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Design and Analysis of Transmission Line Towers in Different Wind Zones - A Review

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Abstract—*A review on recent research done on design and analysis of transmission line towers in different wind zones with effects of wind and earthquake loads by using of STAAD.ProV8i is presented in this paper. A study reports on design and analysis of self-supporting steel lattice transmission line towers of a power system located in Mumbai and Mount Abu. Both cities are in same seismic zones but different wind zones. This study important in term of wind loading because Mumbai is a coastal area and Mount Abu is hilly area with different wind speed. The comparative analysis is carried out with respect of axial forces, deflection maximum sectional properties and critical load condition for both the locations. The load calculations are performed manually but the analysis and design results are obtained through STAAD.ProV8i.*

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

1. INTRODUCTION

In every country, the need of electric power consumption has continued to increase, the rate of demand being greater in the developing countries. The use of electric power has become an increasing important part of the economy of industrial countries. India has a large population residing all over the country and the electricity supply need of this population creates requirement of a large transmission and distribution system. Transmission line towers are necessary for the purpose of supplying electricity to various regions of the nation. These towers are used for supporting the Extra

High Voltage (EHV) electric transmission lines. Transmission tower lines plays important role in the life-line of structures. These lines should be stabled and carefully designed so that they do not fail during natural disaster.

Analysis and design is carried as per the recommendations given in IS: 800-2007 and IS: 802(Part 1/Set 1). This study is performed as per the requirement and recommendation of the management for the validation of the results according to the IS codes to check whether the same structure can be safe for both the places.

2. REVIEW OF LITERATURE

2.1 Gopi Sudan Punse [1] made an attempt of design and analysis of transmission line towers with a view to optimize the geometry by STAAD.ProV8i.The geometry parameters of tower can efficiently be treated as design variables and considerable weight reduction can often be achieved as a result of geometry changes.

2.2 Sharma K. [2] carried out a comparative analysis of different heights of towers using different types of bracing system for different wind zone and earthquake forces by gust factor method is for analysis of wind loads, model analysis and response spectrum analysis, used for earthquake loads.

2.3 R.A Kravitz [3] carried out transmission line tower design and analysis to comparison of results using different types of towers as per some criteria of the ASCE manual 52 "Guide for design of steel transmission line towers" for stimulate further investigation into developing consistent tower design loading criteria; analysis and design method; tower detailing and testing practice.

2.4 Y.M Ghugal, U.S Salunkhe [4] have made 3 legged and 4 legged 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.

2.5 V. Lakshmi, A. Rajagopala Rao [5] performed effect on 21m 132kv tower with medium wind intensity. An analysis is carried out for the tower and the performance of tower and member forces in all vertical horizontal and diagonal members are evaluated. The intensity of wind converted into point loads and applied on panel joints.

2.6 C. Preeti, K.J Mohan [6] made an attempt to compare of three towers analysis by changing of geometry and behavior of structure. A saving of 9.23% steel weight in triangular base self-supporting tower.

2.7 Vinay R.B, Ranjith A., Bharath A. [7] performed 400kv double circuit tower was modeled of angle and tubular sections using STAAD.ProV8i for wind load by linear static and P-delta analysis. After analysis a saving of steel weight up to 20.9% resulted when tubular section is compared with angular section.

2.8 G. Vishweswera Rao [8] has optimum designs of transmission line towers for extra high-voltage transmission lines. The optimization is with reference to both tower weight and geometry. A derivative free method of nonlinear optimization is incorporated in the program, specially developed for the configuration, analysis and design of transmission line towers.

2.9 S. Christian Johnson [9] has done an experimental study on corrosion of transmission line tower foundation and its rehabilitation. Physical, Chemical and electro chemical parameters, studied on transmission line tower stubs excavated from inland and coastal areas have been presented. A methodology for rehabilitation of transmission tower stubs has been discussed.

2.10 G.M. Samuel Knight, N. Prasad Rao [10] studied on failure of transmission line towers in testing. Types of premature failure observed during full scale testing of transmission line towers at Tower Testing and Research Station Structural Engineering Research Centre, Chennai are presented. Different types of failures are modeled using finite element method software the analytical and the test results are compared used to model the elasto-plastic behavior of the tower.

3. APPLICATION OF PROPOSED METHODOLOGY

The present problem can solve by using ANSYS 15.0.

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 degree, and as a result, many utilities feel testing is not warranted. However, while great strides have been made in the analysis and design of self -supported lattice steel transmission towers, differences between analysis results and full-scale tests still occur.
- Manual calculations is important for the recommendations of IS codes but the validation of these results and study of effects of these loads on the structure is also an important part to do.
- Analysis of the performed task is the key to success for the safe and durable serviceability of the structure under various load combinations.
- Now based on the validation of results through STAAD.ProV8i, the important conclusions are made.

4. GEOMETRY OF TOWERS

- 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

4.1 Design calculations:-

➢ Area of segment (A_s):

$A_{s1} = 26m^2$ (For trapezoidal section)

$A_{s2} = 24m^2$ (Foe rectangular section)

$A_{s3} = 2m^2$ (For peak section)

$A_{s4} = 14.5m^2$ (For 6 cross arms)

➢ Calculation of cable load:

Unit Load of the cable = $\pi/4\times D^2\times\rho$ = 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 Manual 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 code).

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 k_3 is assumed to be 1 for plain terrain of Mumbai.

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 = 44×1.07×1.02×1 = 48.02m/sec

V_z at 20m = 44×1.07×1.05×1 = 49.43m/sec

V_z at 25m = 44×1.07×1.07×1 = 50.37m/sec

V_z at 30m = 44×1.07×1.10×1 = 51.78m/sec

V_z at 35m = 44×1.07×1.12×1 = 52.72m/sec

Calculation of Design Wind Pressure:

The design wind pressure is calculated as:

$p_z = 0.6\times V_z^2$

p_z at 15m = 0.6× $(48.02)^2$ = 1383.46N/m^2

p_z at 20m = 0.6× $(49.43)^2$ = 1465.98N/m^2

p_z at 25m = 0.6× $(50.37)^2$ = 1522.28N/m^2

p_z at 30m = 0.6× $(51.78)^2$ = 1608.70N/m^2

p_z at 35m = 0.6× $(52.72)^2$ = 1667.63N/m^2

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. RESULTS AND 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 k_1 is taken as 1.08 (from IS code).

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 = 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 k_3 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/m^2

p_z at 20m = 0.6× $(58.21)^2$ = 2033.04N/m^2

p_z at 25m = 0.6× $(60.00)^2$ = 2158.56N/m^2

p_z at 30m = 0.6× $(61.18)^2$ = 2245.79N/m^2

p_z at 35m = 0.6× $(62.37)^2$ = 2334.01N/m^2

Design wind force:

The design wind force is calculated as:

$F = C_f\times A_e\times p_z\times\varphi$

F at 15m = 3.3×52.0×1870.19×0.22 = 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

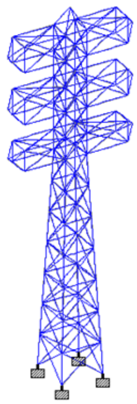
F at 30m = 3.3×38.5×2245.79×0.28 = 79.88KN

F at 35m = 3.3×40.5×2334.01×0.28 = 87.34KN

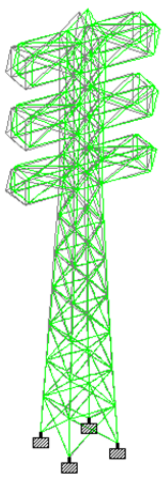
Critical load combination for Mumbai is 1.2(Cable load) +1.2(Live load) + 1.2(Wind load in X-direction) and Critical load combination for Mount Abu is 1.2(Cable load) +1.2(Live load) +1.2(Wind load in Z-direction).

For Mumbai

Beam stress, bending in Z direction analysis:

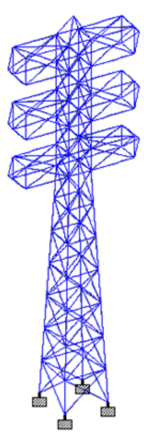


Nodal Displacement analysis:

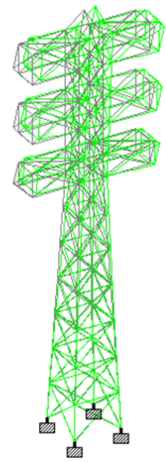


For Mount Abu

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)
Delhi	152	66.762	5.52	-1.228
	278	160	7.28	1.512
	313	59.62	-1.083	0.987
	353	147.53	24.25	1.334
	415	23.52	7.81	0.360
	483	56.25	-0.52	0.218

Location	Beams	Axial force F_X(KN)	Shear force F_Y(KN)	Bending Moment M_Z(KNm)
Mount Abu	152	66.122	5.82	2.258
	278	178.25	11.12	1.834
	313	72.38	1.47	0.632
	353	154.25	14.32	1.877
	415	19.25	2.73	-1.648
	483	38.74	-1.56	-0.529

6. CONCLUSION

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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