Comparative Study on 4-Legged Transmission Line Tower with Different Bracings by using STAAD Pro

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Abstract – The purpose of a transmission line tower is to support conductors carrying electrical power and one or two ground wires at suitable distances above the ground level and from each other. The transmission line towers cost about 28 to 43 per cent of the total cost of the transmission line. A transmission tower is a space truss and is an indeterminate structure.The increasing demand for electricity can be made more economical by developing different light weight configuration of transmission line tower.The present study reports the design and analysis of a steel lattice transmission line towers of a power system located in Pune. The design and analysis of the considered power system has been done using STAAD Pro. Under the design and analysis of the system, the effect of wind and earthquake loads were studied and the results so obtained were compared for wind zones III for four legged tower. Transmission line towers carry heavy electrical transmission conductors at a sufficient and safe height from ground. In addition to their self-weight they have to withstand all forces of nature like strong wind, earthquake load. The main objective of this project is to design and comparison between four legged 220 kV transmission line tower and its configuration as per Indian Standard (IS:800-2007 and IS:875-1987).

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INTRODUCTION

India has a large population residing all over the country and the electricity supply need of this population creates requirement of large transmission and distribution system. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical support of transmission line represents a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in wide variety of shapes, types, sizes, configuration and materials. The supporting structure types used in transmission line generally fall into one of the three categories: lattice, pole and guyed.

The supports of high voltage transmission lines are normally steel lattice towers. The cost of tower constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower.

The tall structure with relatively small cross-section and with a large ratio between the height and the maximum width are known as tower or masts. Tower is also known as pylon. A tower is a single cantilever freely standing self.

DESCRIPTION OF TOWER CONFIGURATION

For the present study, 220KV transmission line towers of different types of bracing are considered. First model of tower is tower with X-bracing, second model is of tower with K-bracing and third model of tower is tower with composite bracing. The tower is square base self-supporting type.

LOADS ON TRANSMISSION LINE TOWERS

The transmission line towers are subjected to the following loads:

(a) Vertical loads

(b) Lateral or horizontal loads

(c) Longitudinal loads

(d) Torsional loads

OBJECTIVES OF PRESENT STUDY

(1) To analyse and design the transmission line tower using STAAD Pro software.

(2) To analyse and design the transmission line tower for different types of bracing.

(3) To compare different towers for its structural stability.

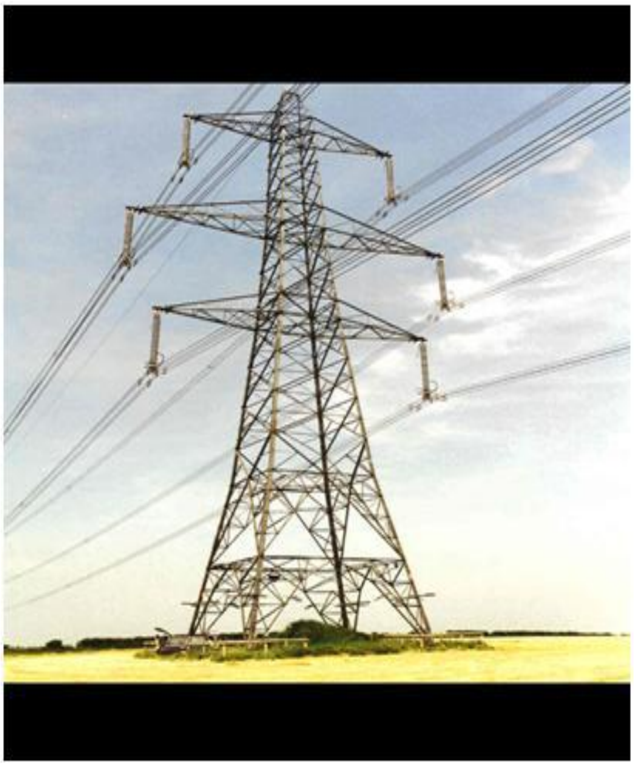


Figure. 1- Transmission line tower

INTRODUCTION TO STAAD Pro SOFTWARE

STAAD or (STAAD. Pro) is a structural analysis and design computer program originally developed by Research Engineers International at Yorba Linda, CA in year 1997. In late 2005, Research Engineers International was bought by Bentley Systems. An older version called STAAD-III for windows is used by Iowa State University for educational purposes for civil and structural engineers. Initially it was used for DOS-Window system. The commercial version STAAD Pro is one of the most widely used structural analysis and design software. It supports several steel, concrete and timber design codes.

It can make use of various forms of analysis from the traditional 1st order static analysis, 2nd order p-delta analysis, geometric nonlinear analysis or a buckling analysis. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.

In recent years it has become part of integrated structural analysis and design solutions mainly using an exposed API called Open STAAD to access and drive the program using a VB macro system included in the application or other by including Open STAAD functionality in applications that themselves include suitable programmable macro systems. Additionally STAAD Pro has added direct links to applications such as RAM Connection and STAAD. Foundation to provide engineers working with those applications which handle design post processing not handled by STAAD Pro itself. Another form of integration supported by STAAD Pro is the analysis schema of the CIM steel Integration Standard, version 2 commonly known as CIS/2 and used by a number modeling and analysis applications.

TRANSMISSION LINE COMPONENTS:

The following parameters for transmission line and its components are assumed from I.S. 802: Part 1:Sec: 1:1995, I.S. 5613: Part 2: Sec: 1:1989.

Table 1 Parameters for transmission line and its component

Transmission LineVoltage	220 kV(A/ C)
Tower Type	Self-Supporting
Tower geometry	Square base
Angle of line deviation	0-2
Wind zone	IV
Basic wind speed	39m/s
Weight of ground wire	2.00KN
Terrain type	Plains
Insulator type	Suspension type
No of circuit	Double

Conductor

A substance or a material which allows the electric current to pass through its body when it is subjected to a difference of electric potential is known as Conductor.

Table 2 Parameters for conductor.

Conductor material	ACSR
Conductor size	30/7/3.00 mm
Area of the conductor	2.6155 cm2
Overall diameter of the conductor (d)	21 mm
Weight of the conductor (w)	0.973 kg/m
Coefficient of linear expansion (α)	17.73 × 10-6/°C
Modulus of elasticity Final (E1)	0.787 × 106kgf/cm2
Modulus of elasticity Initial (E2)	0.626 × 106kgf/cm2

Earthwire

The earthwire is used for protection against direct lightning strokes and the high voltage surges resulting there from. There will be one or two earthwire depending upon the shielding angle or protection angle.

Table 3 Parameters of earthwire

Material of earthwire	Galvanized steel
wire diameter	7/3.15mm
Total sectional area	54.55mm2
Overall diameter	9.45 mm
Approximate weight	428kg/km
Modulus of elasticity	19361 kg/mm2
Coefficient of linear expansion	11.50 × 10-6/°C
Maximum allowable temperature	53°C

Insulator Strings

Insulators are devices used in the electrical system to support the conductors or to support the conductors carrying at given voltages.The insulators separate thecurrent carrying conductors of a transmission line from their support structures to prevent the flow of current through the structure to ground and to provide necessary mechanical support to the conductors at a safer height above the ground level.

RESULTS

Table 4 Maximum Displacement for Dead Load

Sr. NO	Member No	Maximum Displacement in mm		
		X-bracing	K-bracing	Hybrid bracing
1	5	0.005	0.011	0.007
2	6	0.027	0.007	0.005
3	7	0.005	0.012	0.005
4	8	0.027	0.007	0.037
5	9	0.012	0.012	0.025
6	10	0.031	0.031	0.037

Table 5 Maximum Displacement for Wind Load

Sr.No	Member No	Maximum Displacement in mm		
		X-bracing	K-bracing	Hybrid bracing
1	5	0.01	0.750	0.021
2	6	0.009	0.250	0.020
3	7	0.01	0.750	0.020
4	8	0.011	0.250	0.006
5	9	0.011	1.333	0.002
6	10	0.004	1.500	0.007

Table 6 Displacement in Tower with X- bracing for Nodes for Dead Load

Node No	Displacement in mm			Max. Permissible Displacement in mm
	X	Y	Z	
13	0.00	0.623	0.00	0.623
38	0.025	0.132	0.025	0.137
61	0.009	0.657	0.00	0.657
78	0.009	0.657	0.00	0.657
81	0.474	1.277	0.00	1.363

Table 7 Displacement in Tower with X- bracing for Nodes for Wind Load

Node No	Displacement in mm			Max. Permissible Displacement in mm
	X	Y	Z	
13	7.783	0.004	19.366	20.871
38	0.020	0.15	0.144	0.213
61	5.69	2.812	14.60	18.91
78	5.814	2.807	14.045	15.45
81	6.294	2.184	15.582	16.944

Table 8 Displacement in Tower with K- bracing for Nodes for Dead Load

Node No	Displacement in mm			Max. Permissible Displacement
	X	Y	Z	
13	0.004	0.669	0.0	0.669
38	0.001	0.138	0.001	0.138
61	0.00	0.154	0.047	0.161
78	0.009	0.707	0.00	0.707
81	0.006	1.327	0.00	1.327

Table 9 Displacement in Tower with K- bracing for Nodes for Wind Load

Node No	Displacement in mm			Max. Permissible Displacement in mm
	X	Y	Z	
13	7.509	0.739	19.103	20.539
38	0.005	0.195	0.008	0.196
61	0.136	0.270	0.402	0.503
78	6.337	0.846	16.460	17.870
81	6.330	0.031	16.418	17.596

Table 10 Displacement in Tower with Hybrid bracing for Nodes for Dead Load

Node No	Displacement in mm			Max. Permissible Displacement in mm
	X	Y	Z	
13	0.00	0.679	0.011	0.679
38	0.001	0.166	0.002	0.166
61	0.00	0.565	0.037	0.556
78	0.78	0.255	0.075	0.277
81	0.053	0.288	0.054	0.278

Table 11 Displacement in Tower with Hybrid bracing for Nodes for Wind Load

Node No	Displacement in mm			Max. Permissible Displacement in mm
	X	Y	Z	
13	4.328	0.003	10.738	11.577
38	0.096	0.115	0.024	0.151
61	0.707	0.545	1.596	1.829
78	0.106	0.186	0.021	0.215
81	0.023	0.398	0.077	0.408

Table 12 Axial Forces in Member for Dead Load

Sr. NO	Member No	Axial Force (N/mm2)		
		X-bracing	K-bracing	Hybrid bracing
1	5	2.665	2.701	2.880
2	6	5.341	0.405	0.387
3	7	2.665	3.363	0.387
4	8	5.341	0.022	3.307
5	9	3.363	3.363	0.412
6	10	0.22	0.22	3.307

Table 13Axial Forces in Member for Wind Load

Sr. NO	Member No	Axial Force (N/mm2)		
		X-bracing	K-bracing	Hybrid bracing
1	5	21.43	4.670	1.522
2	6	7.143	4.395	0.077
3	7	20.093	0.668	0.220
4	8	8.427	0.520	0.525
5	9	0.630	1.015	0.499
6	10	0.519	1.471	0.246

Table 14 Maximum Tensile and Compressive Stresses for X- bracing

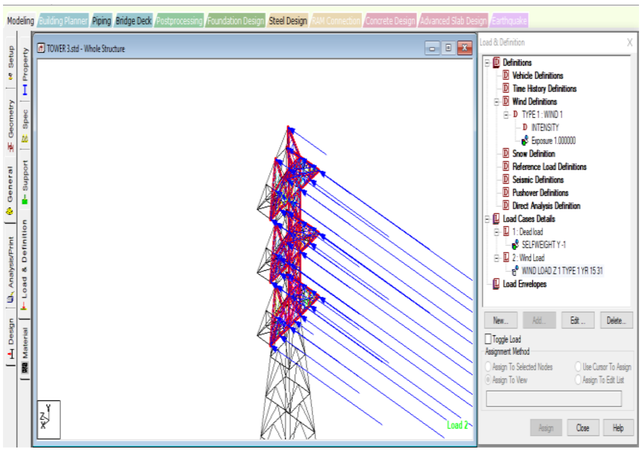
Sr. No	Member No	Load	Max. Stress(N/mm2)	
			Comp.	Tensile
1	156	Wind	3.8060	0.00
		Dead	13.003	11.112
2	94	Wind	1.581	0.00
		Dead	15.834	15.990
3	82	Wind	0.820	1.878
		Dead	0.00	2.824
4	64	Wind	0.00	6.514
		Dead	1.808	4.743
5	46	Wind	0.00	27.835
		Dead	19.355	0.314

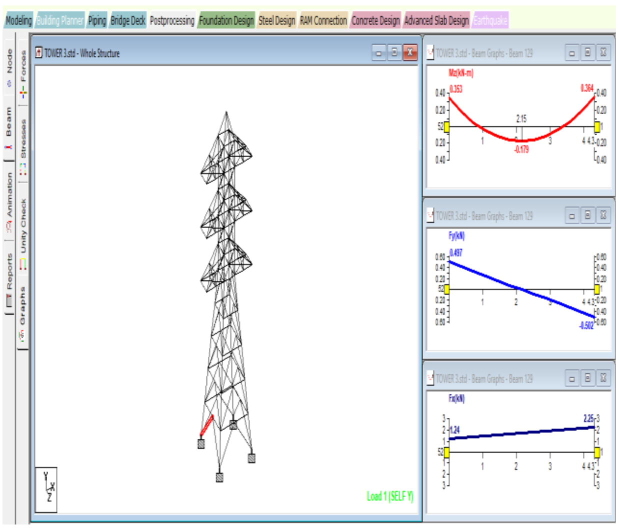
Table 15 Maximum Tensile and Compressive Stresses for K- bracing

Sr No	Member No	Load	Max. Stress(N/mm2)	
			Comp.	Tensile
1	156	Wind	0.945	0.064
		Dead	3.896	2.320
2	94	Wind	0.00	0.858
		Dead	4.832	4.967
3	82	Wind	4.855	4.959
		Dead	4.287	4.173
4	64	Wind	2.873	1.946
		Dead	0.559	2.176
5	46	Wind	0.00	13.766
		Dead	8.179	0.00

Table 16 Maximum Tensile and compressive Stresses for Hybrid bracing

Sr. No	Member No	Load	Max. Stress(N/mm2)	
			Comp.	Tensile
1	156	Wind	1.432	1.698
		Dead	1.854	1.754
2	94	Wind	0.699	0.00
		Dead	2.707	2.372
3	82	Wind	0.995	0.00
		Dead	0.00	2.786
4	64	Wind	0.132	0.202
		Dead	2.578	1.420
5	46	Wind	0.00	7.248
		Dead	8.407	0.00





RESULT DISCUSSION

In result analysis we compare the three tower of different bracing for displacement of member, displacement of nodes, axial forces and maximum tensile and compressive stresses.

CONCLUSION

In this paper an attempt has been made to compare the same transmission line tower with different bracing system i.e X- bracing, K- bracing and Hybrid bracing system. Following conclusions are drawn on basis of STAAD Pro analysis.

- Stresses developed in hybrid bracing are less as compared to X and K- bracing.
- Axial forces developed in hybrid bracing tower are very less as compared to other types of bracing.
- Displacement of nodes is more for K- bracing and lesser for hybrid bracing.
- Displacement of members of K- bracing tower is more as compare to X and hybrid bracing.
- Maximum bending moment is greater for wind load than dead load.
- Tower structure with least weight is directly proportional to deduction of cost. Tower of X-bracing gives least weight.

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