Analysis of Transmission Tower of 132 KVA under Different Wind Loads (as per IS:875-2015 Part-III) by using STAAD Pro

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Abstract - *This document presents a review of recent research conducted on the design and analysis of transmission line towers in different wind areas with the effects of wind loads and earthquakes using STAAD.ProV8i. A study reports the design and analysis of the self-supporting towers of the lattice transmission line of an energy supply system located in Mumbai and Mount Abu. Both cities are in the same seismic areas but in different wind zones. This study is important in terms of wind load because Mumbai is a coastal area and Mount Abu is a mountainous area with different wind speeds. The comparative analysis is carried out respecting the axial forces, the maximum properties of the bending section and the critical load conditions for both positions. Load calculations are done manually, but analysis and design results are obtained through STAAD.ProV8i..*

Key Words: *Steel lattice towers, Wind zones, STAAD.ProV8i, Earthquake zone....*

1. INTRODUCTION

In each country, the need for electricity consumption has continued to increase, with a higher rate of demand in developing countries. The use of electricity has become an increasingly important part of the economy of industrial countries. India has a large resident population across the country and the electricity needs of this population create the requirement for a large transmission and distribution system. Transmission line towers are needed to supply electricity to various regions of the nation. These towers are used to support very high voltage (EHV) transmission lines. Transmission tower lines play an important role in the lifeline of structures. These lines must be stable and carefully designed so as not to fail during the natural disaster. The analysis and design are carried out in accordance with the recommendations given in IS: 800-2007 and IS: 802 (Part 1 / Set 1). This study is performed in accordance with the requirements and recommendations of the administration for the validation of the results according to the IS codes to verify if the same structure can be safe for both places.

1.1 APPLICATION OF PROPOSED METHODOLOGY

The present problem can solve by using Finite Element Analysis Software. In this problem we have used STAAD Pro V8i software to analyze and calculations of member forces and reactions (stresses)

The following procedure is described:-

- The software tool used in the design and analysis of the tower is STAAD.ProV8i. In today's world, analysis tools allow engineers to refine designs to an unprecedented point, and as a result, many utility companies believe that testing is not guaranteed. However, although great strides have been made in the analysis and design of self-supporting steel transmission towers, there are still differences between the results of the analysis and large-scale tests.
- Manual calculation is important for IS code recommendations, but validation of these results and study of the effects of these loads on structure are also important.
- The analysis of the activity carried out is the key to success for the safe and lasting maintenance of the structure in various load combinations.
- Now based on the validation of results throughSTAAD.ProV8i, the important conclusions are made.

2. LITERATURE REVIEW

1.1 **Gopi Sudan Punse [1]** attempted to design and analyze transmission line towers to optimize geometry with STAAD.ProV8i. The geometric parameters of the tower can be efficiently treated as design variables, and often considerable weight reduction can be achieved as a result of geometric changes.
1.2 **Sharma K. [2]** performed a comparative analysis of the different heights of the towers using different types of reinforcement systems for different wind zones and seismic forces with the gust factor method for the analysis of wind loads, Analysis of response spectrum model and analysis, used for seismic loads.
1.3 **R.A Kravitz [3]** carried out the design and analysis of transmission line towers to compare the results using different types of towers according to some criteria of the ASCE 52 manual "Guide for the design of towers for steel transmission lines" for stimulate

further research on the development of coherent project loading criteria; analysis and design method; Tower detail and test practice.

1.4 **Y.M Ghugal, U.S Salunkhe [4]** have made 3 legged and 4legged transmission line tower models using common parameters such as constant height, bracing system with an angle system. The analysis is carried out to slenderness effect, critical sections, forces and deflection of both towers. A saving of steel weight up to 21.2% resulted to comparison of both 3 legged and 4 legged tower.

1.5 **Lakshmi, A. Rajagopala Rao [5]** performed the effect on the 21k 132kv tower with medium wind intensity. A tower analysis is performed and the performance of tower members and forces is evaluated on all horizontal and vertical diagonal members. The intensity of the wind converted into point loads and applied in panel joints.

1.6 **Preeti, K.J Mohan [6]** attempted to compare the analysis of the three towers by changing the geometry and behavior of the structure. A saving of 9.23% in weight of steel in the self-supporting triangular tower.

1.7 **Vinay R.B, Ranjith A., Bharath A. [7]** made a 400kv dual circuit tower that was modeled of angular and tubular sections using STAAD.ProV8i for wind loading by static linear and P-delta analysis. After analysis, steel weight savings of up to 20.9% were obtained by comparing the tubular section with the angle section.

1.8 **G. Vishweswera Rao [8]** has optimal transmission line tower designs for high voltage transmission lines. Optimization refers to both the weight of the tower and the geometry. The program incorporates a nonlinear non-linear optimization method developed specifically for the configuration, analysis, and design of transmission line towers.

1.9 **S. Christian Johnson [9]** carried out an experimental study on the corrosion of the transmission line tower foundations and their rehabilitation. The physical, chemical and electrochemical parameters were presented, studied in the centers of the transmission line towers excavated in coastal and inland areas. A methodology for the rehabilitation of the transmission tower centers was discussed.

3. GEOMETRY OF TOWER

- Location of Towers – Mumbai and Mount Abu
- Wind Zones – III (Mumbai) and V (Mount Abu)
- Seismic Zones - III (Same for both locations)
- Factor of Safety of the tower - 1.2
- Height of Tower – 35m
- Base width – 4m
- Top width – 2m
- Flange width – 1.75m
- Number of cables supported by tower – 7

4. CALCULATIONS

4.1 DESIGN CALCULATIONS

- Area of segment (As):
  $As_1 = 26m^2$ (For trapezoidal section)
  $As_2 = 24m^2$ (Foe rectangular section)
  $As_3 = 2m^2$ (For peak section)
  $As_4 = 14.5m^2$ (For 6 cross arms)

- Calculation of cable load:
  Unit Load of the cable = $\pi/4 \times D2 \times \rho$ = 0.0245KN/m
  Cable Load = Unit load × Centre to Centre distance of one cable to other cable = 7.5KN
  Total load of the cable = 1.5 cable load + Weight of Man with loads + Weight of earth wire attachment = 14.5KN

4.2 MANNUAL CALCULATIONS OF LOADS ON TOWER:

For Mumbai

1. The basic wind speed in Mumbai is 44m/sec.
2. The probability factor k_1 is taken as 1.07 (from IS 875-2015, Part-III).
3. The Terrain, height and structure size factor k_2 is varying at different levels of the tower and is taken from IS code as follows:

k_2 at 15m height = 1.02
k_2 at 20m height = 1.05
k_2 at 25m height = 1.07
k_2 at 30m height = 1.10
k_2 at 35m height = 1.12

4. The Topography factor k3 is assumed to be 1 for plain terrain of Mumbai.

Calculation of wind load:

The design wind speed is calculated as:
$V_z = Vb \times k_1 \times k_2 \times k_3$
V_z at 15m = 44×1.07×1.02×1 = 48.02m/sec
Vz at 20m = 44×1.07×1.05×1 = 49.43m/sec
Vz at 25m = 44×1.07×1.07×1 = 50.37m/sec
Vz at 30m = 44×1.07×1.10×1 = 51.78m/sec
Vz at 35m = 44×1.07×1.12×1 = 52.72m/sec

Calculation of Design Wind Pressure:

The design wind pressure is calculated as:
$p_z = 0.6 \times Vz^2$
p_z at 15m = 0.6× (48.02)2 = 1383.46N/m²
p_z at 20m = 0.6× (49.43)2 = 1465.98N/ m²
p_z at 25m = 0.6× (50.37)2 = 1522.28N/ m²
p_z at 30m = 0.6× (51.78)2 = 1608.70N/ m²
p_z at 35m = 0.6× (52.72)2 = 1667.63N/ m

Design wind force:

The design wind force is calculated as:
$F = C_f \times A_e \times p_z \times \varphi$
F at 15m = 3.3×52.0×1383.46×0.22 = 54.60KN
F at 20m = 3.3×38.5×1465.98×0.24 = 44.42KN
F at 25m = 3.3×38.5×1522.28×0.26 = 50.28KN
F at 30m = 3.3×38.5×1608.70×0.28 = 57.22KN
F at 35m = 3.3×40.5×1667.63×0.28 = 62.40KN

5. RESULT & DISCUSSIONS

All the stresses generated in the tower in both location on application of wind load, cable load, and live load. The total beam stresses due to bending in Z direction.

For Mount Abu

1. The basic wind speed in Mount Abu is 50m/sec.
2. The probability factor k1 is taken as 1.08 (from IS code).
3. The Terrain, height and structure size factor k2 is varying at different levels of the tower and is taken from
IS code as follows:
k_2 at 15m height = 0.94
k_2 at 20m height = 0.98
k_2 at 25m height = 1.01
k_2 at 30m height = 1.03
k_2 at 35m height = 1.05
4. The Topography factor k3 is assumed to be 1.10 for hilly area of Mount Abu.

Calculation of wind load:

The design wind speed is calculated as:
$V_z = V_b \times k_1 \times k_2 \times k_3$
V_z at 15m = 50×1.08×0.94×1.10 = 55.83m/sec
V_z at 20m = 50×1.08×0.98×1.10 = 58.21m/sec
V_z at 25m = 50×1.08×1.01×1.10 = 60.00m/sec
V_z at 30m = 50×1.08×1.03×1.10 = 61.18m/sec
V_z at 35m = 50×1.08×1.05×1.10 = 51.79m/sec

Calculation of Design Wind Pressure:

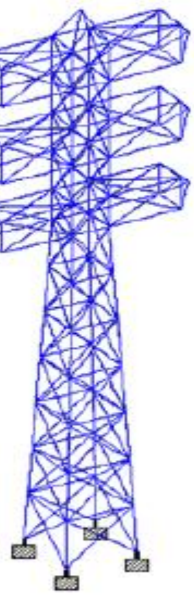
The design wind pressure is calculated as:
$p_z = 0.6 \times V_z^2$
p_z at 15m = 0.6× (55.83)2 = 1870.19N/m2
p_z at 20m = 0.6× (58.21)2 = 2033.04N/m2
p_z at 25m = 0.6× (60.00)2 = 2158.56N/m2
p_z at 30m = 0.6× (61.18)2 = 2245.79N/m2
p_z at 35m = 0.6× (62.37)2 = 2334.01N/m2

Design wind force:

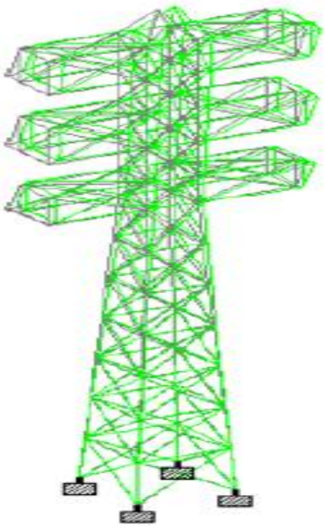
The design wind force is calculated as:
$F = C_f \times A_e \times pz \times \varphi$
F at 15m = 3.3×52.0×1870.19×0.22 = 70.60KN
F at 20m = 3.3×38.5×2033.04×0.24 = 62.00KN
F at 25m = 3.3×38.5×2158.56×0.26 = 71.30KN
F at 30m = 3.3×38.5×2245.79×0.28 = 79.88KN
F at 35m = 3.3×40.5×2334.01×0.28 = 87.34KN
Critical load combination for Mumbai is 1.2(Cable load) +1.2(Live load) + 1.2(Wind load in X-direction)
Critical load combination for Mount Abu is 1.2(Cable load) +1.2(Live load) +1.2(Wind load in Z-direction).

For Mumbai

Beam stress, bending in Z direction analysis:

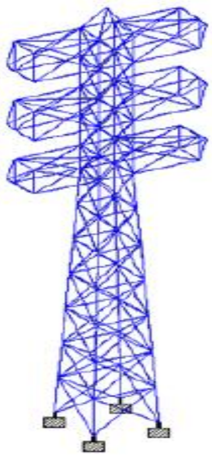


Nodal Displacement analysis:

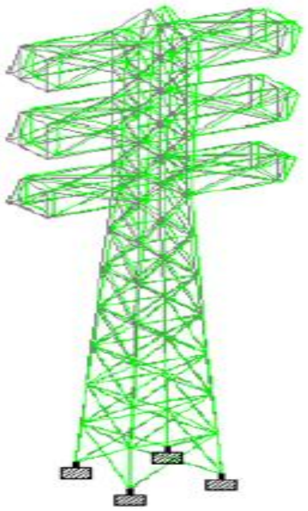


For Mount Abu

Beam stress, bending in Z direction analysis:



Nodal Displacement analysis:



Comparative results:

Location	Beams	Axial force F_X(KN)	Shear force F_Y(KN	Bending Moment M_Z(KNm)
Mumbai	152	67.362	5.32	-1.208
	278	155	7.08	1.432
	313	60.62	-1.183	1.007
	353	146.53	24.05	1.229
	415	24.02	7.931	0.399
	483	56.27	-0.50	0.207

Location	Beams	Axial force F_X(KN)	Shear force F_Y(KN)	Bending Moment M_Z(KNm)
Mount Abu	152	66.52	5.91	2.275
	278	175.40	11.20	1.901
	313	72.45	1.501	0.650
	353	153.35	14.412	1.892
	415	19.30	2.761	-1.629
	483	38.771	-1.59	-0.538

6. CONCLUSIONS

In this paper an attempt has been made to compare the same transmission towers with same bracing system at different wind zones viz. zone III and V but same seismic zone i.e. zone III located at Mumbai and Mount Abu. The following conclusions are drawn on the basis of the research and analysis done through the STAAD.ProV8i and conforming the safety of same tower at both the mentioned places:-

- There is large change in the axial forces in cross arm member of the transmission line tower of both locations on member no. 353 and 415.
- There is large change in the shear force in same member of the transmission line tower of these locations on member no. 313.
- There is big difference in the bending moment on the member on the two specified locations with the slight change of the wind pressure force on member no. 353 and 415.

Transmission tower with same bracing can be used at these two different wind zones with same seismic zone by using different steel members at different phases of the transmission tower according the effect of the load on the specific location members.

Further study can be made for different wind zones and seismic zones with different bracing system.

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