Analysis & Design of Transmission Tower & Monopole by using Manual Calculation & Software

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Abstract— This research work is focused on comparison of transmission tower and monopole tower for different parameters viz. different height and different loading combinations. The comparative analysis is carried out with respect to axial force deflection maximum sectional property and critical load conditions. The transmission tower and monopole are design by manually by using limit state method based on IS 800, IS 802 IS 875 and gust factor method. Based on steps and formulas involved, a design program will be prepare in MS-EXCEL. The veracity of program will be check by first designing the manually designed transmission tower and monopole using the software and compare results. Wind analysis is carried out using standard codes and software. The behaviour of tower and pole is analysed for different load combination. The maximum displacement values, shear forces and bending moments are obtained. Therefore, transmission tower and monopole should be designed considering both structural and electrical requirements for safe and economical design as per Indian code. It is concluded from past study that transmission tower have lower lateral displacement as compared to monopole. This is because they have higher stiffness. Transmission tower carry heavy electrical transmission conductor at sufficient and safe from the ground than monopole. Loads acting on the tower and monopole are wind load, dead load of the structure, braking load of conductor and earthquake load considered as per Indian standard code. The steel quantity required for transmission tower is approximated two times more than monopole. The idea is to reach a definite conclusion regarding the superiority of two structures.

Key words: Transmission Tower, Monopole, Bracing, Loads

I. Introduction

In last several studies have been performed in the area of analysis and design of metallic towers. The electric transmission is the process by which large amounts of electricity produced at power plants is transported over long distances for use by consumers. Usually steel transmission towers and monopoles are used to transmit the electric power. This is in view of non-availability of adequate land for installation of conventional lattice type tower. To overcome these practical difficulties, a new concept of transmission line is being used world-wide, called monopole. The cost of transmission tower constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The transmission tower are designed and constructed in wide variety of shapes, types, sizes, configuration and material. The supporting structure type used in transmission line generally fall into one of the three categories: lattice, pole guyed. According to IS 800-07, the wind forces are much prominent on the tower, conductors and insulators, besides the self-weight. Tower structural calculations include applied loads like wind load, dead load, seismic load and design strength of structural steel member on superstructure including connection and foundation. From safety considerations, along the route of the transmission line clearances above open countries, roads, rivers, railway tracks, tele-communication lines, other power lines, etc. up to conductor needs to be maintained. The basic function of the tower is to isolate the conductors from their surroundings, including other conductors and the tower structure. . An alternative to the transmission tower, the monopole tower, is also used in this power corridor. In this case, the monopole supports much lower voltage conductors for distribution to industrial customers and substations. The voltages required for economical transmission of electric power exceeds the voltages appropriate for distribution to customers.

Fig. 1: Transmission Tower

Fig. 2: Monopole

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II. Review of Literature

There are several studies done on the design and analysis of transmission tower and monopole by using software. This literature review reveals the amount of research work done in India.

Sai Avinash, and Rajasekhar ISSN0974-5904, Vol 09, no. 03 June-2016 [1] Analysis and design of transmission tower by using Staad.Pro.v8i. This work is focused in optimising the transmission tower with employing the X and K bracings, and by varying the sections, using static analysis. They concluded that the transmission tower modelled with X bracing required lesser percentage of steel i.e. 6% when compared to K bracing. In design aspect it reveals that by providing unique sectional property throughout the transmission tower leads to uneconomical design.

Shivam Panwar, Yogesh Kaushik ISSN 2349-4476, Vol 4, Issue 5, May-2016 [2]. This research work an attempt has been made to compare the same transmission towers with same bracing system at different wind zone viz. zone II and zone IV located at Delhi and Panjim. The conclusion are drawn on the basis of the research and analysis done through the Staad.Pro.V8i. There is large difference in the bending moment forces on the members and there is huge change in axial force in cross arms members of tower.

D.B. Sonowal, J.D. Bharali ISSN2278-1684, 2015[3] This work focused on Analysis and design of 220kV transmission line tower (conventional method of analysis and Indian code based design) The transmission line tower is a statically indeterminate structure and the manual analysis of such a structure is very complex. This paper considering linear behaviour with two dimensional approaches gives satisfactory results which should be further verified with advanced software like Staad.Pro, Ansys etc. As per the design concern all section we consider are found safe against worst condition.

M. Pavan Kumar, P. Markandeya Raju Vol 18, no. 6, 2017 [4] this research work presents a comparison between monopole and self-support type towers with different heights for basic wind speed. This study was concluded that self-supporting towers have lower lateral displacements compared to monopole towers of same height and same amount of loading due to the fact that they have higher stiffness. But due to their rigidity, self-support tower have more load carrying capacity than monopoles for towers of height less than or equal to 40M, Monopoles may be preferred but with increase in height above 50M self-supporting towers are more suitable. This is because, during unexpected higher wind speeds due to cyclones (like hud hud), the structural rigidity will be intact and the cost of damage and the repair of the structure may not be so high unlike monopole

III. Aim & Objective

This works includes the analysis and design of transmission tower and monopole for voltages 132 KV & 220 KV for single and double circuit. As the transmission tower required more authentication for installation and also required more right of way (ROW). Monopole suggests the better option to overcome this problem, without disturbing forest property.

1) The main objective of this study is to analyse and design of transmission tower and monopole and to compare the performances of transmission tower and monopole.
2) To check the variations in lateral displacement for better stiffness of structure.
3) To check the tensions for the conductors and ground wire.
4) To check the variations in stresses or forces in cross arms members in tower and monopole.
5) To check the effects of different loads on transmission tower and monopole.
6) To check the bending moment of transmission tower and monopole for which structure gives better strength.
7) To check whether the transmission tower and monopole should be used in future.

IV. Methodology

The transmission tower and monopole are design by manually by using limit state method based on IS 800, IS 802, IS 875 and IS 5613. Based on steps and formulas involved, a design program will be prepared in MS-EXCEL. The veracity of program will be check by first designing the manually designed transmission tower and monopole, & then using the software and compare results. An identical procedure will be followed for both. The program for designing the same will develop by using MS-EXCEL and its fidelity will check by first solving manually also in software and then comparing results. The transmission tower and monopole will design for voltage between 132KV & 220KV. 4-legged transmission tower and 16 sided polygonal shape monopole will design for single circuit and double circuit power.

V. Design of Transmission Tower

A steel tower is to be erected for transmission tower for a single circuit three phase.

GIVEN DATA	SIZE / VALUE / QUANTITY
Voltage of transmission	132 KV
Power conductor	ACSR (Panther)
30 mm dia ACSR	30/7/3mm (Consisting of 54 strands 3 mm dia of aluminium & 7 strands of 3 mm dia of steel
Unit weight of conductor	16.76 N/mm (0.01676 KN/m)
Permissible axial tension	35.60 KN
Young’s modulus of elasticity	0.842×10^5 N/mm^2
Circuit	Single (three phase)
Material of ground wire	Galvanised steel
No. of ground wire	1
Dia of ground wire	10 mm
Permissible axial tension	25.40 KN
Wind span of tower (L)	240 m

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Variation of temp range	5˚ to 60˚c
Wind span	39 m/s
Snowfall	Not expected

Table 1:

Tower: Tangent type of tower with not more than 2˚ line deviation shall be erected.
2˚ line deviation to be used on straight runs. (From IS 802 part 1/sec1:1995)

1) Terrain type considered - plain
2) Terrain category - 2
3) Reliability level - 1
4) Return period - 50 years

A. *Geometry of Tower*

The total height of tower is decided keeping in view the clearance requirements and maximum sag for power conductor.

1) Clearance Requirements

Vertical height of conductor above ground (H_1) = 6.1m ….. (IS 5613 part2/sec1 1995)
Vertical spacing between power conductor (H_3) = 4m ….. (IS 5613 part2/sec1 1995)
Horizontal spacing between power conductor = 6.25m …. (IS 5613 part2/sec1 1995)
Height of ground wire above topmost power conductor shall be half the horizontal spacing of power conductor.
Height of ground wire above top most conductor
H_4 = 3.12m

B. *Calculation of Sag Tension*

Tension T = $\frac{U.T.S}{F.O.S}$
UTS - Bearing strength of conductor = 9130 Kg
F.O.S. - Factor of safety for conductor = 4
Sagging = $\frac{wl^2}{8T}$
= 5.28 m
Increasing 4% of calculated sag
= 5.49m
Total height of tower = $H_1 + H_2 + H_3 + H_4$
H ≈ 20 m

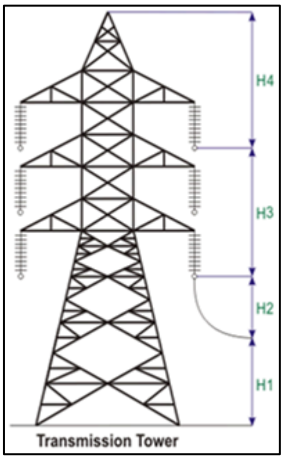

Fig. 3: Height of Tower

Width of base of tower
For stability requirement the width of tower at base as kept as
= $\frac{1}{4}$Th × height of tower

C. *Design Wind Pressure*

$P_d = 0.6 \times Vd^2$ ……(From IS 802 part1/sec1-1995)

1) To Calculate Wind Speed

$V_d = V_R \times K_1 \times K_2$ …..(From IS 802 part1/sec1-1995)
V_R - reference wind speed
K_1 - Risk coefficient for different reliability level ….. (From IS 802 part1/sec1-1995)
K_2 - Terrain roughness coefficient for three categories ….. (From IS 802 part1/sec1-1995)
$V_R = \frac{Vb}{K0}$

D. *Calculation of Wind Load*

Wind load on conductor and ground wire: (From IS 802 part1/sec1-1995)
$F_{WC} = P_d \times c_{dc} \times L \times d \times G_c$
Wind load on insulator string (From IS 802 part1/sec1-1995)
$F_{Wi} = C_{di} \times P_d \times A_i \times G_i$
$A_i = \frac{1}{2}$ × dia of conductor × insulator length
Wind load on tower (From IS 802 part1/sec1-1995)
$F_{Wt} = P_d \times C_{DT} \times A_e \times G_t$
Vertical loads (From IS 802 part1/sec1-1995)
Line man with tools = 1.5KN
Load at tip of cross arm = 3.5KN
Weight of conductor = 1.5 LWC
Base width = 5m.
Top width = $\frac{1}{3}$ or $\frac{1}{3.5}$of base width

VI. DESIGN OF TRANSMISSION MONOPOLE

GIVEN DATA	SIZE/VALUE/QUANTITY
Voltage of transmission monopole	132KV
Conductor	
Type of conductor	ACSR panther (30/7/3mm)
Total sectional area	212.1mm^2
Approximate overall diameter	21mm
Approximate weight	973 kg/km
Coefficient of linear expansion (α)	17.8 × 10^{-6}/degree
Final modulus of elasticity	0.815 × 10^6 Kg/cm^2
Circuit	Single
Ground wire	
Material of wire	Galvanized steel
No. ground wire	1
Stranding and wire diameter	7/3.15mm
Approximate overall diameter	9.5mm
Approximate weight	428Kg/Km or 0.428KN/m
Coefficient of linear expansion (α)	11.50 × 10^{-6} / degree
Final modulus of elasticity	1.938 ×10^6 Kg/ cm^2
Type of monopole	A type , Tangent type
Maximum line deviation	2^0 on straight runs
Terrain type consider	Plain
Terrain category	2
Return period	50 years
Reliability level	1

Table 2:

A. *Design Wind Pressure*

$P_d = 0.6 \times V_d^2$

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1) To Calculate Design Wind Pressure

$V_d = V_R \times K_1 \times K_2$ … (From IS 802 part1/sec1-1995)

$V_R = \frac{Vb}{K0}$

Calculation of wind load … (From IS 5613 part 1/ sec 1)

B. Clearance Requirement

Vertical height of conductor above ground = 7 m … (IS 5613 part2/sec1 1995)
Vertical spacing between conductor = 4.5m … (IS 5613 part2/sec1 1995
Horizontal spacing between power conductor = 6.25m … (IS 5613 part2/sec1 1995)
Height between topmost conductor to earth wire = H = 3m
Total H = 14.5 m

C. Calculation of Sag & Tension

$T = \frac{UTS}{F.O.S.}$

Sagging = $\frac{wl^2}{8T}$

Sagging = 3.06m;
Sag increased by 4%
 Sagging = 3.18m
Total height of monopole ≈ 18m

D. Calculation of Wind load:

1) Transverse Load for Conductor

$F_{wc} = P_d \times Cdc \times L \times d \times G_c$

Transverse load for ground wire:

$F_{wg} = P_d \times Cdc \times L \times d \times G_c$

Transverse load for insulator:

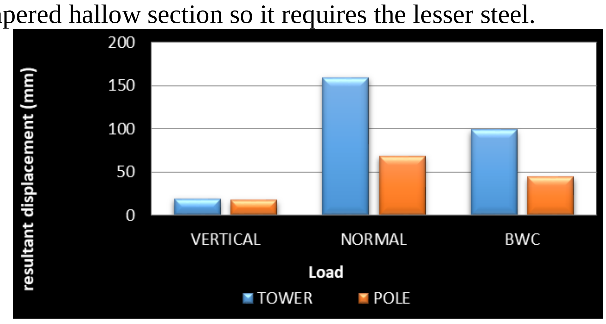
$F_{wi} = P_d \times Cdi \times Ai_{\times} G_i$

VII. RESULT & DISCUSSION

Fig.1 shows resultant displacement on transmission tower and monopole of for single circuit 132 KV. Results showing differentiation in between monopole and transmission tower, which structure best for given loading condition.

In resultant displacement for vertical displacement transmission tower and monopole gives the nearby same displacement whereas in other two conditions transmission tower gives the maximum displacement as compare to monopole.

Fig.2, 3, shows compression and tensile stresses for three loading condition i.e. VLC, NC and BWC. In compressive stresses and tensile stresses for all three load conditions the transmission tower gives the maximum stresses as compare to the monopole. In quantity of steel the transmission tower required the more steel because transmission tower has a different type of bracings and angle section so it requires the more steel whereas, monopole is tapered hallow section so it requires the lesser steel.



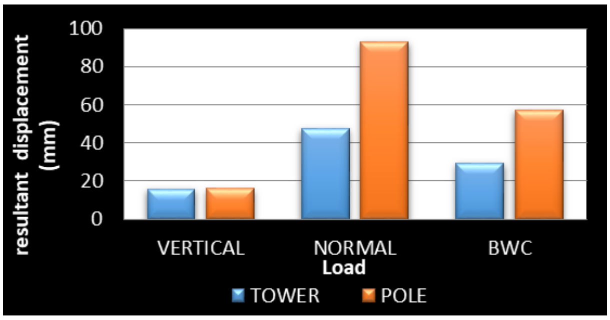


Fig. 1: Shows Resultant Displacement V/S Three Loading Conditions (132 KV & 220 KV Single Circuit)

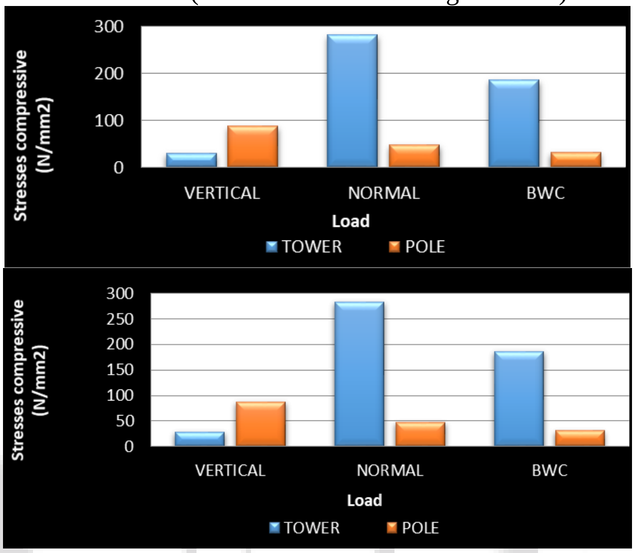


Fig. 2: Shows Compressive Stresses V/S Three Loading Conditions (132 KV & 220KV Single Circuit)

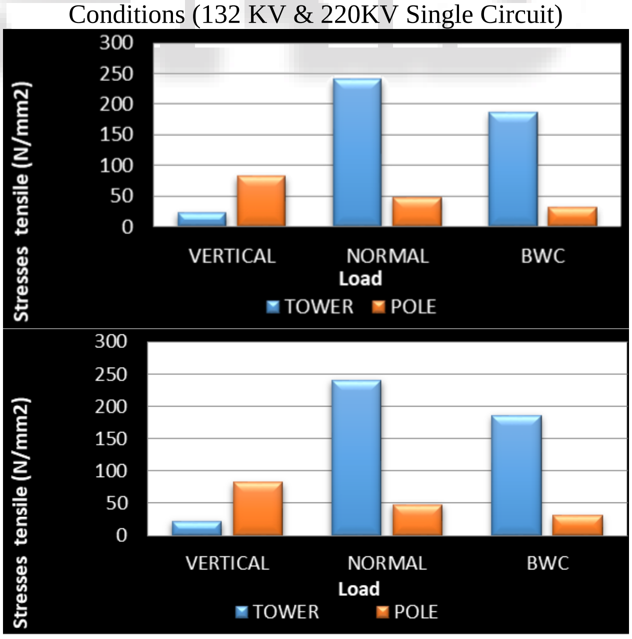


Fig. 3: Shows Tensile Stresses V/S Three Loading Conditions (132 KV & 220 KV Single Circuit)

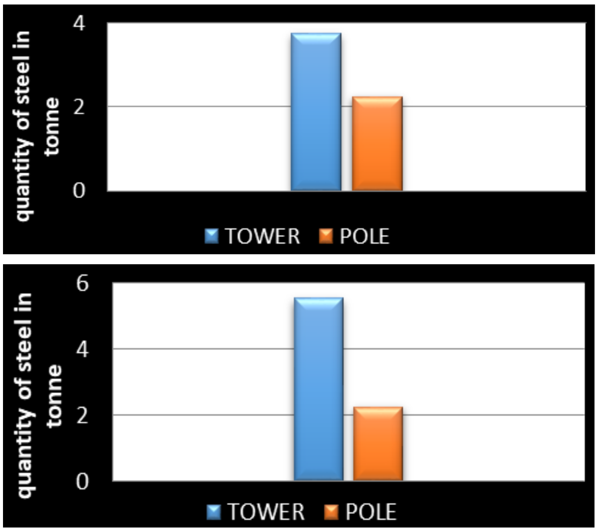


Fig. 4: Shows Quantity of Steel Required (132 KV & 220 KV Single Circuit)

VIII. CONCLUSION

The present work attempt has been made to analysis and design of transmission tower and monopole by manual calculation and using software. Based on the results obtained following conclusion appears to be justified:

1) From results average displacement for transmission tower is 43.05mm whereas for monopole is having displacement is 4.10mm, this displacement found for 132KV & 220KV single circuit structure. Where 'K' Bracing used for the transmission tower and for monopole tapered section is used, here we conclude, monopole showing minimum displacement.
2) As the bracing is changes the values of displacement and bending moment goes decreases for the transmission tower even though the weight of structure increased due to double circuit. But in monopole the values is increases. From above values it concludes that the monopole is more effective and then transmission tower.
3) From results, percentage of steel for single circuit transmission tower requires 60% greater than the single circuit monopole.
4) From results of analysis the monopole required lesser percentage of steel when compared to transmission tower. From this it reveals that monopole gets economical and lighter structure as compared to transmission tower.
5) From calculations transmission tower requires the more right of way (ROW) as compared to monopole. To overcome these difficulties monopole suggests the best option for crowded area as well.
6) From analysis it is observed that the values of maximum displacement and bending moment are higher for monopole as compare to transmission tower. This makes the monopole structure less effective.

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