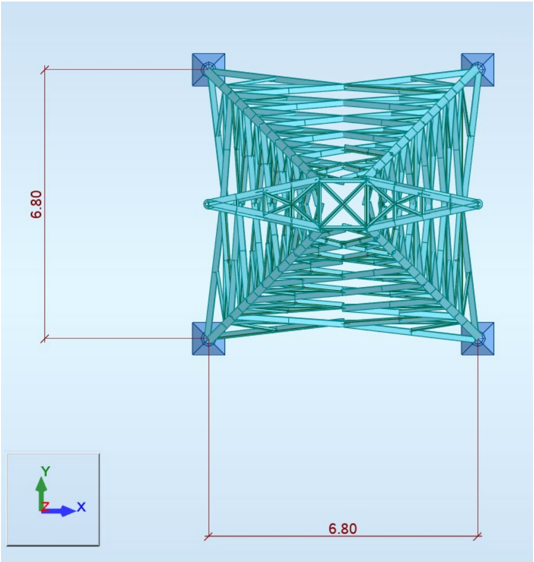


Figure 2. Top view tower model (meters).

In order to apply the wind action, the method based on the historical series of wind measurement in Brazil, contained in the ABNT NBR 6123 standard, is used, the summary of the basic wind speeds is presented in Fig. 3, where the curves and values represent the basic wind speeds in m/s.

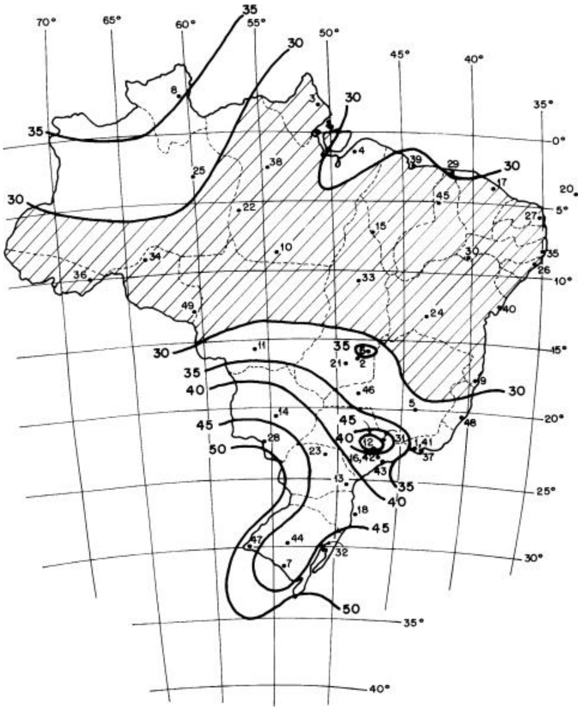


Figure 3. Wind isopleth map in Brazil.

The characteristic wind speed Vk was calculated considering the basic speed obtained in the isopleth map (Fig. 3), multiplied by 3 factors, being represented in (1), in which the referred factors are described in Tab. 2.

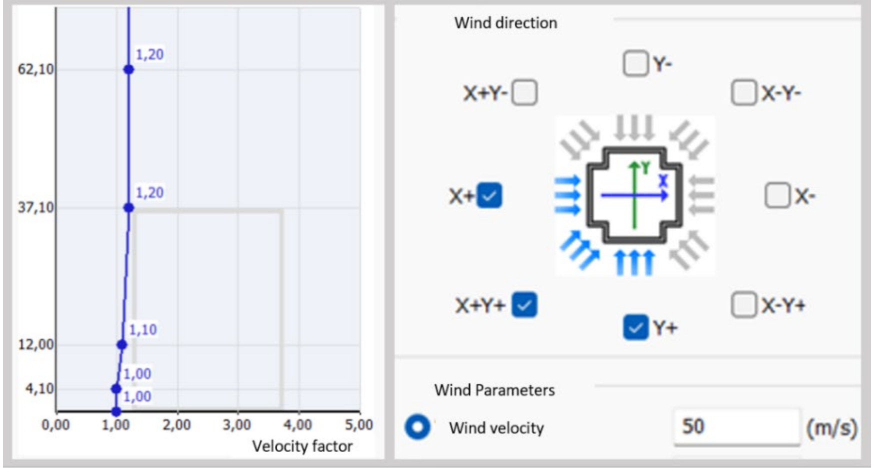
$$V_k = V_0 \cdot S_1 \cdot S_2 \cdot S_3 \tag{1}$$

Table 2. Formulation components for characteristic wind speed

Label	**Symbol**	**Value**
Topographic Factor	S1	1.0
Roughness factor	S2	It variates depending on the height and shape of the structure.
Statistical factor	S3	1.0
Basic wind speed	Vk	50 m/s

The S2 factor considers the dimensions of the building and the roughness of the land (neighborhood), as characteristics of the place, it fits into the following standard condition: Category 1: Large smooth surfaces, more than 5 km long; Class B: Any building or part of a building for which the greatest horizontal or vertical dimension of the front surface is between 20 m and 50 m.

Resulting in the following wind profile, shown in Fig. 4, along with the wind simulation directions:



Wind direction

☐ Y-
X+Y- ☐
☐ X-Y-
X+ ☑
☐ X-
X+Y+ ☑
☐ X-Y+
☑ Y+

Wind Parameters

● Wind velocity 50 (m/s)

Figure 4. Velocity factor and wind analysis direction

The profile is relative to the basic wind speed V0, being dimensionless. The wind directions considered in analysis by the software are shown in Fig. 4.

3 Results

The results obtained for the structure are presented below in the form of diagrams with representation of pressure maps and deformation on an exaggerated scale for visualization and better understanding of the mechanical behavior.

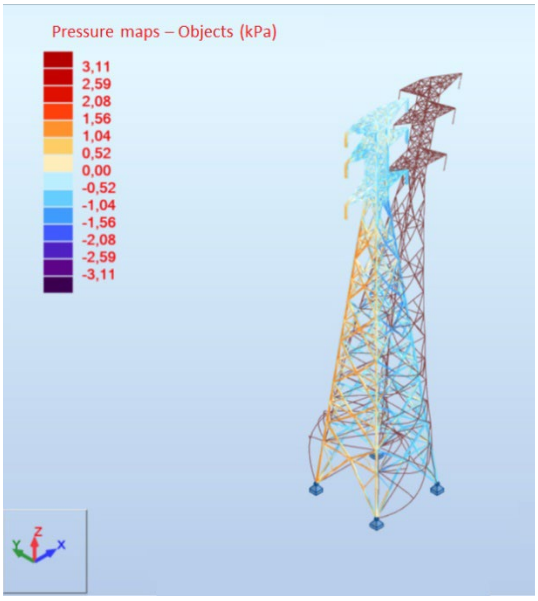


Figure 5. Analysis from simulation of wind on X positive direction.

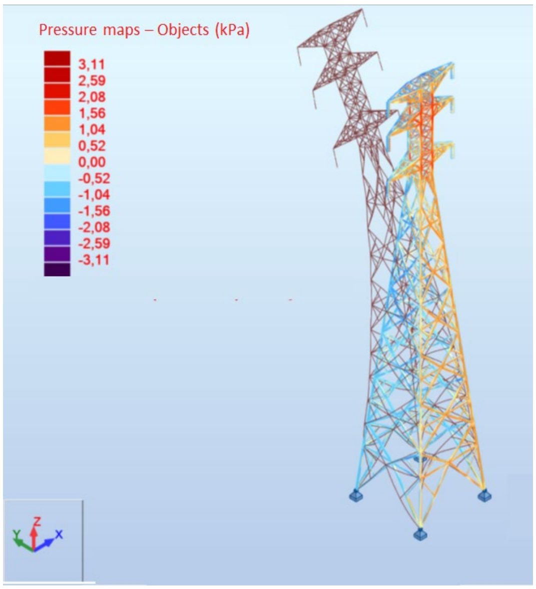


Figure 6. Analysis from simulation of wind on Y positive direction.

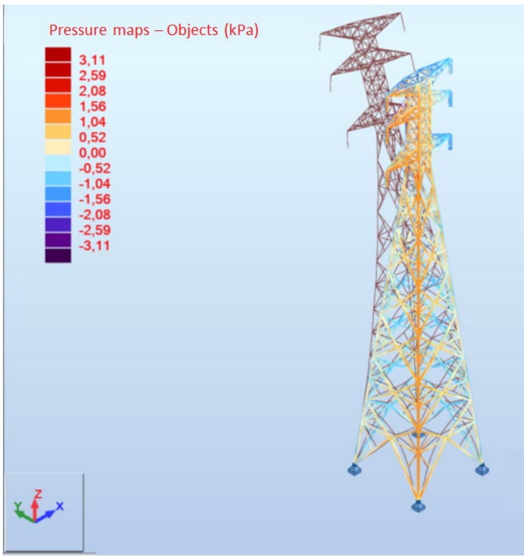


Figure 7. Analysis from simulation of wind on X positive, combined with Y positive direction.

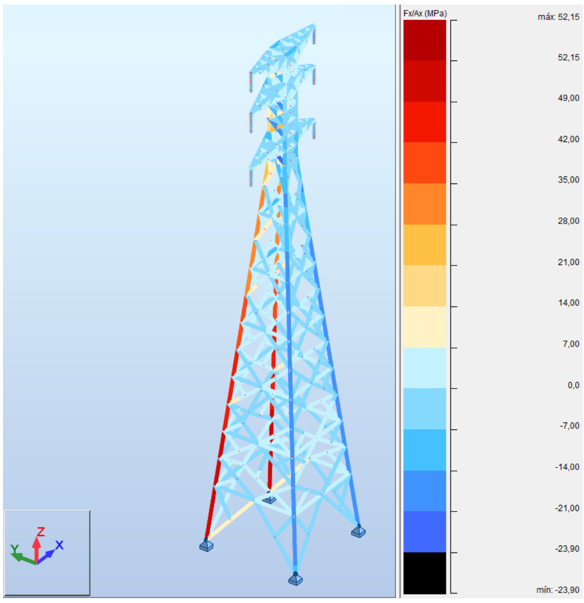


Figure 8. Maps of axial forces if incident wind in positive Y direction.

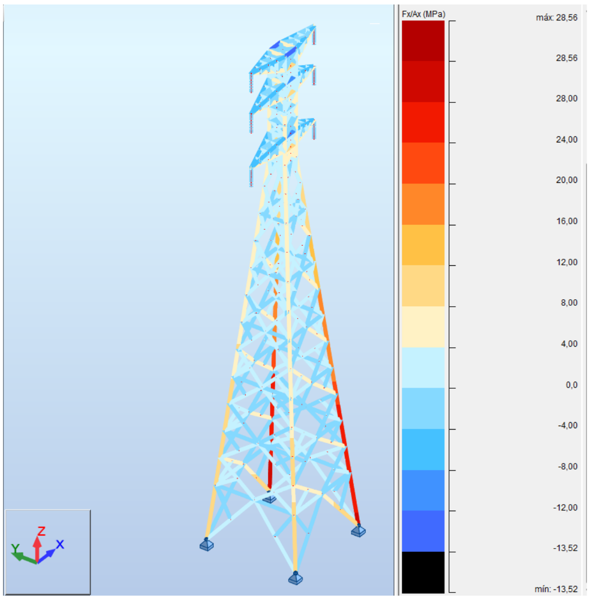


Figure 9. Maps of axial forces if incident wind in positive X direction.

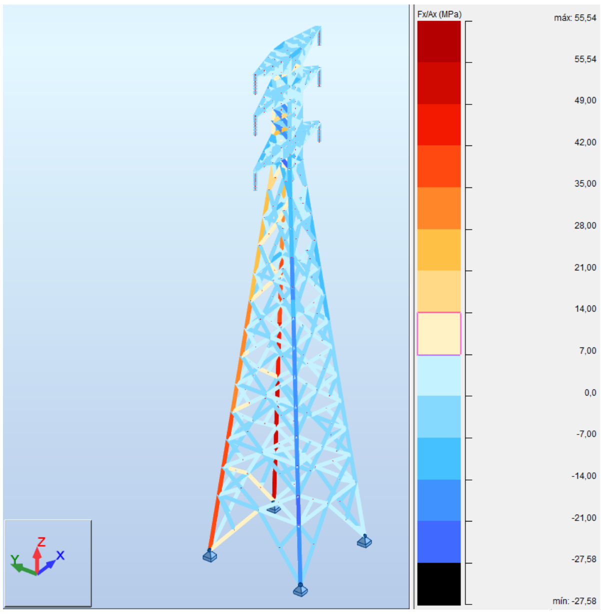


Figure 10. Maps of axial forces if incident wind in positive X/Y direction.

In the case of axial forces, the combination of forces due to the wind in the analyzed directions caused the maximum and minimum axial loads, with causes stress values of 55.54MPa, in the base elements, and -27.58MPa in the member that supports the cables, respectively. These being the extreme values for axial stresses. The maximum displacement occurs at the top of the structure when the wind acts in the Y direction, and it value reach 5.8 cm.

4 Conclusions

The results lead us to conclude that the wind effects on the truss analyzed in the conditions presented by the city of Foz do Iguaçu, suffers significant effects in the induction of displacements reaching 5.8 cm, in the Y direction, in the case of the wind acting in Y. The analyzed model presents the expected behavior for a three-dimensional truss, where the axial forces are preponderant and that the pre-sizing of the structure meets the resistance requirements, not suffering collapse. However, in an eventual case of collapse, this must result from the failure of the bar elements closest to the support, and will occur by buckling. This statement is based on the fact that the maximum axial compressive stress analyzed is on the order of 2 times the highest tensile stress.

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