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Analysis and Design of Four Legged Transmission Tower

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Abstract: ***Transmission line towers carry heavy electrical transmission conductors at a sufficient and safe height from ground. In addition to their self-weight they have to withstand all forces of nature like strong wind, earthquake and snow load. The main objective of this paper is to determine the most economical section of tower and its configuration as per Indian Standard IS-800. The present work describes the analysis and design of four legged self-supporting 220 kV double circuit steel transmission line towers models with an angle, tubular and channel sections. In this study dead load and wind load as per IS: 802 (1995) are taken into account in these three models. STAAD. Pro program has been used to analysis and design the members of 220 kV double circuit tower. A comparative study is conducted with respective to axial forces, deflections, maximum sectional properties, critical loading conditions between these three models of tower. The study shows that tower with angle sections are most economical and effective section compared to other two sections. The transmission tower has a height of 40 m and square base width of 11.5 m. The members are also grouped for better fabrication. Steel optimization has been carried out to find the most suitable and economical section for the design.***

Keywords: Four legged, axial force, deflection.

1. Introduction

Transmission tower lines are one of most important life-line structures. Transmission towers are necessary for the purpose of supplying electricity to various regions of the nation .This has led to the increase in the building of power stations and consequent increase in power transmission lines from the generating stations to the different corners where it"s needed. Transmission line should be stable and carefully designed so that they do not fail during natural disaster. It should also conform to the national and international standard. In the planning and design of a transmission line, a number of requirements have to be met from both structural and electrical point of view. From the electrical point of view, the most important requirement is insulation and safe clearances of the power carrying conductors from the ground. The cross-section of conductors, the spacing between conductors, and the location of ground wires with respect to the conductors will decide the design of towers and foundations.

The major components of a transmission line consist of the conductors, ground wires, insulation, towers and foundations. Most of the time transmission lines are designed for wind and ice in the transverse direction. However, the Indian Sub-continent is prone to moderate to severe earthquakes seismic loads may be important because the transmission line towers and the cables may be subjected to higher force and stressed during ground motion. However, the major concern of the transmission line during high earthquakes may be that the large displacements do not causes the cables to touch each other or any surrounding objects, causing power failure and accidents. Therefore, earthquake forces may be important in design in high earthquake zones of the country.

2. Modeling of Tower

The general software STAAD. Pro has been used for modeling. It is more user friendly and versatile program that offers a wide scope of features like static and dynamic analysis, non linear dynamic analysis and non linear static pushover analysis, etc.

2.1 Software used

STAAD.Pro V8i is the software used for the seismic analysis of multistory building with and without floating column. STAAD.Pro V8i is a comprehensive and integrated finite element analysis and design offering, including a state of the-art user interface, visualization tools, and design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, wind, earthquake, and moving loads. STAAD.Pro V8i provides FEM analysis and design for any type of project including towers, culverts, plants, bridges, stadiums and marine structures.

STAAD. Pro is a structural analysis and design computer program originally developed by Research Engineers International at Yorba Linda, CA in year 1997. In late 2005, Research Engineers International was bought by Bentley Systems. STAAD.Pro is one of the most widely used structural analysis and design software. It supports several steel, concrete and timber design codes. It can make use of various forms of analysis from the traditional 1st order static analysis, 2nd order p-delta analysis, geometric non linear analysis or a buckling analysis. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.

2.2 Plan and dimension details

The following are the specification of 40 m height tower. Here four legged transmission tower is used in the model. The complete detail of the structure including modeling concepts is given below:

Table 1: Details and Dimension of the Tower

Type of tower	220 kV double circuit 4 legged tower
Height of tower	40 m
Base width of tower	11.5 m square base
Length of cross arm	17 m
Type of bracing	Diamond bracing
Width of top hamper	2 m
Conductor Material	Aluminium Conductor Steel Reinforced
Span of tower between two towers	150 m
Vertical spacing between conductors	5 m

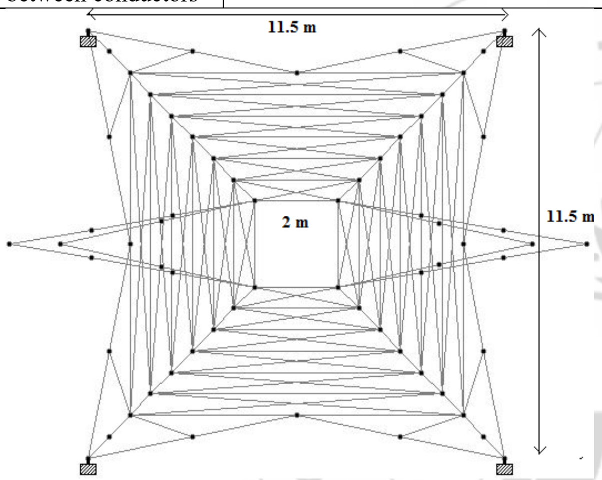

Figure 2.1: Plan of Tower

A square base transmission tower with 11.5 m base width and 40 m height was considered in this study. Figure 2.1 shows the plan of the tower representing the X and Y direction used for analysis. Figure 2.2 shows an elevation of the transmission tower. Figure 2.3 shows a three dimensional line sketch of the transmission tower in the X, Y and Z direction.

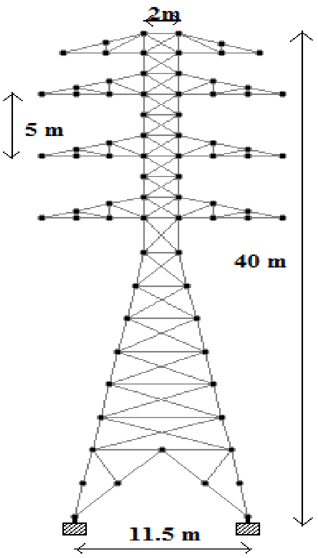

Figure 2.2: Elevation of the Transmission Tower

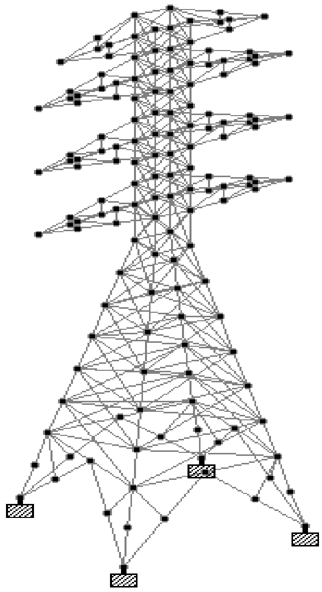

Figure 2.3: Three Dimensional View of Tower

2.3 Assigning support

The support provided for the transmission tower is fixed support. They are provided at the four legs of the tower. They are rigidly fixed to the foundation.

2.4 Load assigning

The load acting on the towers are:
1. Dead load. Self-weight of the tower and the conductors and wires. Figure 2.4 shows the assigning of dead load.

- Weight of insulator and wire-7 kN

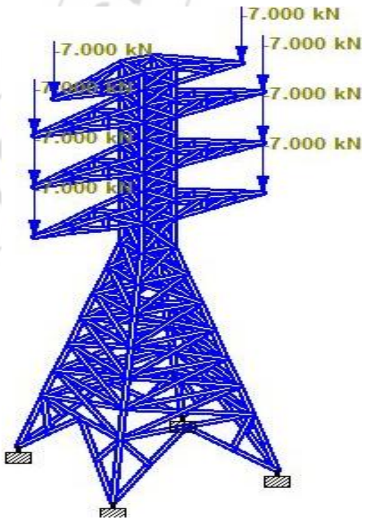

Figure 2.4: Assigning dead load

2. Wind load calculated as per IS 802 (Part1/sec 1): 1995

- **Calculation of wind load**

A tower of square base cross-section the resultant wind load normal to the direction on face of tower, on a panel height „h‟ applied is;

$$Fwt = Pd \times Cdt \times Ae \times GT$$

$$Pd = 0.6Vd^2 \text{ ,Basic wind speed,}$$

$$Vb = 55m/s \ \{zone\ 6\}$$

$$Ko = 1.375, \text{ Therefore } VR=55/1.375=40m/s$$

Design wind speed, Vd
K1=1.3 {reliability level 3}
K2=1.08, terrain category 1
Vd= 40 x 1.3 x 1.08= 56.16 m/sec
Design wind pressure, Pd= 0.6 x 56.162 =1890 N/m^2

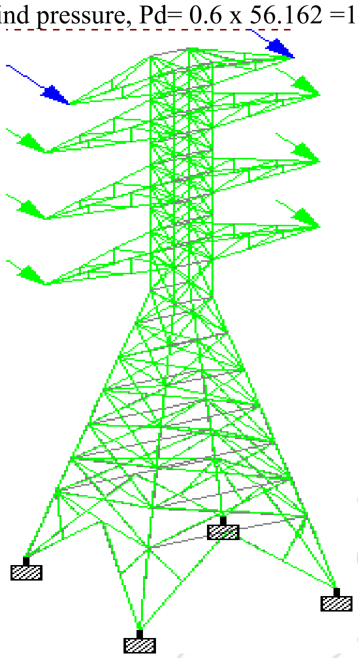

Figure 2.5: Assigning Wind Load

Wind load on lowest conductor (ht 25 m) - 9.072 kN
Wind load on mid conductor (ht 30 m) - 9.072 kN
Wind load on top conductor (ht 35 m) - 9.29 kN
Wind load on insulator wire (ht 40 m) - 14.2 kN
Figure 2.5 shows the assigning of wind load.

- **Load combination**

The load combination have been created with the command of define combinations. By selecting the Indian code we generate loads according to that and then adding these loads. These combinations do not require to be assigned on members. Figure 2.6 shows assigning of combination load. Hence all the loads are assigned on the structure we will move towards forward steps.

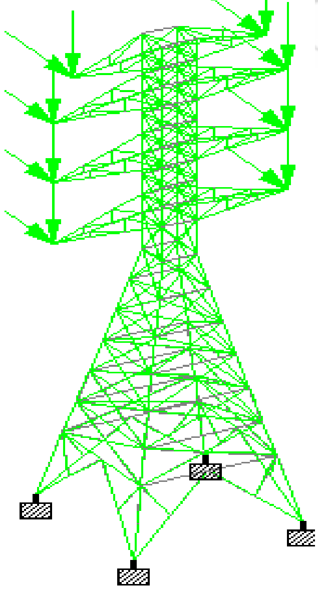

Figure 2.6: Assigning Combination Load

3. Analysis

After assigning the loads to the structure, analysis is done to evaluate the axial force displacement and steel take off for determining the economic section. After analysis design can be executed in the software STAAD.Pro V8i as it includes various international codes and the structure can be designed using these codes. After following above mentioned steps the results obtained from the study are summarized below.

Table 3.1: Maximum Axial Force

S. No	Different Node Point	Beam No	Axial Force (kN)
1	Bottom leg	31	30.918
2	Top column	291	56.39
3	Bottom horizontal member	112	14.508
4	Top horizontal member	257	11.260
5	Bottom bracing	123	16.832
6	Top & cross arm bracing	328	7.738
7	Inclined member in cross arm	397	47.758

Table 3.2: Maximum Displacement

S. No	Different Node Point	Beam No	Displacement (mm)
1	Bottom leg	31	10.064
2	Top column	291	42.728
3	Bottom horizontal member	112	15.457
4	Top horizontal member	257	104.44
5	Bottom bracing	123	12.974
6	Top & cross arm bracing	328	89.254
7	Inclined member in cross arm	397	59.299

Table. 3.3: Maximum Displacement

S. No	Different Node Point	Beam No	Displacement (mm)
1	Bottom leg	31	11.523
2	Top column	291	43.67
3	Bottom horizontal member	112	17.059
4	Top horizontal member	257	110.155
5	Bottom bracing	123	17.642
6	Top & cross arm bracing	328	93.54
7	Inclined member in cross arm	397	67.143

Table 3.4: Maximum Axial Force

S. No	Different Node Point	Beam No	Axial Force (kN)
1	Bottom leg	31	36.497
2	Top column	291	56.39
3	Bottom horizontal member	112	16.117
4	Top horizontal member	257	17.50
5	Bottom bracing	123	21.790
6	Top & cross arm bracing	328	12.415
7	Inclined member in cross arm	397	48.472

Table 3.5 : Maximum Displacement

S. No	Different Node Point	Beam No	Deflection (mm)
1	Bottom leg	31	11.280
2	Top column	291	43.002
3	Bottom horizontal member	112	17.056
4	Top horizontal member	257	109.176
5	Bottom bracing	123	16.587
6	Top & cross arm bracing	328	91.749

7	Inclined member in cross arm	397	61.407

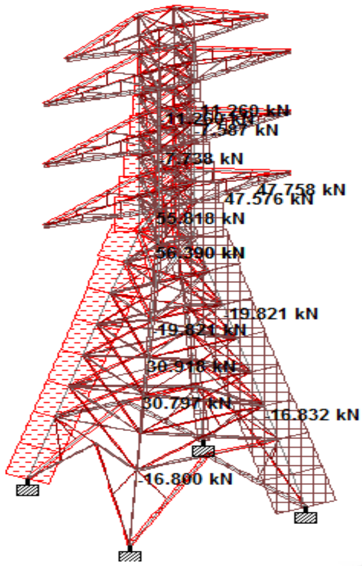

Figure 3.1: Axial force diagram

Axial force diagram of angular section is shown in figure 3.1.

Table 3.6 : Maximum Axial Force

S. No	Different Node Point	Beam No	Axial Force (kN)
1	Bottom leg	31	54.419
2	Top column	291	66.21
3	Bottom horizontal member	112	19.821
4	Top horizontal member	257	18.527
5	Bottom bracing	123	27.515
6	Top & cross arm bracing	328	17.260
7	Inclined member in cross arm	397	67.143

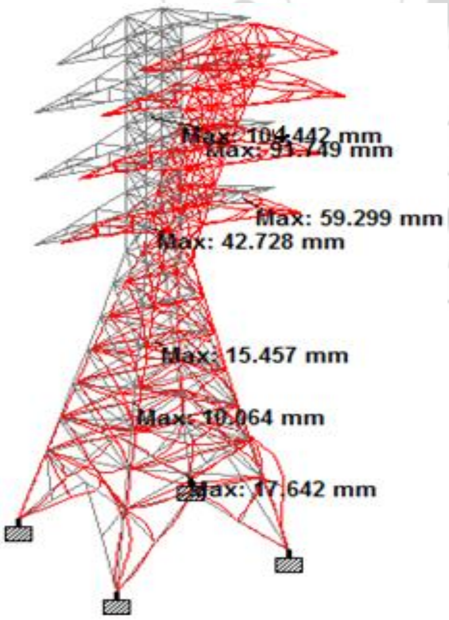

Figure 3.2: Displacement Diagram

Displacement diagram of angular section is shown in figure 3.2. Axial force, deflection for angular, tubular and channel section are calculated. Table 3.1, table 3.2 give maximum axial force and deflection respectively. Table 3.3, table 3.4 give maximum deflection and axial force respectively. Table 3.5, table 3.6 give maximum deflection and axial force respectively.

4. Design of Tower

The design is process of section percussion from the analysis results by using suitable analysis method. By selecting the code IS 800:2007 for the steel design we will then define parameters for our design design as:

1) Beam: Perform design at ends and 1/12th section locations along member length.
2) D max: Maximum allowable depth 1m.
3) D min: Minimum required depth 0 m
4) Fy b: Allowable bearing stress in bolt 300000 kN/m^2
5) Fy ld: Yield strength of steel 250000kN/m^2
6) Ky: K value in local y axis usually minor axis 1.
7) Kz: K value in local z axis usually major axis 1.
8) Ly: Length in local Yaxis for slenderness value kL/r 0 m.
9) Lz: Length in local Zaxis for slenderness value kL/r 0 m.
10) Main: Allowable L/R in compression.

After assigning all these inputs we will now give commands as for the design of structures. These are selected once are added and then assigned to the structure to appropriate components. All the section are thus safe and are suitable for the designing of tower.

5. Discussions and Results

5.1 Maximum axial forces

As the applied increases axial force will also increases causing the member to become unstable and is said to have buckled.

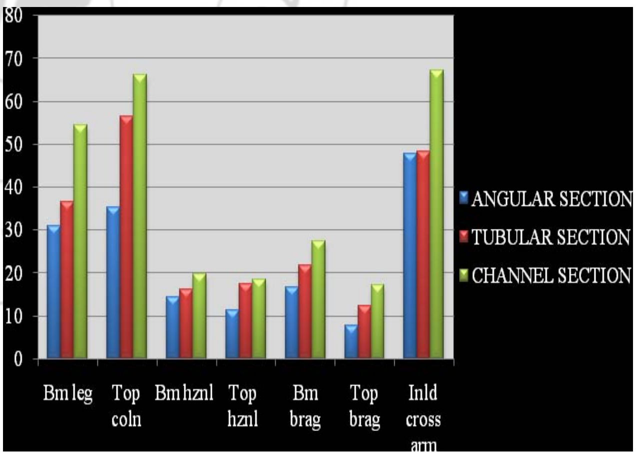

Figure 5.1: Bar Chat of Maximum Axial Force

5.2 Maximum deflection

As deflection increases it cause esthetic and functional problem, damage to structural and non structural element attached to the member. Excessive deflection causes objectionable sagging and hogging.

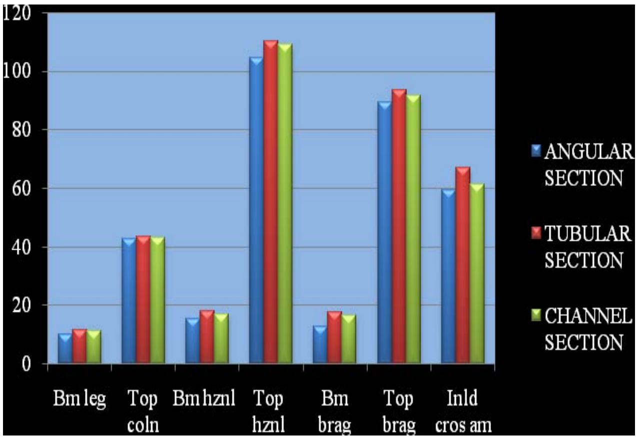

Figure 5.2: Bar Chat of Maximum Deflection

5.3 Steel Takeoff

The following table gives the total amount of angular, tubular and channel sections required for the safe and economical transmission tower.

Table 5.1: Comparisons of Steel Weight

S. No	Tower Configuration	Steel Weight (kN)
1	Angle section	321.652
2	Tubular section	388.072
3	Channel section	437.780

6. Conclusion

As all the towers are analyzed and designed, the following conclusions are made they are as follows:

- The self weight for the angular section is found to be 321.652 kN less than that of the tubular and channel section.
- Angular section saving a steel weight as 20.62% compared to tubular section and it saves 36.10% compared to channel section.
- The angular section is more economical than the other section.
- The angular section is found to have the lesser amount of displacement throughout the height of the tower as compared with the other sections. This implies that this section behaves more rigidly than the other section tower.
- The angular sections are found to have lesser amount of axial forces in comparison with the other section of tower.
- From the whole analysis it is concluded that angular section is more economical and more effective section compared with other sections.

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