# ANALYSIS AND DESIGN OF TRANSMISSION TOWERS FOR DIFFERENT WIND VELOCITIES

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## ABSTRACT

*The Transmission towers are constructed for transmitting the electricity from generation station to substations. It costs almost 25 to 40 percent of the total cost of the transmission line. Transmission tower is an integrated system of conductor, ground wire and support structure. The function of transmission tower is to support the conductor wires and ground wire at suitable distance. Economical design can be obtained by selecting optimum base width and low tower weight. The proposal work is the analysis and design of 220 kV double circuits steel transmission line towers for different wind velocities of 50 m/s, 60 m/s, 70 m/s .STAAD. Pro program is going to be used for analysis and design the members of 220kV double circuit tower of A type. The maximum sag and tension calculations of conductor and ground wire as per IS: 5613 (Part 3/Sec 1) 1989. Loads on transmission tower are to be calculated using code IS802 (Part 1/Sec 1):1995.foundation is done according to IS 4091-1979.*

***KEYWORDS:*** *transmission tower; sag; tension; foundation;*

## I. INTRODUCTION

The components of Transmission line tower are transmission tower, conductor wire, insulator strings and earthwire.

### 1.1 Transmission Tower

The Electrical energy is generated in hydro electrical, nuclear and thermal power plants which are located far away from the cities. So transmission of power from generators to the substations is done with the help of overhead power lines i.e. transmission towers.
The design of transmission tower is generally based on minimum weight of tower. Lattice type tower which consists of primary bracing, secondary bracing and cross arms. The structural design of towers is mainly governed by wind loads acting on tower and conductors and self weight and other loads due to line deviation, broken wire condition, erection and maintance. The tower is modeled as a pin jointed space truss. Steel angle sections of different grades are generally used for towers. Steel poles are also used for transmission line but they are confined to short distances.
Tower foundation generally costs 10 to 15 % of tower. With increase in transmission voltage and size of tower, the loads on tower also increase. The problem of design and construction of foundation becomes challenging these days due to encounter of different soil conditions.

### 1.2 ASCR Conductor

A conductor is a material that allows the electric current to pass through its body when it is subjected to a potential difference.Aluminum provides conductivity while steel provides mechanical strength.

### 1.3 Earth wire

The earthwire is used for protection against lightning and high voltage surges. Depending upon the shielding angle we generally provide one or two earth wires.

**Table 1** Property of Conductor and Earth wire

| Property | Conductor wire | Earth wire |
|---|---|---|
| Material of wire | ASCR MOOSE conductor | Galvanized steel |
| No of wires | 2 | 1 |
| Stranding/Wire diameter | 54/3.53 mmAL+7/3.18mm Steel | 7/3.15mm |
| Total sectional area($mm^2$) | 597 | 54.55 |
| Overall diameter(mm) | 31.77 | 9.44 |
| Approximate weight(KN/Km) | 1998 | 428 |
| Calculated D.C resistance at 20 $^0$C (ohm/Km) | 0.05595 | 3.375 |
| Min.UTS | 16269.1 | 571 |
| Elasticity modulus (Kg/$mm^2$) | 6900 | 19361 |
| Co – efficient of linear expansion(/$^0$C) | $19.3\times10^{-6}$ | $11.50 \times 10^{-6}$ |
| Max allowable temperature($^0$C) | 75 | 53$^o$C |

### 1.4 Insulator Strings:

Insulators are the materials that don't allow current to pass through them. They are devices which are use to support the conductors. They separate the conductors of a transmission line from their supporting steel structures and prevent the flow of current into the ground through the structure. They provide mechanical support to the conductors at a greater height above the ground level. 2×14 No. Disc of double insulator string of length 2640mm is chosen.

## II. DETAILS OF TOWER CONFIGURATION

**2.1 Type of tower**: Suspension tower
**2.2 Wind:** Wind speeds of 50 m/s, 55 m/s, 60 m/s respectively are taken.

**Table 2** Design wind speed

| Tower | Design wind speed(m/s) | Design wind pressure(N/mm2) |
|---|---|---|
| Tower 1 | 50 | 925 |
| Tower 2 | 55 | 1120 |
| Tower 3 | 60 | 1332 |

The tower outline can be determined by:

- Tower height from ground level
- Tower width at the base and at top hamper
- Length of cross arm
- Spacing between the conductors

**2.3 Tower Outline**:
Height of tower =h1+h2+h3+h4
h1=Min permissible ground clearance = 7m
h2=Maximum sag calculated=7.5m
Sag calculations is done from IS 5613 (PART 2/SEC 1)-1985 for 220KV of MOOSE type of conductor and Earth wire.

**Table 3** Sag calculation for conductor wire

| **Temperature** | **12$^0$** | **32$^0$** | | | **55$^0$** |
|---|---|---|---|---|---|
| Wind (%) | 0 | 0 | 75 | 100 | 0 |
| Tension(kg) | 4443 | 4352 | 5734 | **6470** | 4172 |
| Sag(m) | 6.886 | 7.028 | 5.33 | 4.728 | **7.33** |

**Table 4** Sag calculation for Earth wire

| **Temperature** | **$12^0$** | **$32^0$** | | | **$55^0$** |
|---|---|---|---|---|---|
| Wind (%) | 0 | 0 | 75 | 100 | 0 |
| Tension(kg) | 2358 | 1986 | 2350 | **2547** | 1606 |
| Sag(m) | 2.76 | 3.284 | 2.775 | 2.56 | **4** |

h3=spacing between conductors vertically = 5.2m
h4= clearance between earth wire and top conductor vertically
= 5.2 m
Width at the base : 5m
Width at the waist level: 3m
Width at the bottom cross-arm level: 2m

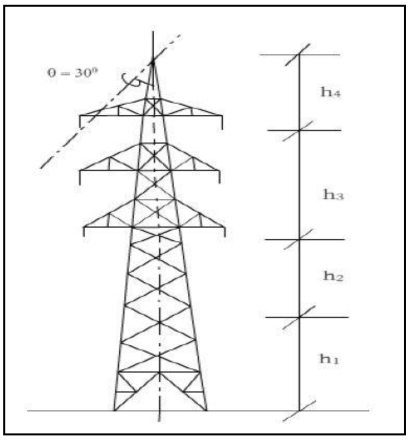


**Fig. 1:** Tower with dimensions marked

## III. LOADINGS ON TOWER

Loadings on tower are calculated as per IS802 1995 for:
i. Reliability condition
ii. Security condition
iii. Safety condition

Reliability of a transmission system is the probability of that the system would perform its function under the designed load criteria for a specified period. Thus, it covers climatic loads such as wind loads and ice loads.

Security of a transmission system is the capacity of the system to protect itself from any major failure arising out of the failure of its components. Thus, this covers unbalanced longitudinal loads due to broken wires.

Safety of a transmission system is the ability of the system to provide protection against any injuries or loss of lives to human beings out of the failure of any of its components. Thus, it covers loads imposed on tower during the construction of transmission line and loads imposed on tower during the maintenance of transmission line.

The loads acting on tower are longitudinal, transverse and vertical loads.

Longitudinal loads due to tension in the conductor, transverse loads due to wind acting on tower and conductors, vertical loads due to self weight of tower and weight of conductor wires.

## IV. MODELLING

Modelling of 3 towers was done in STAAD Pro for different wind velocities.
Angle sections were used for the members.
The height and base width of each tower is made constant of 30.2m and 5 m.

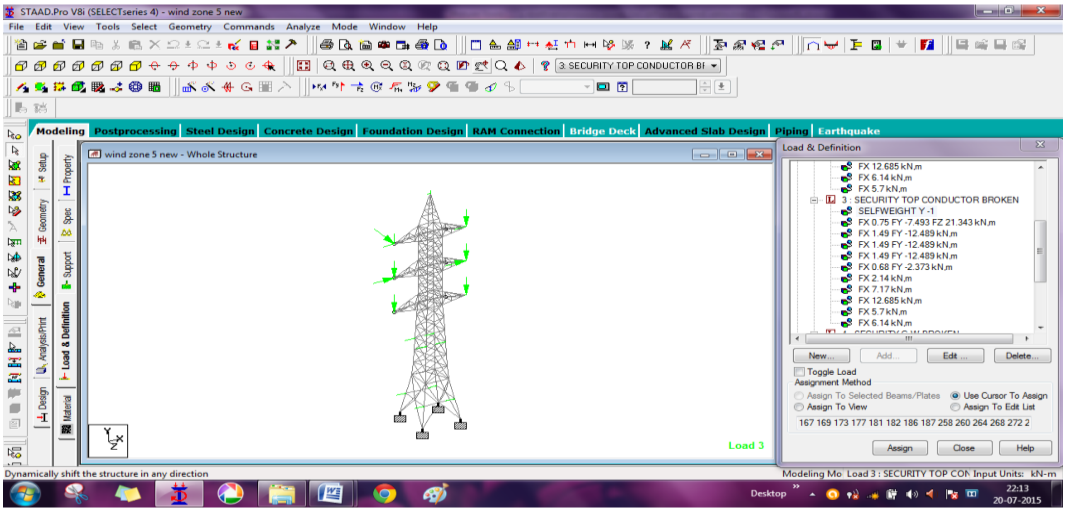


**Fig. 2:** Modelling of tower in STAAD Pro

## V. RESULTS

The tower was analyzed and designed using Staad Pro. Maximum deflections of the nodes and maximum axial forces in the members are the important parameters of this study and they are compared for 3 wind velocities. Foundation is done for clayey soil and hard rock conditions. The depth of pile foundation and depth of pile cap for is designing for clayey soil of bearing capacity of 80KN/m$^2$.The rock anchor type foundation is designed for hard rock of bearing capacity of 1250 KN/m$^2$.

**Table 5** Maximum deflection

| Tower | Max X(mm) | Max Y(mm) | Max Z(mm) |
|---|---|---|---|
| 1 | 296.4 | 59 | 96 |
| 2 | 325.9 | 73 | 85 |
| 3 | 312.14 | 68.9 | 69.75 |

**Table 6** Maximum forces in members

| Tower | Axial force (KN) |
|---|---|
| 1 | 423.9 |
| 2 | 552 |
| 3 | 643 |

**Table 7** Weight of the Tower

| Tower | Weight(KN) |
|---|---|
| 1 | 46.64 |
| 2 | 47.543 |
| 3 | 52.323 |

**Table 8** Support Reactions

| Tower | X(KN) | Y(KN) | Z(KN) |
|---|---|---|---|
| 1 | 60.24 | 377.5 | 127 |
| 2 | 70 | 495 | 154 |
| 3 | 81.06 | 577.1 | 179 |

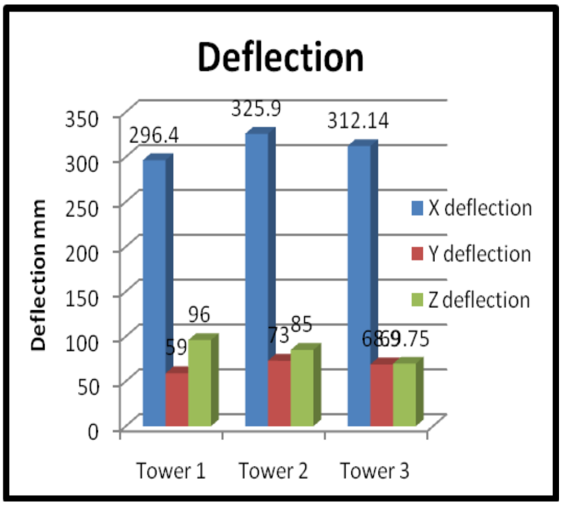


**Fig 3** Maximum deflection of nodes

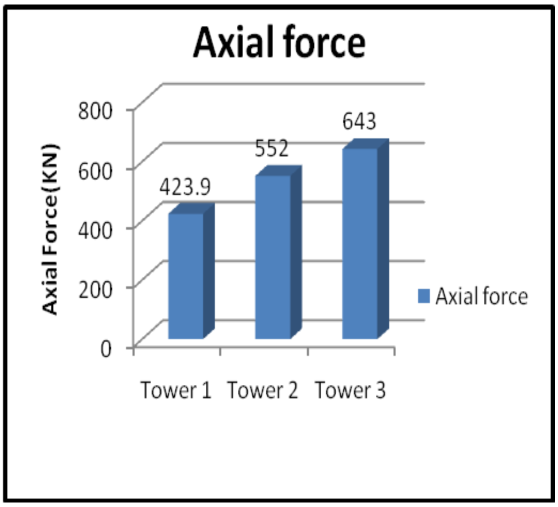


**Fig 4** Maximum axial forces in members

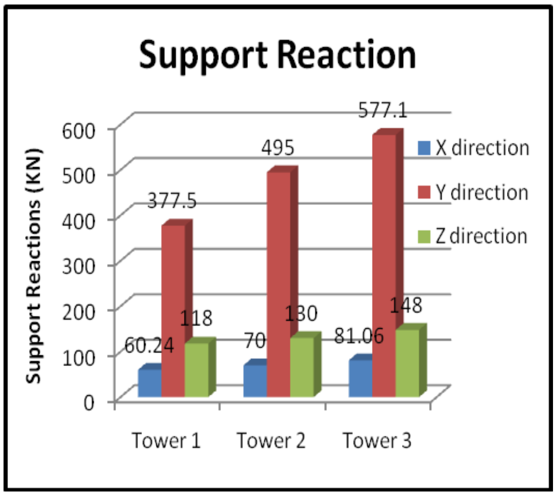


**Fig 5** Support reactions

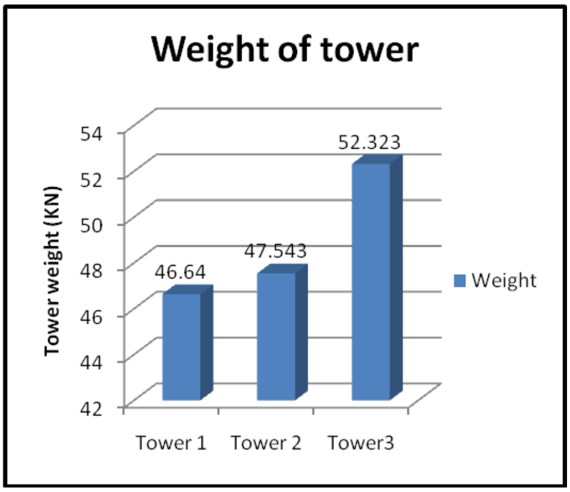


**Fig 6** Weight of the tower

**Table 9** Pile foundation

| | **Tower 1** | **Tower 2** | **Tower 3** |
|---|---|---|---|
| Pile length(m) | 14 | 16 | 18 |
| Diameter of pile(mm) | 500 | 500 | 500 |
| Compression (KN) | 120 | 134 | 149.4 |
| Lateral load(KN) | 36 | 40.1 | 44.8 |
| Ast provided and Lateral reinforcement | 5no 20mm # and 8 mm ϕ @ 160 c/c spacing | 5 no25 mm# and 8 mm ϕ @ 160 c/c spacing | 5 no 25 mm# and 8 mm ϕ @ 160 c/c spacing |
| Pile cap thickness(mm) | 420 | 490 | 540 |
| Reinforcement in pile cap | 20 mm # @320mm c/c spacing | 20 mm # @280mm c/c spacing | 20 mm # @250mm c/c spacing |

For rock anchor type foundation slab of size of 1.5 m×1.5m and depth of slab of 1000mm and with 4 anchor bars embedded in grouted anchor holes of 1.2 m depth for each footing is recommended for 3 towers.

## VI. CONCLUSIONS

The study shows that the

- The deflection of tower increases with increase in wind velocities.
- The weight of tower increases with increase in wind velocities and the for the 3rd tower there is more increment when compared to the other towers as double angles is provided at leg members due to high axial forces were developed in leg members.

- The maximum forces are obtained at middle panel for all the 3 towers.
- The depth of piles increased with increase in wind loads as the compressive loading and lateral forces increases.
- For Rock anchor type foundation the minimum depth of slab provided 1000mm is sufficient for all the 3 towers against uplift of foundation.

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