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Dynamic Analysis of Transmission Towers

Yoganantham.C
P.G Student, Division of Structural Engineering
VIT University, Chennai Campus.
Chennai – 600127, Tamil Nadu, India.

Helen Santhi.M
Professor, Division of Structural Engineering
VIT University, Chennai Campus.
Chennai – 600127, Tamil Nadu, India.

***Abstract*— Transmission towers have to carry the heavy transmission conductor at a sufficient safe height from ground. In addition the towers have to sustain all kinds of natural calamities. Therefore transmission tower designing is an important engineering job to make them safe and economical. In this paper an attempt has been made to find an economical configuration among square base and triangular base for seismic loading. A 220 KV transmission tower of 30 m height with angle sections is considered for all two types of towers. The towers have been modeled as a three dimensional structure and analyzed using the software STAAD.Pro. The acceleration time history for zone III as per IS 1893 is applied to the towers as input. The dynamic response such as fundamental frequency, mode shape, displacement time history and acceleration time history are determined.**

***Keywords*— Transmission towers; dynamic analysis; earthquake loads; wind loads; natural frequency; mode shape.**

I. Introduction

Transmission line towers are constructed to transmit power from generating stations to various load centers. In India, development of electric power over the years has been unparalleled. The increasing demand for electrical energy can be met more economically by developing different light weight configurations. Therefore analysis and design of transmission towers for different loading conditions are important. Gopiram Addala [1] investigated the dynamic analysis of transmission towers under strong ground motion. The analysis is carried out by SAP 2000. It was observed from the analysis that the forces developed when the Northridge (1994) ground motion is applied in direction of cables are more when compared to forces developed when the ground motion is applied perpendicular to the conductors. Mathur [2] studied the dynamics of a guyed transmission tower system. Very high forces occur when the conductors are connected directly to the tower. Alaa C. Galeb [3] found the optimum design of transmission towers subjected to wind and earthquake loading. The geometry parameters of the tower can efficiently be treated as design variables, and considerable weight reduction can often be achieved as a result of geometric changes. Visweswara Rao [4] described the optimum designs of transmission line towers. A systematic procedure has been presented for obtaining minimum weight tower design in both crisp and fuzzy environments.

In the present work an attempt has been made to find the influence of various base geometric parameters such as triangular base and square base on the dynamic response of the tower i.e., fundamental frequency, mode shape, displacement and acceleration.

II. Loading Calculations

The loads are calculated as per I.S. 802 (Part 1: Sec 1)-1995, I.S. 5613 (Part 2 : Sec 1)-1989 and CBIP Manual No. “268”. The following parameters are assumed: for 220 kV the span between two towers (L) is 350 m; the diameter(d) for ground wire, conductor wire and insulator is considered as 10.98 mm, 28.62 mm and 255 mm, respectively; the gust response factor (G_c) for ground wire, conductor and insulator is 2.115, 2.055 and 2.25, respectively; angle of deviation (Φ) is taken as 2^0; unit weight(w) and ultimate tensile strength(T) are assumed as 0.0159 kN/m^3 and 130.32 kN, respectively.

The sag tension for both ground wire and conductor wire are calculated as per IS 5613 part-2 sec 1 – 1989 with temperature (0^0,32^0,75^0) and wind pressure percentage (0, 36, 75,100). As per IS 875 (part 3)-1987, the wind pressure (p_d) is calculated as 0.7 kN/m^2.

As per CBIP (Central Board of Irrigation and Power) in “Transmission Line Manual” the nature of loads are given by

1. *Transverse loads:*

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

Wind on Wire: $FWC = P_d . L . d . G_C . C_{dC}$.
Wind on Insulator: $FWi = n . m . P_d . A_i . G_i . C_{di}$
Due to deviation $FWd = 2 . T . \sin(\Phi_2 / 2)$

2. *Vertical loads:*

   a) Loads due to weight of each 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 VR = w . L
Weight of G.W. Clamp: VR = 50 N
Weight of Insulator : VR = 2kN (n.m. wt of insulator)
Weight of Man with Tool: VM = 1.5 kN

3. *Longitudinal loads:*

a) Unbalanced horizontal loads in longitudinal direction due to mechanical tension of conductor and/or ground wire during broken wire condition.

LR = 0.5 * T . cos(Φ/2)

4. *Anti cascading checks:*

In order to prevent the cascading failure in line, angle towers are checked for anti cascading loads for all conductors and ground wires broken in the same span.

As per IS 802: Part 1: Sec: 1:1995 the loading combinations are calculated. The transverse, vertical and longitudinal forces for reliability condition, security condition and safety condition are shown in Tables 1, 2 and 3, respectively. From the load combination for different towers, it is observed that the critical condition for triangular and square base towers is the security- broken wire condition.

TABLE 1. LOAD CALCULATIONS FOR RELIABILITY CONDITION

S.No	Load Components	Ground Wire (kN)	Conductor Wire (kN)
1	**Transverse load**		
	Normal Condition		
	Wind on Wire	6.83	14.42
	Wind on Insulator	0	0.56
	Deviation	1.07	2.32
	Total	7.90	17.31
2	**Vertical load**		
	Normal Condition		
	Weight of Wire	3.00	8.34
	Weight of Clamp/Insulator	0.049	1.96
	Total	3.05	10.30
3	**Longitudinal load**		
	Normal Condition		
	load	0	0

TABLE 2. LOAD CALCULATIONS FOR SECURITY CONDITION

S. No	Load Components	Ground Wire (kN)	Conductor Wire (kN)
1	**Transverse load**		
a	**Normal Condition**		
	Wind on Wire	5.12	10.81
	Wind on Insulator	0	0.42
	Deviation	0.9	0.98
	Total	6.029	12.22
b	**Broken Wire Condition**		
	Wind on Wire	3.079	6.49
	Wind on Insulator	0	0.42
	Deviation	0.45	0.49
	Total	3.53	7.41
2	**Vertical load**		
a	**Normal Condition**		
	Weight of Wire	3.00	8.35
	Weight of Clamp/Insulator	0.05	1.96
	Total	3.05	10.30
b	**Broken Wire Condition**		
	Weight of Wire	1.80	5.00
	Weight of Clamp/Insulator	0.05	1.96
	Total	1.85	6.97
3	**Longitudinal load**		
a	**Normal Condition**		
	load	0	0
b	**Broken Wire Condition**		
	load	13.02	16.29

TABLE 3. LOAD CALCULATIONS FOR SAFETY CONDITION

S.No	Load Components	Ground Wire	Conductor Wire
1	**Transverse**		
a	**Normal Condition**		
	Wind on Wire	0	0
	Wind on Insulator	0	0
	Deviation	0.45	1.13
	Total	0.45	1.14
b	**Broken Wire Condition**		
	Wind on Wire	0	0
	Wind on Insulator	0	0
	Deviation	0.23	0.28
	Total	0.23	0.28

2	**Vertical**		
a	**Normal Condition**		
	Weight of Wire	6.00	16.69
	Weight of Clamp/Insulator	1.50	1.50
	Weight of Man with Tool	0	0
	Weight at Arm Tip	0	0
	Total	7.50	18.19
b	**Broken Wire Condition**		
	Weight of Wire	3.60	10.01
	Weight of Clamp/Insulator	0.098	3.92
	Weight of Man with Tool	0	0
	Weight at Arm Tip	0	0
	Total	3.70	13.94
3	**Longitudinal**		
a	**Normal Condition**		
	load	0	0
b	**Broken Wire Condition**		
	load	5.00	10.00

III.MODELING AND ANALYSIS

The modeling and dynamic analyses of triangular base and square base tower been done using the software STAAD.Pro. Double k down bracings is used with angle sections and the tower configurations are given in Table 4. The self-weight of all the two towers is given in Table 5.

TABLE 4. TOWER CONFIGURATION

	SQUARE TOWER (m)	TRIANGULAR TOWER (m)
Base Width	4.5	6
Hamper width at lower cross arm (L.C.A)	1.5	2
Hamper width at upper cross arm (U.C.A)	1.5	2
Height till L.C. A. Level	18.9	18.9
Height till U.C. A. Level	24.1	24.1

TABLE 5. SELF-WEIGHT OF TOWERS

Tower type	Weight (kN)
Triangular base	98.396
Square base	115.747

The models of triangular base and square base towers are shown in Figs 1 and 2, respectively. The acceleration time history for the zone III of Indian seismic code IS 1893 as shown in Fig.3 is taken as input for the dynamic analysis.

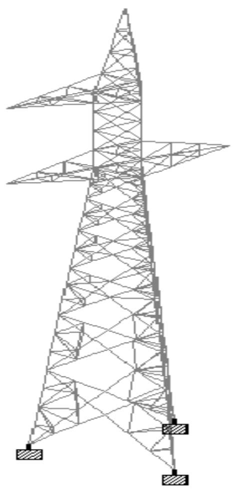

Fig. 1. Triangular base tower

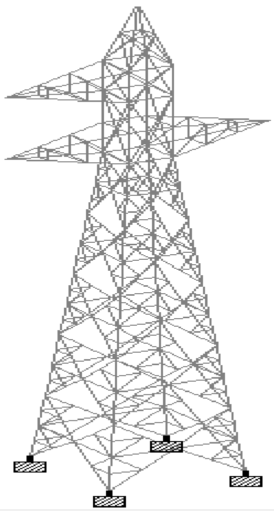

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Fig. 2. Square base tower

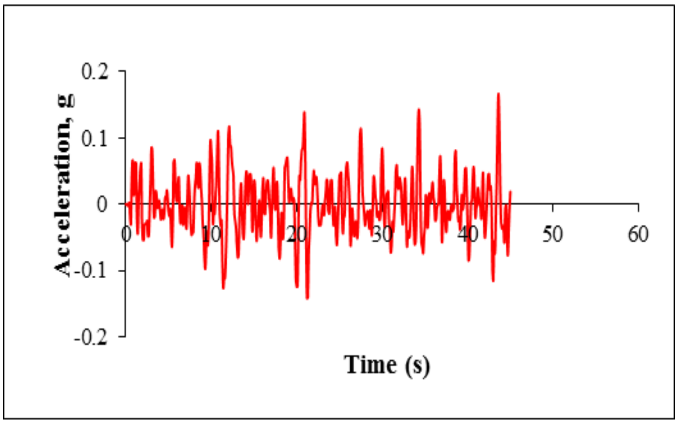

Fig. 3. Acceleration Time History

III. RESULTS AND DISCUSSION

A. *Frequency*

The fundamental frequency for all the two towers is obtained from modal analysis and is shown in Fig 4. It is observed that the frequency for the square base tower is 5% less than triangular base towers.

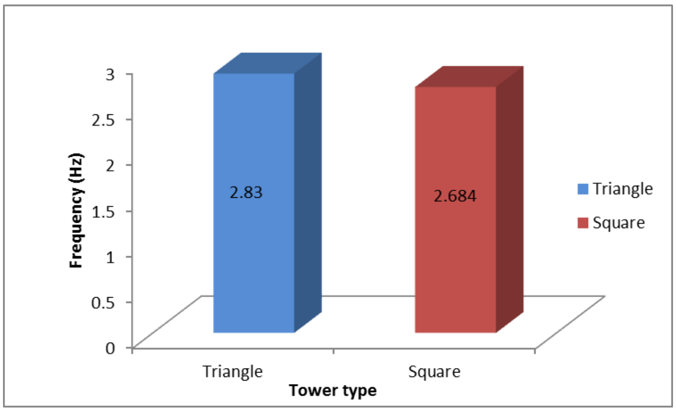

Fig. 4. Frequency for two types of towers

B. *Mode shape*

The fundamental mode shapes of all the towers are shown in Fig. 5.

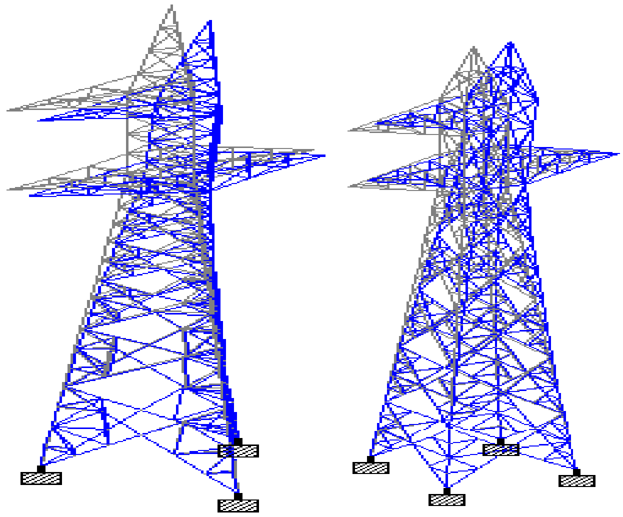

Fig. 5. First mode shape of towers

C. *Displacement time history*

The response displacement time history from seismic analysis of towers is shown in Fig. 6. The difference displacement response between square and triangular towers is 5 %. The top displacement response of the towers due to wind load is shown in Fig. 7 and 7 % difference is observed between the towers.

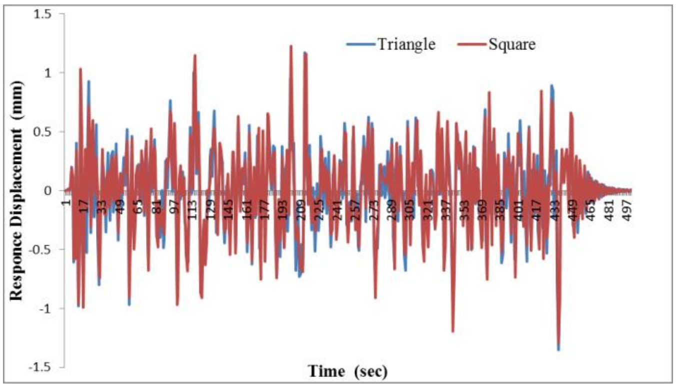

Fig. 6. Response displacement time history of towers

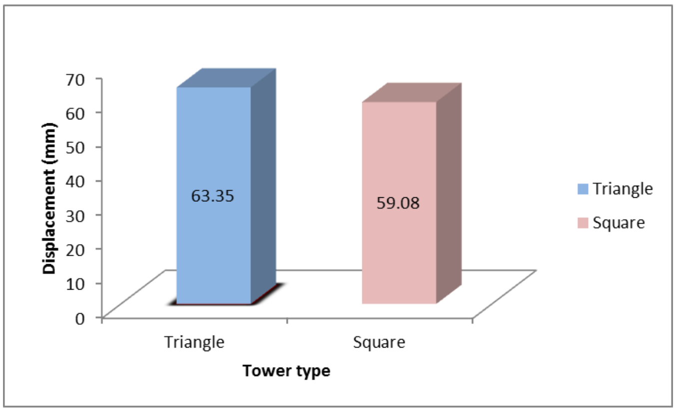

Fig. 7. Comparison of displacement of towers

D. Acceleration

The response acceleration time history of all type of tower is shown in Fig. 8. The maximum acceleration is found to be more in triangular base tower than that of square tower and their comparison is shown in Fig.9.

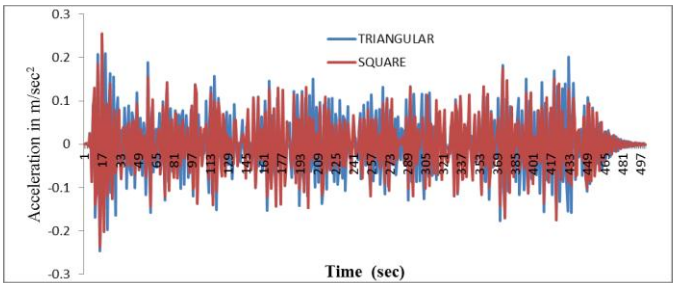

Fig. 8. Response acceleration time history of towers

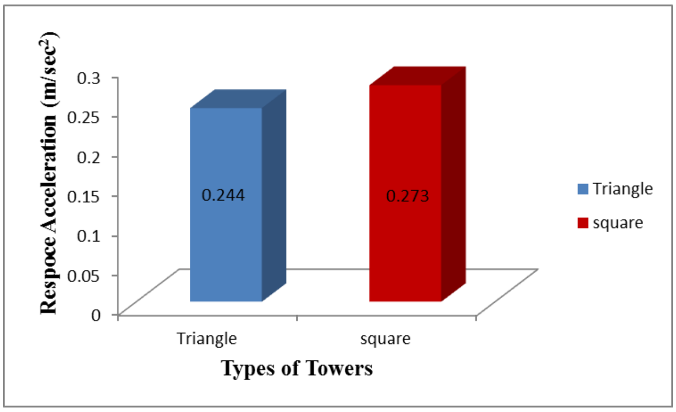

Fig. 9. Comparison of acceleration for towers

IV. CONCLUSIONS

From the dynamic analysis of square and triangular base towers, the following conclusions are drawn.

- The fundamental frequency of the towers is found and the difference between them is about 7%.
- The difference in response displacement of the towers from wind load analysis is nearly 7 %.
- The difference in response displacement of the towers from seismic load analysis is observed about 5 %. The difference in response acceleration of the towers is found to be 11 %.
- The weight of the triangular tower is 12 % less than that of square base.
- When comparing the dynamic behavior of triangular and square base towers, both behave well. However, the triangular base tower gives better behavior.

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