Parametric Studies on Transmission Line Tower Due to Dynamic Loading

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***Abstract*—India has a large population residing all over the country and the electricity need of this population creates requirements of large transmission and distribution system. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one system for each category of support structure. Structural system of transmission line represents a significant portion of the cost of the line and they play an important role in the reliable power transmission. This thesis is concerned with the performance of three types of transmission line towers with varying heights under seismic and wind induced dynamic loads. Wind loads are considered as per IS 802(part1/sec1):1995, IS 875(part3): 1987 and seismic load as per IS 1893(part1):2002. The finite element analyses of transmission line tower involves modal analysis, equivalent static, response spectrum, time history and wind analysis with gust factor. The results obtained from the analyses are compared and the conclusions are drawn**

***Keywords*— Double warren bracing, Diamond bracing, K and double warren bracing, Validation, Modal analysis, Seismic analysis, Wind analysis.**

I. INTRODUCTION

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 is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure

The structure engineer is entrusted with the challenging job of designing and constructing transmission structures to support heavy conductor loads in open weather with high degree of reliability and safety to the general public ensuring satisfactory serviceability. Seismic design of transmission towers is important in the earthquake vulnerable areas. Transmission towers are classified based on their usage and number of circuits. The transmission towers are mainly designed for the forces due to wind, ice and other loading conditions but not for the seismic forces. Since more than 60% of the Indian Sub-continent is prone to moderate to severe earthquakes it has become more vital to design the life line systems for seismic safety.

The scope of the dissertation is to carryout finite element analysis on electrical transmission line towers due to seismic and wind induced dynamic loads. Three types of towers are considered in this study with varying heights and base widths as given below.

- Double warren bracing tower (DWT)
- Diamond bracing tower. (DT)
- K and Double warren bracing tower.(KDWT)

II. CONFIGURATION OF TOWER

A transmission line tower is like exposed structure. Its super structure suitably shaped, dimensioned and designed to sustain the external loads acting on the cables (conductors and ground wires) of the super structure itself. The super structure has a trunk and a hamper (cage) to which cables are attached either through insulators or directly.

TABLE 1: THREE TYPE TOWER WITH DIFFERENT PARAMETER

Different types of towers	**Parameters of tower**
Double Warren (DWT)	A typical tower is a 132-KV double circuit tower with angle of inclination is 2^0,wind zone 4 (47m/s) is considered, the basic tower is 6.0 m base width & 30 m height it changes the parameter of 8.0 m base width of 40 m height and 10.0 m base width of 50 m height of tower
Diamond (DT)	A typical tower basic tower is 5.4 m base width &26.58 m height it changes the parameter of 5.4m base width of 30m height,6.43 m base width of 40 m height and 8.04 m base width of 50 m height of tower
K and Double Warren (KDWT)	A typical tower is 400-KV double circuit tower with angle of inclination is 2^0, the basic tower is 8.83 m base width &44.34 m height and it changes the parameter of 5.975m base width of 30m height, 7.965m base width of 40 m height and 9.957 m base width of 50 m height of tower.

III. LOADING CALUCLATION

The loads are calculated as per I S 802 (Part 1:Sec 1)-1995 and CBIP Manual No.268 the above parameters are considered. The load considered for all tower are shown in fig 1 (a-c). As per CBIP (Central Board of Irrigation Power) in "Transmission Line Manual" the nature of the loads are given as follows:

A. *Transverse loads:*

These are the forces applied perpendicular to the longitudinal axis of a member. In transmission tower these loads are acted by

a) Wind load on tower structure, conductor, ground wire and insulator strings.
b) Component of mechanical tension of conductor and ground wire.

Wind load on wire : F_{wc} = Pd. L. d. G_c. C_{dc}
Wind load on Insulator F_{wi} = n. m. P_d. A_i. G_i. C_{di}
Due to deviation Fwd = 2. T. sin (ϕ/2)

B. Vertical load

These are loads due to the self weight of the members acting perpendicular to the towers

a) Loads due to weight of conductor, ground wire based on appropriate weight span, weight of insulator strings and fittings.
b) Self weight of the structure
c) Loads during construction and maintenance

Weight of wire = w. L
Weight of Ground wire = 50 N
Weight of insulator = 2 kN
Weight of man with tools = 1.5 kN

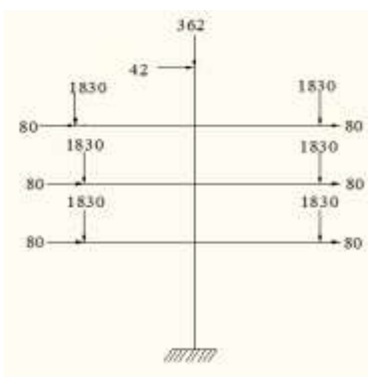

Fig 1(a) : Normal load for DWT

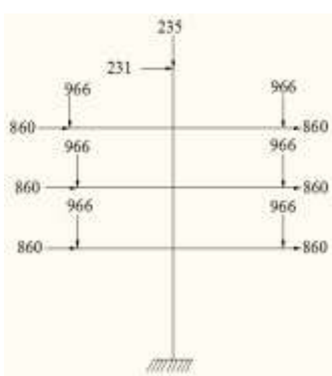

Fig 1 (b): Normal load for DT

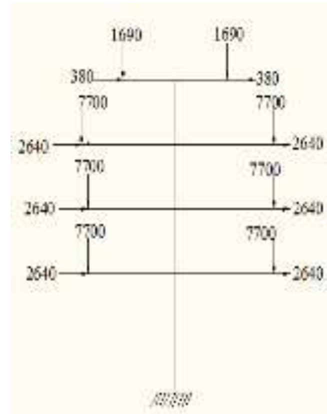

Fig 1 (c): Normal load for KWDT

IV. FINITE ELEMENT MODELING AND ANALYSIS

The modeling and dynamic analysis of three types four legged transmission line towers have been carried out using the software STAAD Pro. Different bracing are used with angle section and the configuration of the towers are given in table 2. The sectional properties are given in table 3.

Table 2: Different parameters for all towers

Different bracing of Towers	Height (Meter)	Base width (Meter)
Double Warren (DWT)	30	6
	40	8
	50	10
Diamond DT	30	5.4
	40	6.43
	50	8.04
K and Double Warren KDWT	30	5.975
	40	7.965
	50	9.957

Table 2: Sectional properties for all towers

Serial No	Different Components	Angle Section
1	Leg members	200x200x25
2	Main members	130x130x12
3	Secondary members	200x200x12
4	Cross arms	150x150x15
5	Diaphragm	80x80x6

The three types of transmission line tower models are shown in fig 2 (a-c).

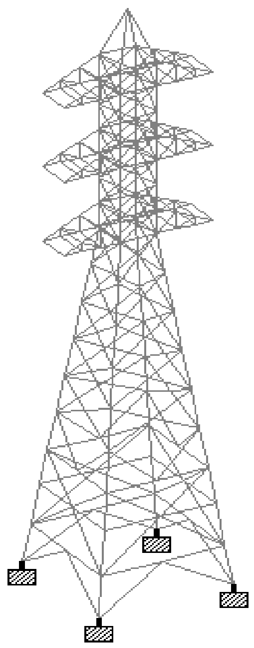

Fig 2(a): DWT

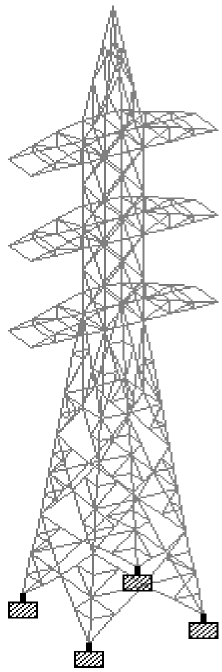

Fig 2(b): DT

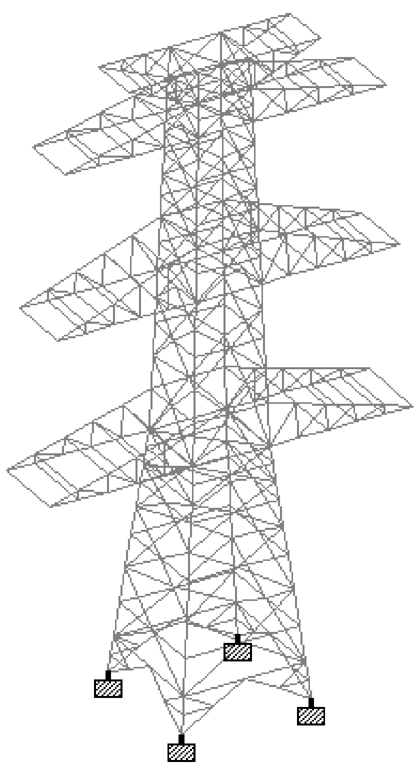

Fig 2(c): KDWT

V. RESULTS AND DISCUSSIONS

A. Modal Analysis

The fundamental frequency for all the towers is obtained from the modal analysis. The first mode shapes for all tower as shown in fig 3

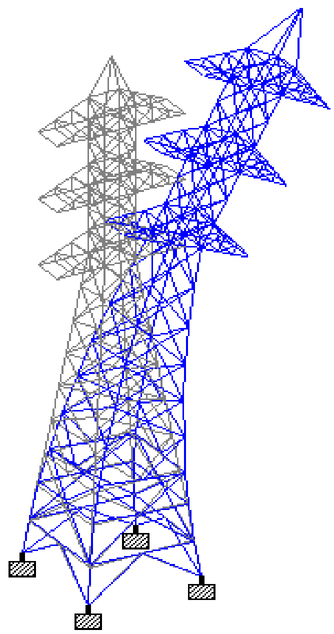

Fig 3 (a): 1st mode for DWT

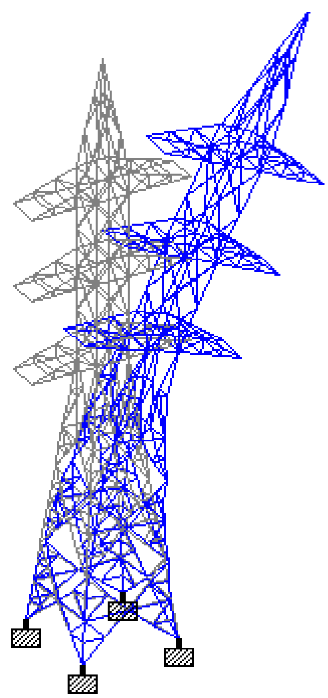

Fig 3 (b): 1st mode for DT

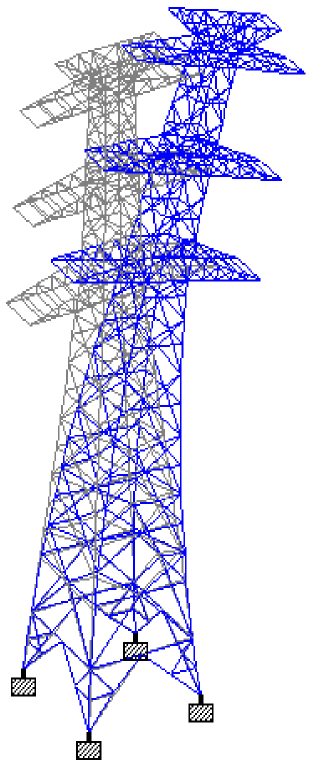

Fig 3 (c): 1st mode for KDWT

B. Response Spectrum Analysis

The Response Spectrum analysis is performed on the all three types of transmission line towers for all the seismic zones as per IS 1893(part1)-2002 Maximum stresses and maximum displacements are taken at pivotal points for zone V. Maximum stresses and displacements of three type towers for main leg members are shown in figure 4(a-f) to respectively.

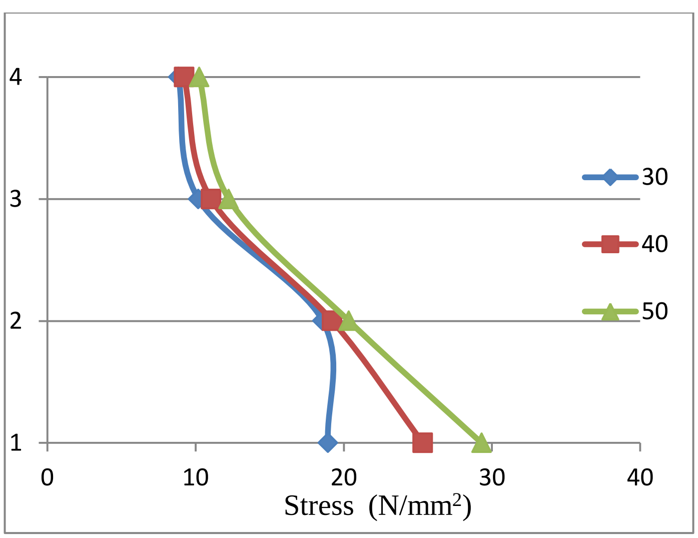

Fig 4(a): Maximum stress of DWT tower for main leg members

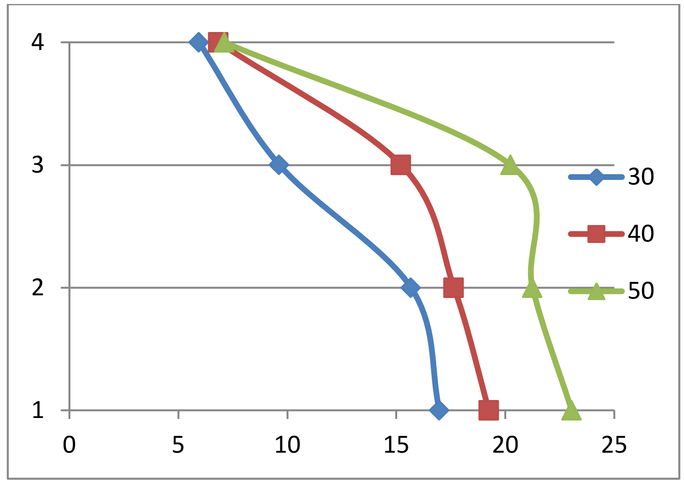

Fig 4(b): Maximum stress of DT tower for main leg members

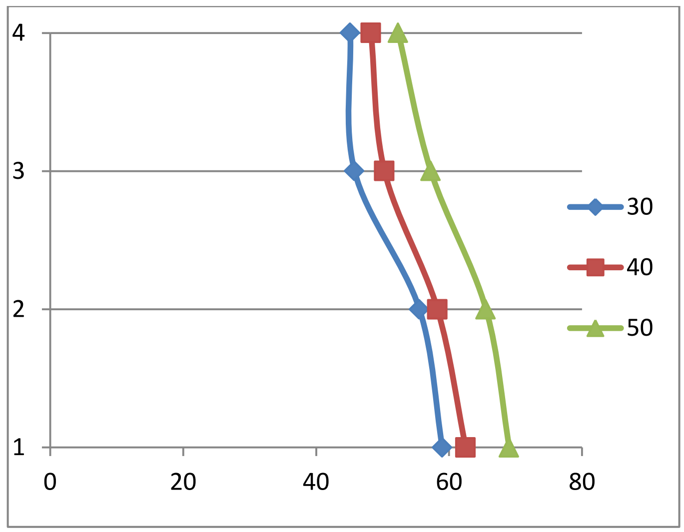

Fig 4(c): Maximum stress of KDWT tower for main leg members

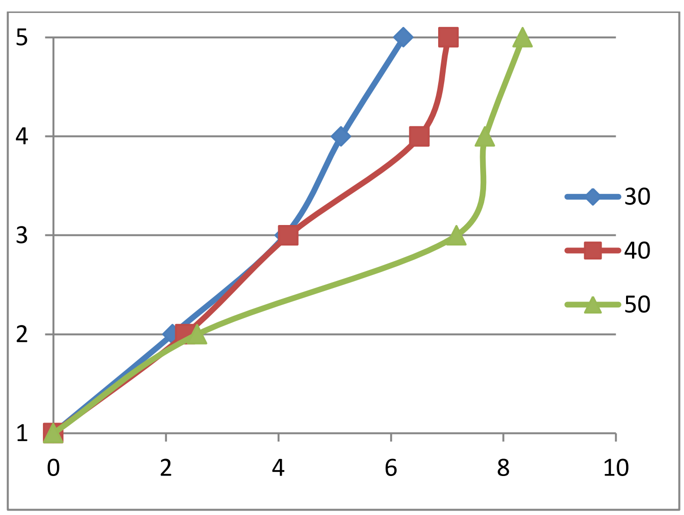

Fig 4(d): Maximum displacement of DWT tower for main leg members

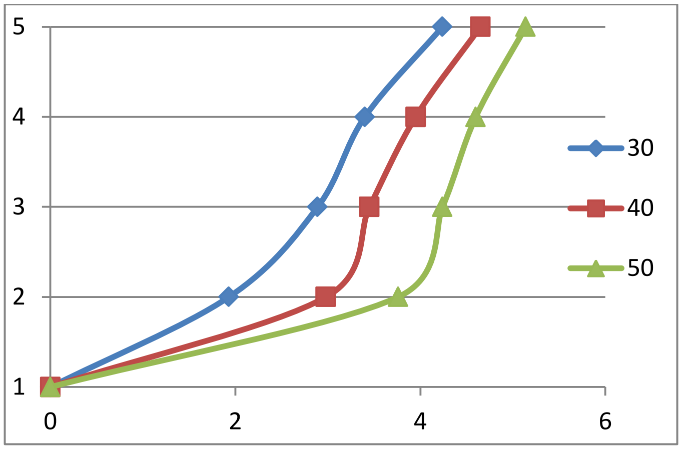

Fig 4(e): Maximum displacement of DT tower for main leg members

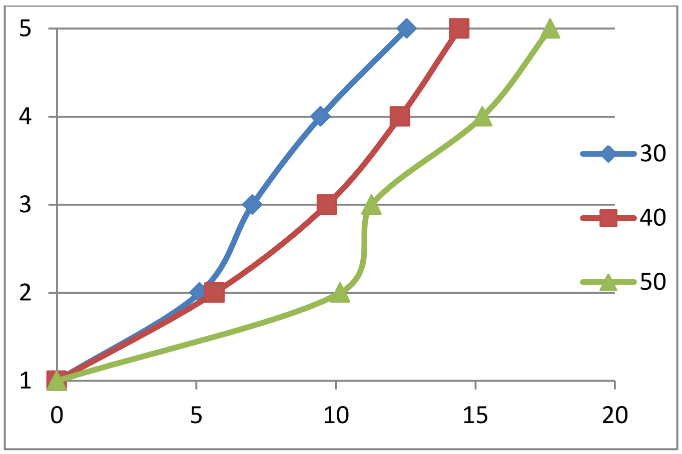

Fig 4(f): Maximum displacement of KDWT tower for main leg members

C. *Time History Analysis*

Time history analysis is performed on all three transmission line tower for all the seismic zones as per IS 1893(part1)-2002. Maximum stresses and maximum displacements are taken at pivotal points for zone V. Maximum stresses and displacements of three type towers for main leg members are shown in figure 5(a-f) respectively.

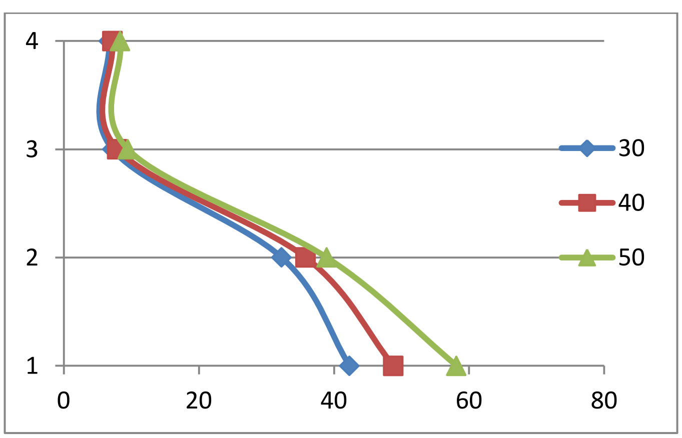

Fig 5 (a): Maximum stress of DWT tower for main leg members

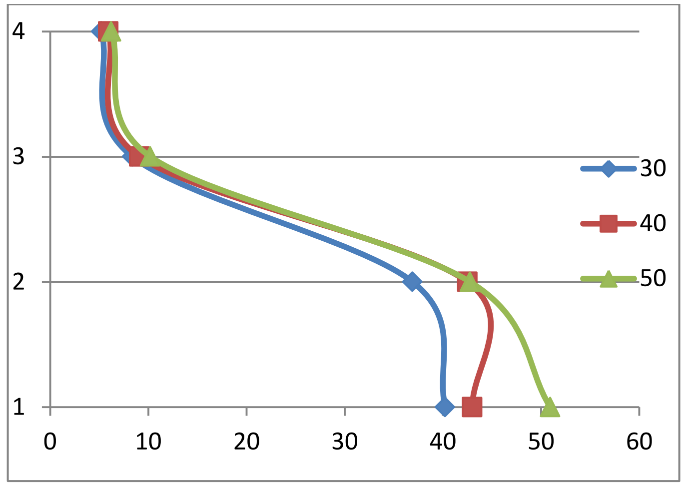

Fig 5 (b): Maximum stress of DT tower for main leg members

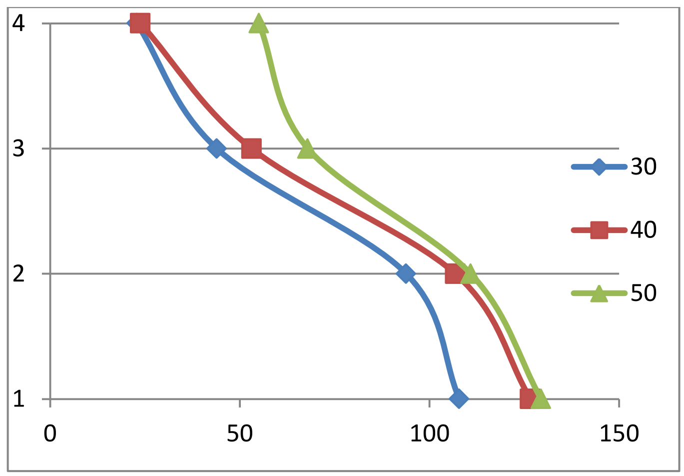

Fig 5 (b): Maximum stress of KDWT tower for main leg members

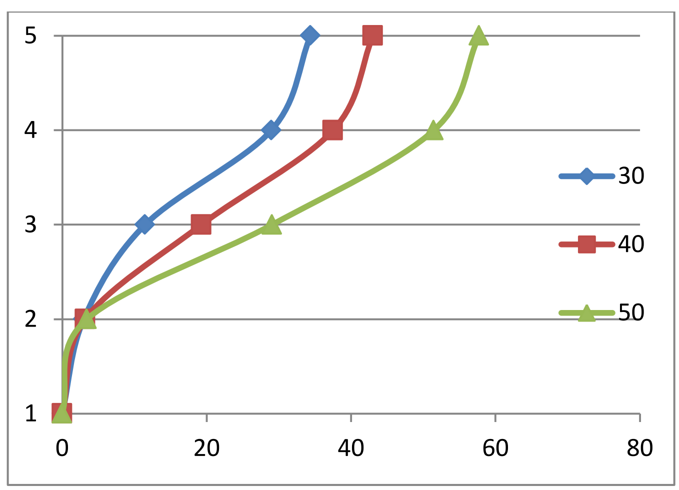

Fig 5 (d): Maximum displacement of DWT tower for main leg members

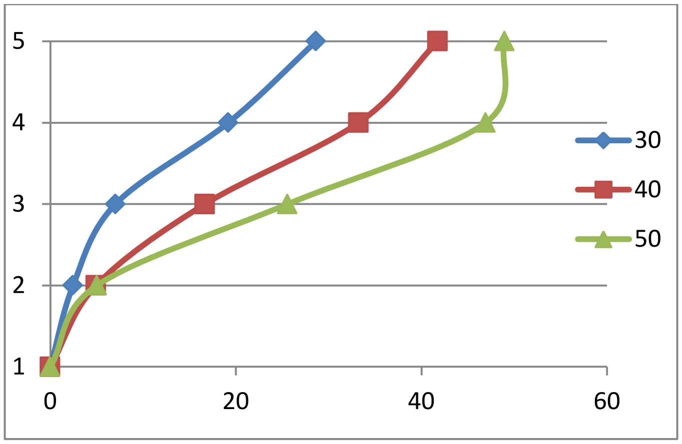

Fig 5 (e): Maximum displacement of DT tower for main leg members

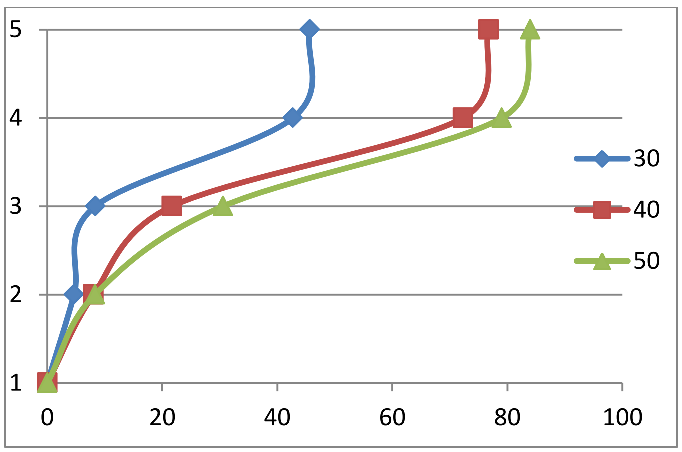

Fig 5 (f): Maximum displacement of KDWT tower for main leg members

D. Wind Analysis

Wind analysis is performed on all three transmission line tower for normal loading condition. The maximum stresses and maximum displacements are taken at pivotal points. Maximum stresses and displacements of three type towers for main leg members are shown in figure 6(a-f) respectively.

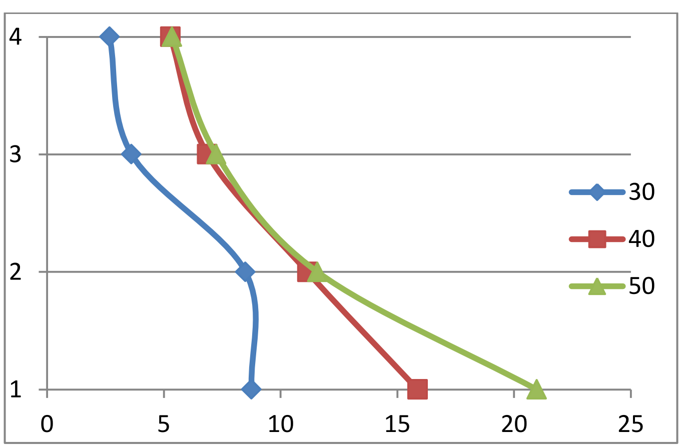

Fig 6 (a): Maximum stress of DWT tower for main leg members

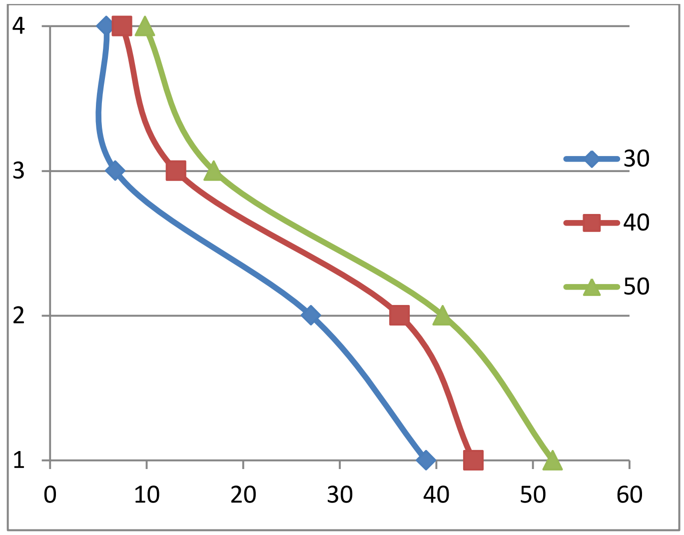

Fig 6 (b): Maximum stress of DT tower for main leg members

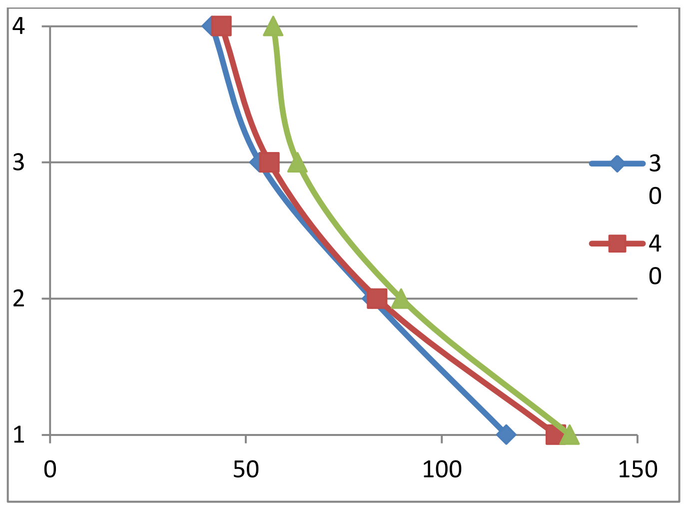

Fig 6 (c): Maximum stress of KDWT tower for main leg members

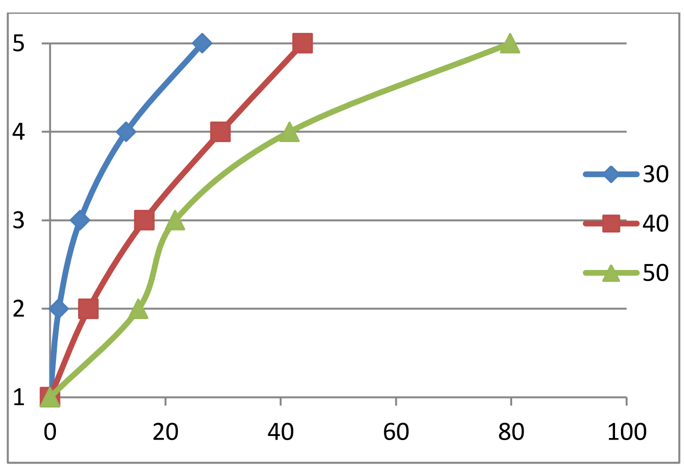

Fig 6 (d): Maximum displacement of DWT tower for main leg members

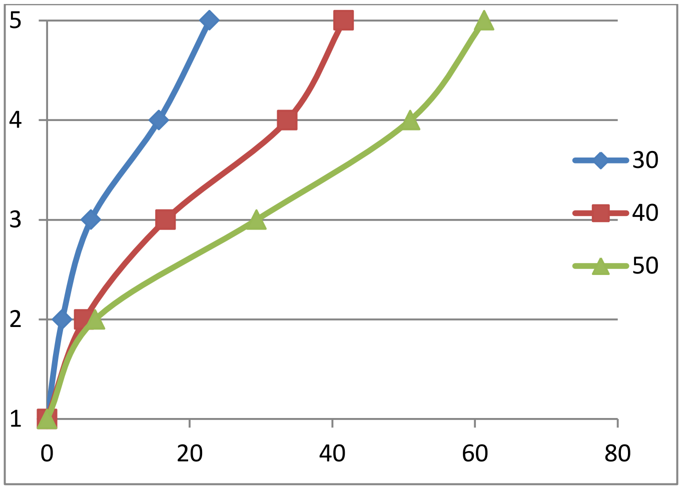

Fig 6 (e): Maximum displacement of DT tower for main leg members

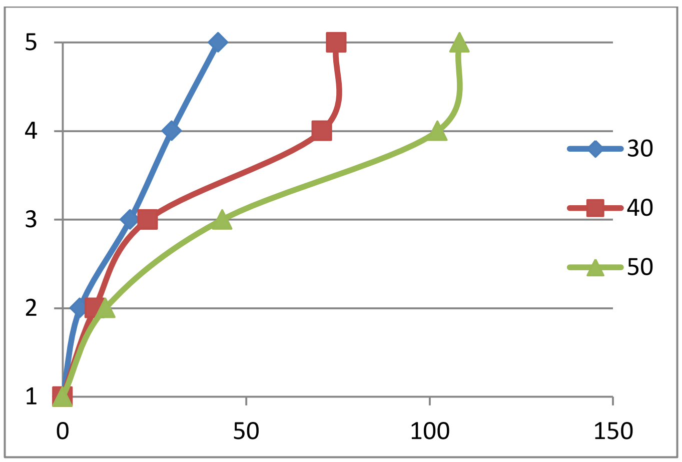

Fig 6 (f): Maximum displacement of KDWT tower for main leg members

VI. CONCLUSIONS

- Result from the modal analysis shows that as the height increases the natural frequencies reduces which shows the reduction in stiffness. The modal frequencies obtain for all the towers lies in the peak range of response spectrum, which needs to be further analysed under dynamic loads.
- Response spectrum analysis result shows that as the height increases stresses increases. The stresses in DWT and DT towers are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increase of stresses in bottom leg member from 30m to 50m height for DWT is 54%, DT is 35% and KDWT is 7% respectively.
- Response spectrum analysis result shows that the displacement increases as the height increases and the displacement for all the towers are within 5% of tower height. The increase of displacement in top most members from 30m to 50m height for DWT is35 %, DT is 21% and KDWT is 68% respectively.
- Time history analysis result shows that as the height increases stresses increases. The stresses DWT and DT tower are within the permissible limits whereas in the cross arm of KWDT tower fails for zone V when the height is 40m and 50m. The increase of stresses in bottom leg member from 30m to 50m height for DWT is 37%, DT is 26% and KDWT is 20% respectively.
- Time history analysis result shows that the displacement increases as the height increases but the displacement for all the towers are within 5% of the tower height. The increase of displacement in top most members from 30m to 50m height for DWT is 68 %, DT is 70% and KDWT is 84% respectively.
- Wind analysis result shows that as the height increases stresses increases. The stresses in DWT and DT towers are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increase of stresses in bottom leg member from 30m to 50m height for DWT is 145%, DT is 34% and KDWT is 14% respectively.
- Wind analysis result shows that displacement increases as the height increases and the displacement for all the towers are within 5% of the tower height. The increase of displacement in top most members from 30m to 50m height for DWT is202 %, DT is 168% and KDWT is 155% respectively.
- Out of the three bracing types K and Double Warren Bracing tower (KWDT) type is the most effective followed by DWT and DT respectively.

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