Analysis of transmission tower using STAAD pro- Wind Loads

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Abstract: The main objective of the present analysis is to analyze the transmission tower. The analysis is carried out for modal and wind conditions. Three types of towers are considered in this study; Double warren bracing tower (DWT), Diamond bracing tower (DT), K and Double warren bracing tower (KDWT). Load calculation of transmission line towers for normal load condition as per IS 802(part1:sec1):1995 and IS 875(part3):1987 are considered. Typical electrical transmission line tower is considered from for validation. Finite element analysis includes the modal analysis and wind analysis. Results obtained from the modal and wind induced loads are compared and conclusion are drawn.

Keywords —, Double warren bracing tower (DWT), Diamond bracing tower (DT), K and Double warren bracing tower (KDWT), Electric transmission tower, modal analysis, seismic analysis, wind analysis.

I. Introduction

Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for every category of support structure. Mechanical supports of cable represent a big portion of the value of the road and that they play a crucial role within the reliable power transmission. They are designed and constructed in big variety of shapes, types, sizes, configurations and materials. The structure types utilized in transmission lines generally fall under one among the three categories: lattice, pole and guyed.

OBJECTIVES

The main objectives of the thesis are summarized in the following:

1 Three types of towers are considered in this study as given below

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

2 Load calculation of transmission line towers for normal load condition as per IS 802(part1:sec1):1995, IS 875(part3): are considered.

3 Typical electrical transmission line tower is considered from for validation.

4 Finite element analysis includes the modal analysis, wind analysis and seismic analysis.

5 Results obtained from wind induced loads are compared and conclusion is drawn.

II. METHODOLOGY

This involves the detailed discussion on previous journal papers related to the dynamic analysis of transmission line towers. **PARAMETERS OF TOWER:** Three types of Transmission line towers are considered in this dissertation as given in table 3.1, typical 30m height towers with different bracing system are shown in figure 3.1(a-c) and table 3.2 lists the parameters such as height and base width considered for the analysis.

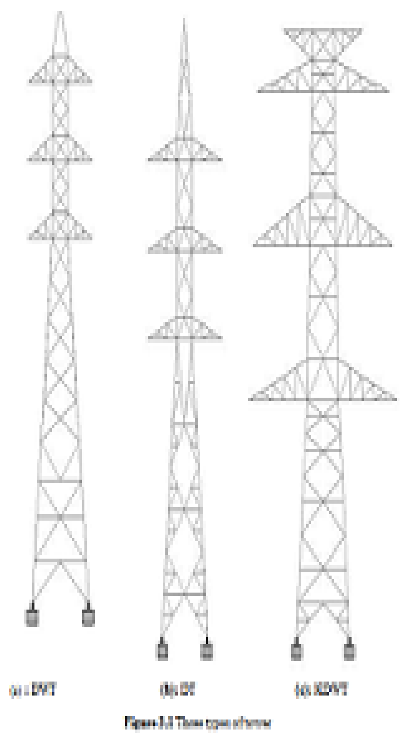


Fig 1

 DOI : 10.35291/2454-9150.2021.0393

ISSN : 2454-9150 Vol-07, Issue-04, JULY 2021

Table 3.1: Three types of tower with different parameters

Sl no	Different types of towers	Parameters of tower
1	Double Warren (DWT)	A typical tower is a 132-KV double circuit tower with angle of inclination is 2°, 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
2	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
3	K and Double Warren (KDWT)	A typical tower is 400-KV double circuit tower with angle of inclination is 2°, 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.

Table 3.2 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

SUPPORT CONDITION:The support conditions are considered to be fixed.

MATERIAL PROPERTIES:The general practice is to use the steel for tower members having the modulus of elasticity of material as 2.1 x 10^5 N/mm^2 and density of the material as 7850 kg/m^3. The following sectional properties are considered in this analysis are given in table 3.3

Table 3.3 Sectional Properties

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

LOAD CONSIDERED ON TRANSMISSION LINE TOWERS

The following load cases are considered in this thesis.

- Dead load is the self-weight of tower members, ground wire, conductor and insulators.
- Live load on the tower is lineman with tools and accessories as per IS 802 (part 1: sec 1)-1995.
- Wind load on the tower members is taken for normal load condition as per IS 802 (part 1: sec 1)1995 and IS 875(part3)-1987.

VERTICAL LOAD

Ground wire

Weight of ground wire = Unit weight x wind span x factor of safety
= 0.7363 x 600 x 2
= 8.66 kN

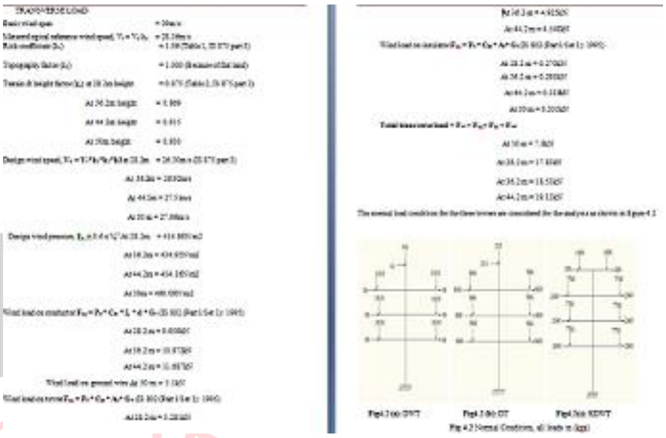
Weight of tower = 1.58 kN
Weight of ground wire = 2 kN
Weight of insulator = 3.5 kN
Load acting on cross arm tip = 3.5 kN
Total load on ground wire = 19.24 kN

Conductor

Weight of Conductor = Unit weight x wind span x factor of safety
= 2 x 600 x 2
= 23.5 kN

Weight of lineman with tools = 1.5 kN
Weight of tower = 5.51 kN
Weight of insulator = 3.5 kN
Load acting on cross arm tip = 3.5 kN

- **Total load on conductor = 37.5 kN**



III. MODEL

INTRODUCTION: The tower consider for validation from the journal paper by Y. M. Ghugal (2011).The structural system consists of a configuration is 400 kV double circuit transmission line tower.

CODE OF PRACTICE: IS: 802 (Part 1 / Sec 1): 1995, IS: 5613 (Part 2 / Sec 1):1989

MATERIAL PROPERTIES:The following parameters are Basic wind speed 39m/s, 400kV double circuit the span between two towers (L) is 400 m, the diameter (d) for ground wire, conductor wire and insulator is considered as 11.0 mm, 31.77 mm and 255 mm respectively. Angle of deviation (Φ) is taken as 2° unit weight (w) for ground wire and conductor wire are 0.7363kg/m and 2 kg/m respectively.

STRUCTURAL ELEMENT DIMENSIONS: The following parameters are Base width is 8.5m x 8.5m, Hamper (Cage) width is 3.6m x 3.6m, Topmost Hamper width (Ground wire) is 2m x 2m and Total tower height is 50m.

LOADS AND LOAD COMBINATIONS: Load due to conductor in transverse direction wind load for Normal condition, Broken Wire Condition Left Bottom Conductor, Left Middle Conductor, Left Top Conductor, Left Ground Wire. Primary Normal Load cases are considered for the design and compare the results.

 DOI : 10.35291/2454-9150.2021.0393

Dead loads (DL): Self-weight of the structure is assigned to the transmission tower by using the software. However, the components not modelled such as insulators have been applied as super imposed load on the structure.

Live loads (LL): Super imposed Live Load for Ground wire = 19.3kN Super imposed Live Load for Cross arm= 37.5kN

Wind load

Transverse wind load on Cross arm at 28.2m = 17.8kN
Transverse wind load on Cross arm at 36.2m = 18.5kN
Transverse wind load on Cross arm at 44.2m = 19.1kN
Transverse wind load on Cross arm at 50m = 7.8kN

A Transmission line tower of validation model for normal loading conditions is as shown below.

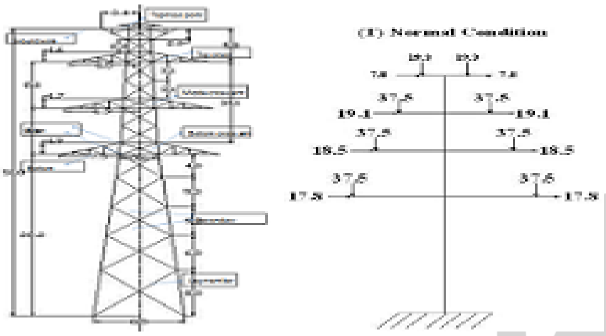


Fig 2

The analysis results obtained from the present work is compared with the journal paper results are tabulated in table 5.1 and 5.2

Table 6.1: Maximum axial force for normal loading condition

Sl. no	Node Points	Maximum Axial Force for Four Legged Tower (kN)	
		Journal paper results	Present Results
1	Leg	613.1	618.5
2	Main Members	108.4	99.37
3	Secondary Members	6.9	7.79
4	Cross Arm	98.2	98.6
5	Diaphragm	24.8	25.7

Table 6.2: Maximum displacement for normal loading condition

Sl.no	Node points	Maximum displacement for Four Legged Tower (mm)	
		Journal paper results	Present Results
1	Bottom Hamper Point	66.3	66.0
2	Bottom Cross arm Tip	85.3	84.5
3	Middle Cross arm Tip	126.2	125.2
4	Top Cross arm Tip	179.3	180.5
5	Ground Wire arm Tip	212.6	213.2
6	Topmost point of Leg	210.3	210.5

IV. RESULTS

The results of maximum axial force and displacement obtained from the present work matches closely with the journal results and hence the model is validated.

WIND ANALYSIS: Wind has motor vitality by ideals of its speed and mass, which is changed into potential vitality of weight when a structure deters the way of wind. Regular breeze itself is neither consistent nor uniform it fluctuates along the components of the structures just as with time.

CBIP in "Transmission Line Manual" has explained that the breeze assumes an imperative job in the heap estimation on tower. So as to decide the breeze load on tower, the pinnacle is separated into various boards having a tallness "h". These boards ought to typically be taken between the convergences of the legs and bracings. For grid tower, wind is viewed as ordinary to the substance of tower acting at the focal point of gravity of the board. Most latticed towers are especially vulnerable to mean breeze impacts.

In the plan of grid towers ordinarily a semi static methodology is embraced with blast reaction consider included to consider the dynamic idea of the breeze for assessing the pinnacle worries in individuals.

Blast reaction factor is the multiplier utilized for the breeze stacking to acquire the pinnacle load impact and records for the extra stacking impacts because of wind disturbance and dynamic enhancement of adaptable structures and links, the accompanying classifications considered for various part components.

Conduit and ground wire is relies upon the territory classes, tallness over the ground and the range. Tower is relies on the landscape classifications and the tallness over the ground.

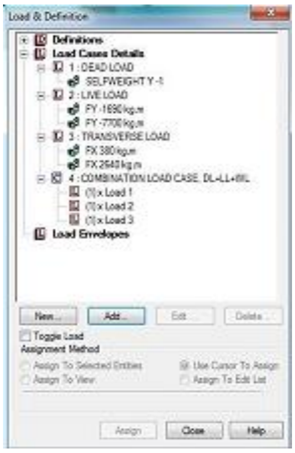
Separator is relies on the ground unpleasantness and tallness of protector connection over the ground.

Drag coefficients under the breeze impact are considered for the conduit, ground wire, tower and the encasing.

The fundamental breeze speed V utilized in the assurance of configuration wind stacks on structures and different structures. The breeze will be expected to originate from any level bearing. The essential breeze speed will be expanded where records or experience show that the breeze speeds are higher than those reflected in Mountainous landscape, canyons, and uncommon districts will be inspected for irregular breeze conditions.

The load cases considered for the wind analysis of transmission tower structure is as shown in figure 6.12.

Drag coefficients under the breeze impact are considered for the conduit, ground wire, tower and the encasing.



RESULTS: Wind analysis is carried out for all types of tower with different parameters to get the maximum stresses

 DOI : 10.35291/2454-9150.2021.0393

and maximum displacement, these results are tabulated for leg members and cross arms as given below in table 6.7 & 6.8.

Table 6.7: Stress obtained from Wind Analysis for leg members and cross arms. All dimensions are in (N/mm²)

Different members	DWT			DT			KDWT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
Bottom leg	8.78	13.87	20.97	28.95	42.86	52.88	116.60	129.22	132.73
Bottom hamper level leg	8.30	11.13	11.38	27.84	36.23	48.70	82.27	83.61	89.70
Top hamper level leg	3.62	6.67	7.25	6.78	13.03	16.98	33.55	36.03	63.25
Top most leg	2.68	3.28	3.36	3.34	7.48	9.84	41.37	42.79	37.80
Bottom cross arm	12.32	13.22	13.48	13.88	19.42	28.97	100.71	97.30	113.14
Top cross arm	12.32	13.20	13.23	13.89	16.33	16.40	122.38	128.07	171.47

Table 6.8: Displacement obtained from Wind Analysis for leg members and cross arms. All dimensions are in (mm)

Element member	DWT			DT			KDWT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
2nd panel leg	1.53	6.69	13.33	2.14	3.25	6.78	4.73	6.78	11.63
Bottom hamper level	3.22	16.27	21.71	6.16	16.63	29.27	18.29	23.20	42.49
Top hamper level	13.21	29.61	41.39	13.66	33.49	50.85	28.71	70.88	102.17
Top most leg	26.42	43.86	79.83	22.50	41.62	61.32	42.38	74.60	108.20
Bottom cross arm	3.03	15.20	28.41	7.22	17.27	30.94	30.27	42.13	62.04
Top cross arm	18.62	24.24	21.94	13.63	22.08	22.80	31.26	30.24	117.43

V. VALIDATION OF FE MODEL RESULTS

A typical 400KV double circuit transmission line tower is considered from the journal paper by Y.M. Ghugal (2011) for validation. The loads are calculated as per IS 802(part1/sec1):1995 and the finite element model is analysed. Table 7.1 and 7.2 gives the maximum axial forces and displacements respectively.

Table 7.1: Maximum axial force for normal loading condition

Sl no	Node Points	Four Legged Tower (kN)	
		Journal paper results	FE analysis
1	Leg	613.1	618.5
2	Main Members	108.4	99.37
3	Secondary Members	6.9	7.79
4	Cross Arm	98.2	98.6
5	Diaphragm	24.8	25.7

Table 7.2: Maximum displacement for normal loading condition

Sl no	Node points	Four Legged Tower (mm)	
		Journal paper results	FE analysis
1	Base of Leg	0	0
2	Bottom Hamper Point	66.3	66.0
3	Bottom Cross arm tip	85.3	84.5
4	Middle Cross arm tip	126.2	125.2
5	Top Cross arm tip	179.3	180.5
6	Ground Wire arm tip	212.6	213.2
7	Topmost point of leg	210.3	210.5

It can be observed from table 7.1 and 7.2 that FE analysis results are closely matches with the journal paper results, hence the model is validated.

WIND ANALYSIS: Wind analysis is performed on all three transmission line tower for normal loading condition. The maximum stresses and maximum displacements at pivotal points are tabulated in Table 7.8 and 7.9 gives for zone V respectively**.** Maximum stresses and displacements of three type towers for main leg members are shown in figure 7.13 to 7.18 respectively.

Table 7.8: Maximum Stresses for leg and cross arm members obtained from Wind analysis (N/mm²).

Different member	DWT			DT			KDWT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
Bottom leg (1)	8.76	13.87	20.97	28.95	43.86	52.08	116.60	129.22	132.73
Bottom hamper (2)	8.30	11.15	11.38	27.04	36.23	40.70	82.27	83.61	89.70
Top hamper (3)	3.62	6.87	7.25	6.78	13.03	16.98	33.55	36.03	63.25
Top most leg (4)	2.68	3.28	3.36	3.34	7.48	9.84	41.37	43.79	37.00
Bottom	12.32	13.22	13.48	13.88	19.42	20.97	100.71	97.30	113.14
Top	12.32	13.20	13.23	13.89	16.33	16.40	122.38	128.07	171.47

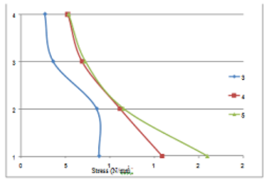


Figure 7.13: Maximum stress of DWT tower for main leg members

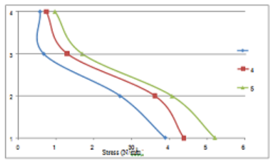


Figure 7.14: Maximum stress of DT tower for main leg members

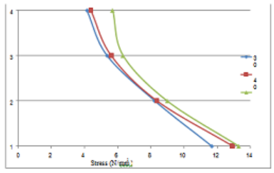


Figure 7.15: Maximum stress of KWDT tower for main leg members

Table 7.9: Displacement obtained from Wind Analysis for leg members and cross arms (mm)

Different member	DWT			DT			KDWT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
2nd panel leg (1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottom hamper (2)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Top hamper (3)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Top most leg (4)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottom	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Top	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

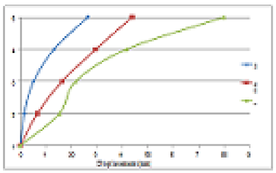


Figure 7.16: Maximum displacement of DWT tower for main leg members

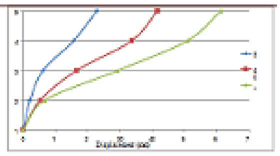


Figure 7.17: Maximum displacement of DT tower for main leg members

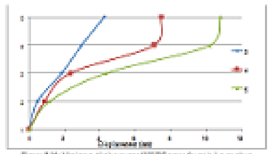


Figure 7.18: Maximum displacement of KWDT tower for main leg members

Result clearly shows that as the height increases stresses increases. The towers DWT and DT are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increases of stresses in bottom leg member form 30m to 50m for DWT is 145%, DT is 34% and KDWT is 14% respectively.

Similarly the displacement increases as the height increases but the displacement for all the towers are within the 5% of the tower height. The increase of displacement in top most member form 30m to 50m for DWT is 202 %, DT is 168% and KDWT is 155% respectively.

VII. CONCLUSIONS

In this dissertation work efforts are made to understand the behaviour of transmission line tower under seismic and wind induced dynamic loads. Three types of towers are considered in the study by varying the parameters like height and base width of towers. Finite element analysis is carried out on the transmission line tower and the results are tabulated, discussed and conclusions are drawn. The following are the major conclusions from this dissertation work.

- Wind loads with gust factor are calculated for normal load condition as per IS 802(part1/sec1):1995 which is adopted for wind loads in finite element analyses.

 DOI : 10.35291/2454-9150.2021.0393

A typical transmission line tower finite element model is validated by comparing the results with the literature.

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.

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 is 202 %, 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.

VIII. SCOPE FOR FUTURE WORK

Shake table tests on scale down models of Transmission line tower can be carried out to understand its dynamic behaviour experimentally.

K and double warren bracing tower can be replaced by X and diamond bracing and analysed on transmission line tower.

The aspect ratios of different height to base width and bracings can be varied and analysed, so that design graphs can be generated.

The analysis can be done for different real time history data available from different earthquakes.

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 DOI : 10.35291/2454-9150.2021.0393