INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY (IJCIET)

ISSN 0976 – 6308 (Print)
ISSN 0976 – 6316(Online)
Volume 4, Issue 3, May - June (2013), pp. 197-209
© IAEME: www.iaeme.com/ijciet.asp
Journal Impact Factor (2013): 5.3277 (Calculated by GISI)
www.jifactor.com

IJCIET
© IAEME

ANALYSIS AND DESIGN OF THREE LEGGED 400KV DOUBLE CIRCUIT STEEL TRANSMISSION LINE TOWERS

Umesh S. Salunkhe[1] and Yuwaraj M. Ghugal[2]

[1] Department of Civil Engineering, Shreeyash College of Engineering & Technology, Satara Tanda Parisar, Plot No 258, Aurangabad-431005, MH.
[2]Department of Applied Mechanics, Government College of Engineering, Karad, MH.

ABSTRACT

Transmission line towers constitute about 28 to 42 percent of the cost of the transmission line. The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers. The present work describes the analysis and design of three legged self-supporting 400 kV double circuit steel transmission line towers models with an angle and tube sections. In this study constant loading parameters including wind forces as per IS: 802 (1995) are taken into account in both models. The efforts have been made to do 3D analysis of tower considering all the members of the space truss as primary members. STAAD. Pro program has been used to analysis and design the members of 400 kV double circuit tower have deviation angle 2 degree. The maximum sag and tension calculations of conductor and ground wire as per IS: 5613 (Part 3/ Sec 1) 1989. The comparative study is presented here with respective to axial forces, deflections, maximum sectional properties, critical loading conditions between both models of towers. The study shows that tower with tube sections are efficient and have better force – weight ratio including 20.6% saving in weight of steel with tubes against steel with angles in three legged transmission line tower.

Keywords: Three Legged, Broken Wire Condition, Sag, Angle Sections, Tube (Hollow Rectangular) Sections.

1. INTRODUCTION

Transmission line towers constitute about 28 to 42 percent of the cost of the transmission line [1]. The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers [2]. The selection of an optimum outline together with right type of bracing system, height, cross arm type and other parameters contributes to a large extent in developing an economical design of transmission line tower [3, 4]. As a goal of every designer are to design the best (optimum) systems. But, because of the practical restrictions this has been achieved through intuition, experience and repeated trials [5].

1.1. Transmission Line Tower

Transmission line towers are used for supporting the high current or Extra High Voltage electric transmission lines. This is simultaneously given rise to the need for relatively large supporting structures. 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 [6].

1.2. Three Legged Tower

Generally four legged lattice towers are most commonly used as a transmission line towers. Three legged towers only used as telecommunication, microwaves, radio and guyed towers but not used in power sectors as a transmission line towers. The configurations of three legged transmission line towers are very difficult because of cross arms and support arrangement not easily and perfectly possible [7]. The axial forces and deflection are increased in three legged tower components as compared four legged tower components but saving in steel weight of 21.2% resulted when using a three legged tower as compared with a four legged towers [8].

2. DESCRIPTION OF TOWER CONFIGURATION

For the present study, 400 kV double circuit steel transmission line with a suspension towers (2^0 angle deviation) two models are considered. The first model of tower is triangular base (three legged) self supporting type with angle sections. Thus, for optimizing the existing geometry, one of these suspension tower is replaced by triangular base self supporting tower with tube sections (hollow rectangular sections). The perception of the three legged transmission line top view is shown in figure 1. The tower configurations are given in table 1 and figure 2. The plan and isometric view of triangular base tower models in STAAD. Pro software is given in figure 3.

As per the guidelines of IS 802 and HVPNL [9], table 2 lists the details of some parameters typical to a 400 kV double circuit suspension type tower and table 3 lists the details of parameters for conductor and ground wire are considered from IS: 802 (Part 1/ Sec 1) 1995 and IS: 5613 (Part 3/ Sec 1) 1989.

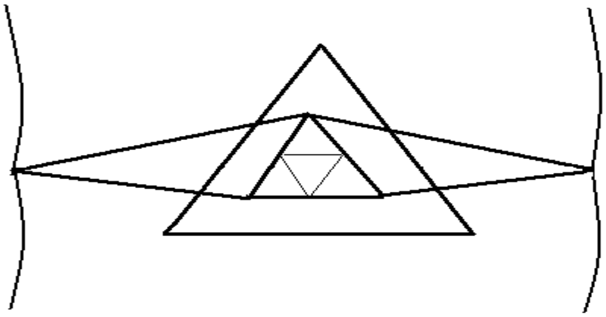


Fig. 1: Transmission line layouts for triangular lattice tower

3. MODELING APPROACH

The general package STAAD. Pro2008 has been used for the analysis and design. In this study, 3D analysis of tower considering all the members of the space truss as primary member has been used in STAAD. Pro programmed [7, 8]. The right and optimum selection of configuration of the tower the sag and tension calculated as per 5613 (Part 2/ Sec 1) 1989 as given in table 4. The load and loading combinations criteria on the ground wire, conductor and the towers are found using IS: 802. The loading calculations on tower due to conductor and ground wire in normal condition (NC) as well as broken wire condition (BWC) considering transverse as well as longitudinal direction wind as specified in table 5 and shown in figure 4.

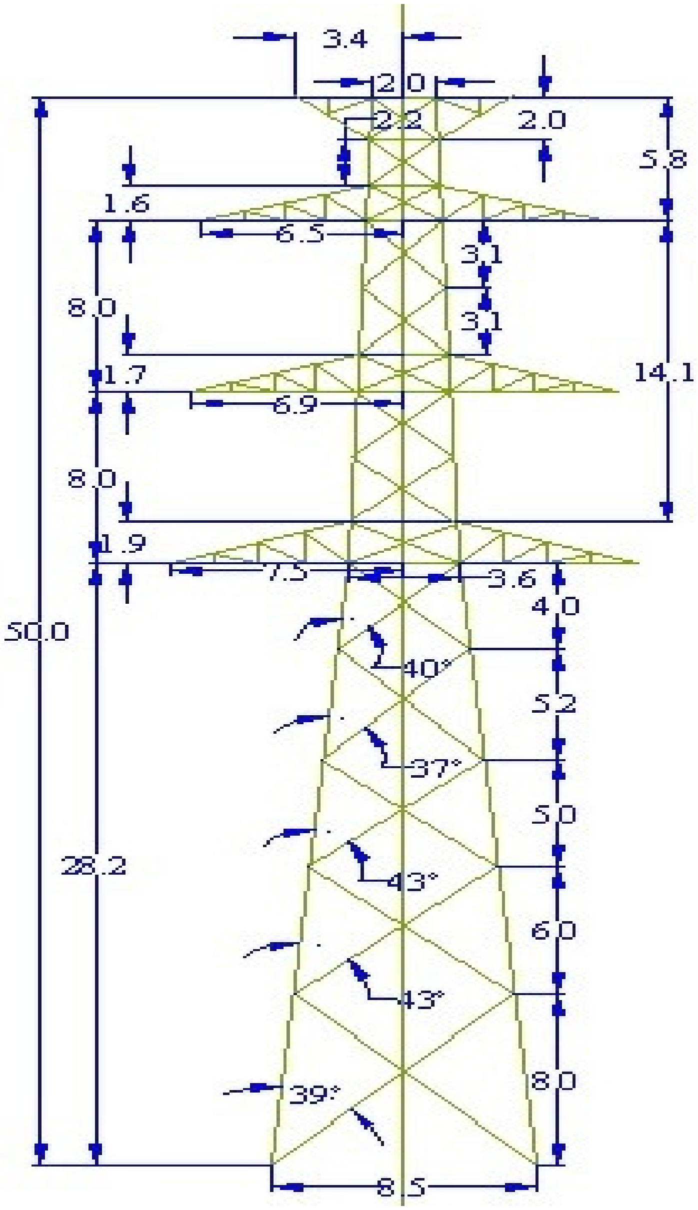
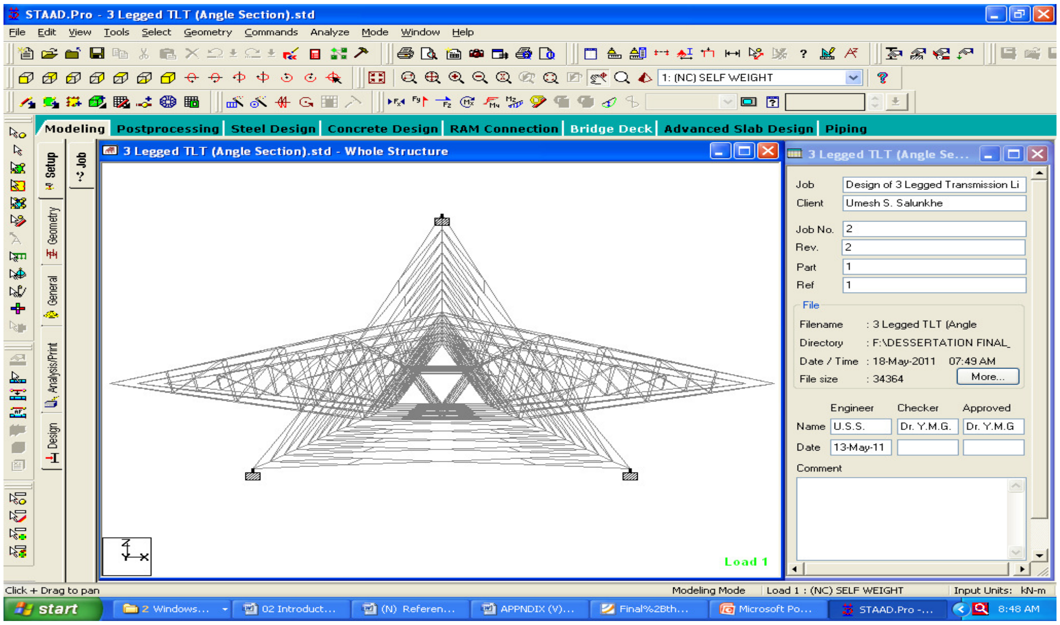


Fig. 2: Configuration of three and four legged towers

Table 1: Configuration of Three and Four Legged Towers

Configuration	Triangular Tower (mm)	Configuration	Triangular Tower (mm)
Base width	Equilateral triangle 8500mm side dimension	Max. Sag of conductor (sag at min. temperature and 36% WL)	13950
Cage bottom width	Equilateral triangle 3600mm side dimension	Max. sag of ground wire (sag at min. temperature and 36% WL)	6900
Cage top width (top of tower)	Equilateral triangle 2000mm side dimension	Vertical spacing b/w conductor	8000
Height till L.C. A. level	28,200	Vertical spacing b/w conductor and ground wire	5800
Height till U.C. A. level	44,200	Horizontal spacing b/w conductor (L.C.A.)	15000
Total tower height (from G.L.)	50,000	Horizontal spacing b/w conductor (M.C.A.)	13700
Minimum ground clearance	8840	Horizontal spacing b/w conductor (T.C.A.)	12800
Horizontal spacing b/w ground wire	7000		



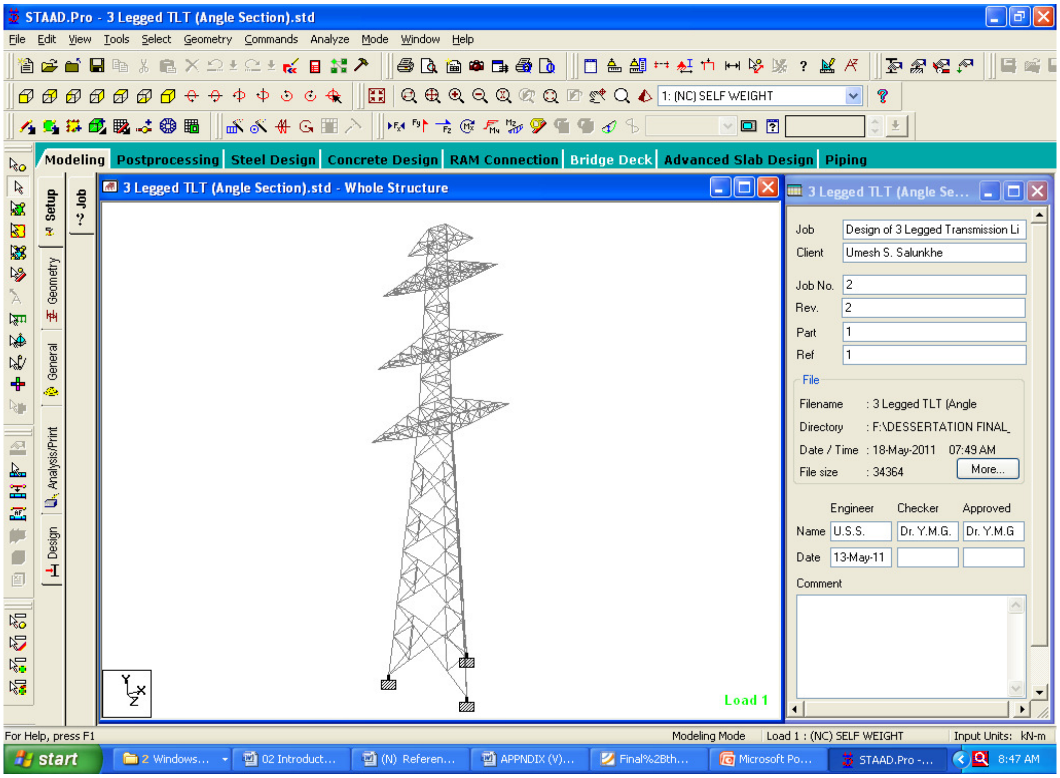
Job: Design of 3 Legged Transmission Li
Client: Umesh S. Salunkhe
Job No.: 2
Rev.: 2
Part: 1
Ref: 1

File
Filename : 3 Legged TLT (Angle
Directory : F:\DESSERTATION FINAL_
Date / Time : 18-May-2011 07:49 AM
File size : 34364

	Engineer	Checker	Approved
Name	U.S.S.	Dr. Y.M.G.	Dr. Y.M.G
Date	13-May-11		

Comment

(A) Plan



Job: Design of 3 Legged Transmission Li
Client: Umesh S. Salunkhe
Job No.: 2
Rev.: 2
Part: 1
Ref: 1

File
Filename : 3 Legged TLT (Angle
Directory : F:\DESSERTATION FINAL_
Date / Time : 18-May-2011 07:49 AM
File size : 34364

	Engineer	Checker	Approved
Name	U.S.S.	Dr. Y.M.G.	Dr. Y.M.G
Date	13-May-11		

Comment

(B) Isometric view

Fig. 3: STADD. Pro model for three legged towers

Table 2: Parameters for the Transmission Line and Tower Components

Transmission line voltage	400 kV Double circuit		Basic wind speed	39 m/s
Tower type	Suspension Tower		Basic wind pressure	68.10 kg/sqm
No. of circuit	Double circuit		Max. temperatures	75°c
Angle of line deviation	0°- 2°		Every day temperature	32°
Cross arm	Pointed		Min. temperature	0°
Tower shape	Barrel shaped		Insulator type	Suspension type
Bracing pattern Body: - Cage: -	X-X Bracing X-B Bracing		Size of insulator disc	280x170
Terrain type considered	Plain (1)		Length of insulator string	3850 mm
Return period	150 years		Length of ground wire attachment	2000 mm
Minimum wind load on insulators	1.0 kN		Weight of Insulator Disk	3.5 kN
Wind span	400m		Weight of Ground Wire	2.00 kN

Table 3: Parameters for the Conductor and Ground Wire

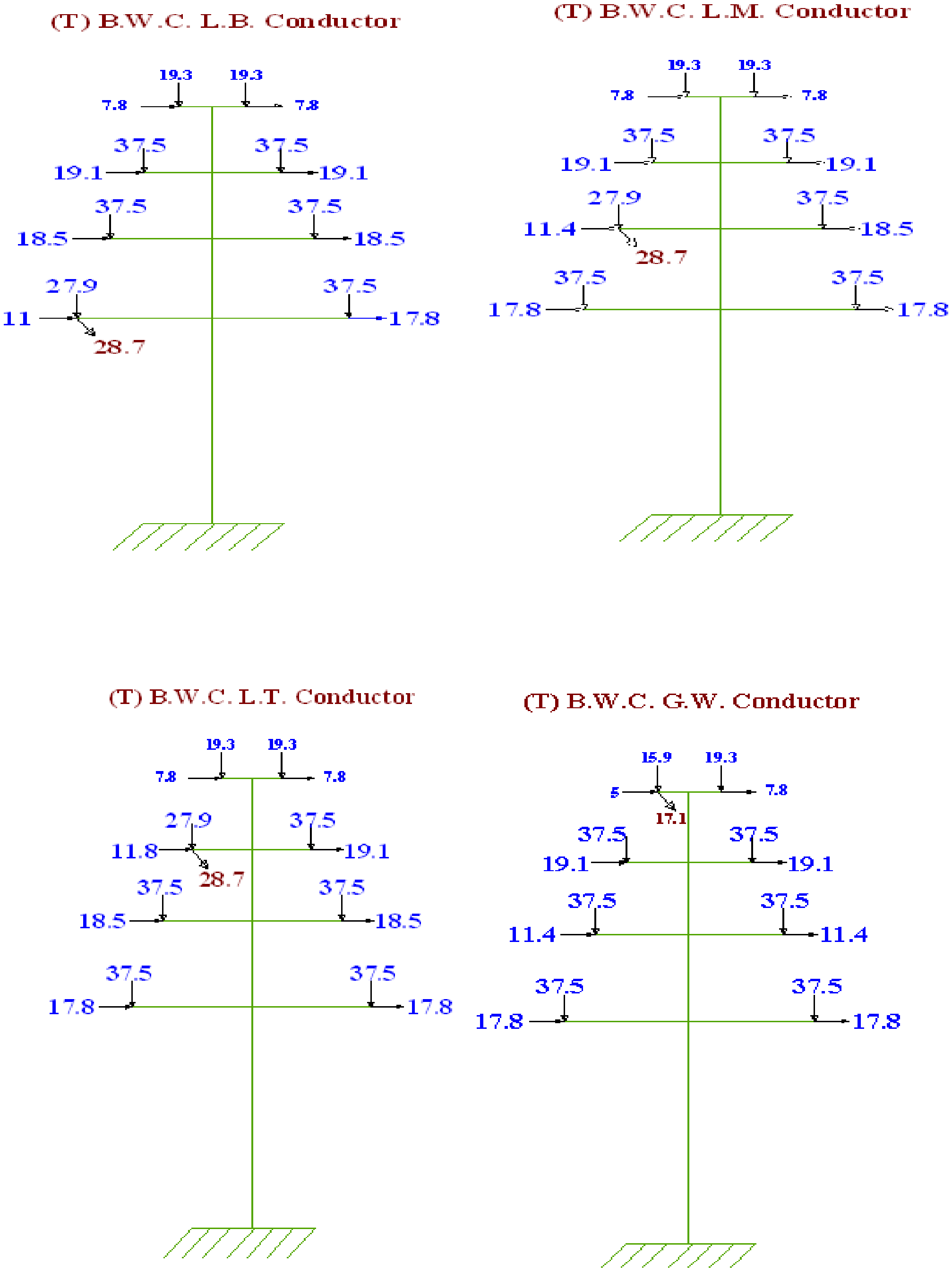
Description	Conductor	Ground wire
Conductor type and material	ACSR	Galvanized steel Earth wire
Conductor size	54/3.53 mm AL + 7/3.53 mm steel	7/3.66
Overall diameter of the conductor	31.77mm	11.0 mm
Area of the conductor	5.97cm^2	0.578cm^2
Weight of the conductor	2.00kg/m	0.7363Kg/m
Breaking strength of the conductor	16280.00Kg	6950Kg
Coefficient of linear expansion (α)	0.193 X10^{-4}/^{0}	0.115X10^{-4}/^{0}
Modulus of Elasticity	686000kg/cm^2	0.1933X10^7 Kg/cm^2

Table 4 Analysis of Sag-Tension of Conductor and Ground Wire under Critical Wind Pressure and Temperature Conditions

Sr. no.	Temperature		ACSR Conductor 54 / 3.53 mm AL + 7 / 3.53 mm steel		ACSR Conductor 7/3.66 mm (Span 400 m)	
	Type	Temp.	Ultimate Tensile Strength (Min.)	Sag	Ultimate Tensile Strength (Min.)	Sag
		ºC	kg	meter	kg	meter
1	At Minimum	0	2693.9	14.88	1640.5	7.86
2	At Minimum	0	2873.6	13.95	1710.0	7.75
3	At Everyday	32	2505.91	15.99	874.75	12.1
4	At Everyday	32	2675.81	14.98	933.75	10.8
5	At Everyday	32	3581.58	11.2	1250	6.09
6	At Maximum	75	2346.1	17.08	796.75	10.1
7	At Maximum	75	3369.2	11.9	1201.65	9.3

Table 5: Wind Loading on Conductors, Ground Wires and Insulators

Level of conductor and ground wire	Conductors and ground wires		Insulators
	Normal condition W.C.	Broken condition 60% * W.C.	Normal condition
Lower cross arm conductor	15.8 kN	9.5 kN	0.856 kN < 1.0 kN
Middle cross arm conductor	16.5 kN	9.9kN	0.874 kN < 1.0 kN
Top cross arm conductor	17.1 kN	10.3 kN	0.945 kN < 1.0 kN
Ground wire	6.2 kN	3.7 kN	0.60 kN < 1.0 kN

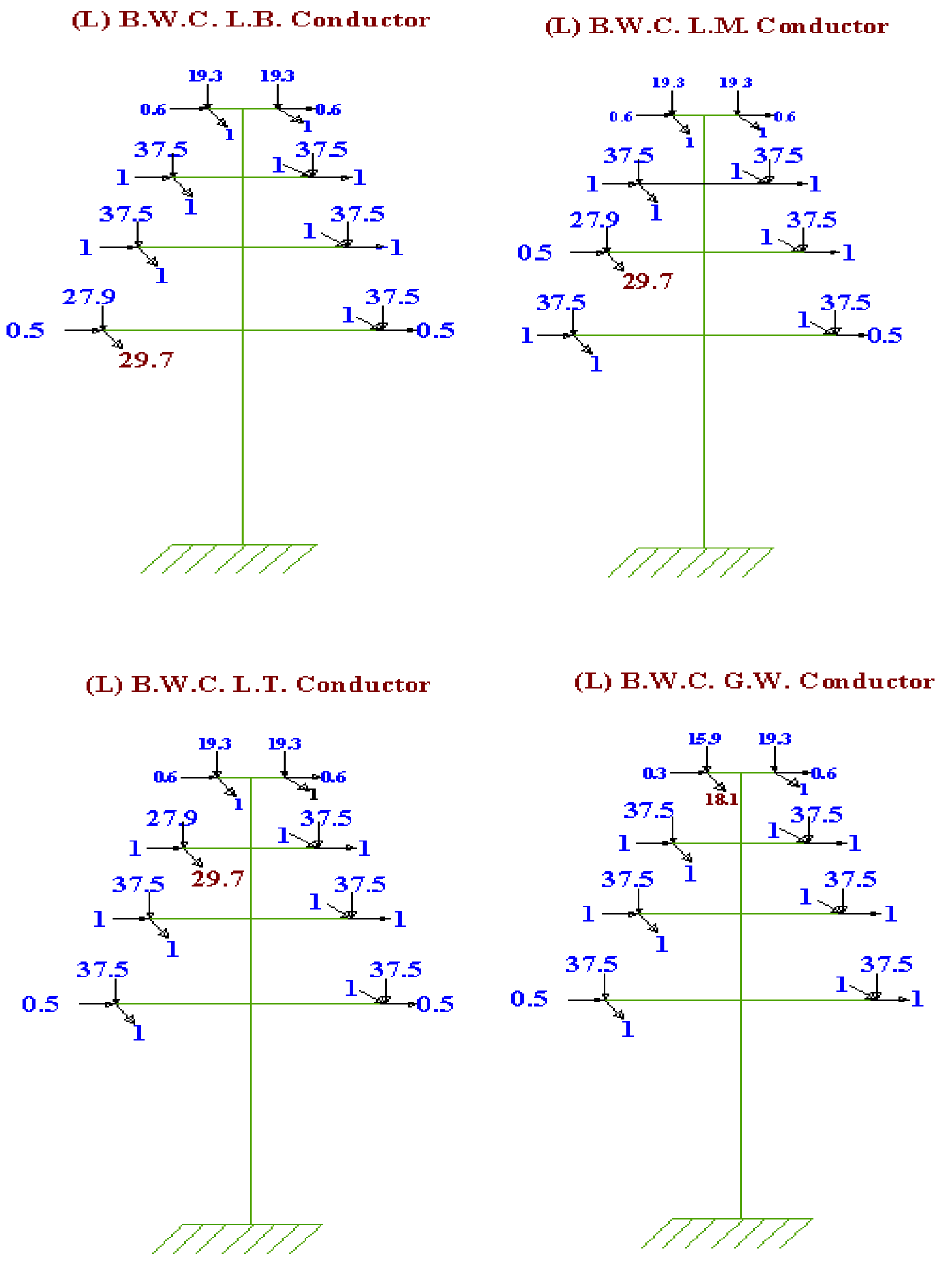

(T) B.W.C. L.B. Conductor

(T) B.W.C. L.M. Conductor

(T) B.W.C. L.T. Conductor

(T) B.W.C. G.W. Conductor

(A) Transverse wind load on the tower



(L) B.W.C. L.B. Conductor

(L) B.W.C. L.M. Conductor

(L) B.W.C. L.T. Conductor

(L) B.W.C. G.W. Conductor

(B) Longitudinal wind load on the tower

Fig. 4: Torsional loads caused by multiple load cases. (A) Transverse wind load on the tower, (B) Longitudinal wind load on the tower (The inclined arrow at each cross arm level in the broken loading conditions indicates the additional longitudinal load due to broken of wires)

4. DISCUSSIONS AND RESULTS

4.1. Maximum forces

Table 6 shows that maximum axial forces for different member nodes. It is apparent that the triangular tower is having the maximum axial force increases by broken wire condition as compared to normal condition. The one leg is having away from cross tip, axial forces are more than if compare with others two legs are having nearest from cross tip. By optimize design of towers, tube sections have better force–weight ratio and forces in legs reduced by 21.73% in normal condition and 2.78% in broken wire condition compared with angle section. Each member's axial forces also decreased by using tube sections. The graphical representation by maximum axial forces in various components is shown in figure 5.

Table 6: Maximum Axial Force for Three Legged Tower

Sr. No	Different Node Point	Angle Section		Tube Section	
		N.C.	B.W.C.	N.C.	B.W.C.
1	Leg (Away from cross arm tip)	1090	1110	852.9	1080
2	Leg (Near from cross arm tip)	870	1090	1020	1040
3	Main Members	89.6	271.8	87	263.6
4	Secondary Members	19.7	61.6	13.8	43
5	Cross Arms	586.7	638.9	581	632.7
6	Diaphragm	58.1	59.9	52.8	52.8

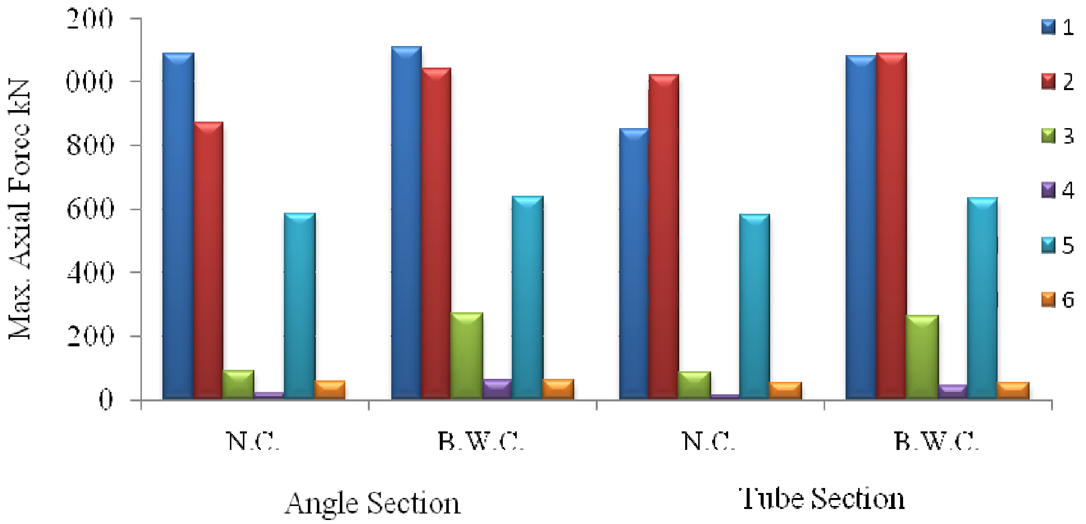


Fig. 5: Comparisons of maximum axial forces in various components of three legged tower towers, [1 Leg (near from cross arm tip), 2 Leg (away from cross arm tip), 3 Main bracing, 4 Secondary bracing, 5 Cross arm, 6 Diaphragm]

4.2. Maximum deflection

Table 7 shows that maximum deflection for different member nodes of towers in normal condition. It is apparent that the triangular tower, tube sections is having the maximum deflection arise as compare angle section and it is around 15 to 20 percent. The graphical representation of height Vs deflection is as shown in figure 6.

Table 7: Maximum Deflection for Three Legged Tower

Sr no	Different Node Point Deflection in mm	Angle Section	Tube Section	Permissible Deflection
1	Base of Tower	0	0	0
2	Bottom cage point	85.2	104.8	282
3	Lower cross arm tip	138.7	170	282
4	Middle cross arm tip	172.5	210	365
5	Upper cross arm tip	292.8	331	442
6	Ground wire arm tip	270	326.8	480
7	Topmost point of tower	249.7	253.6	500

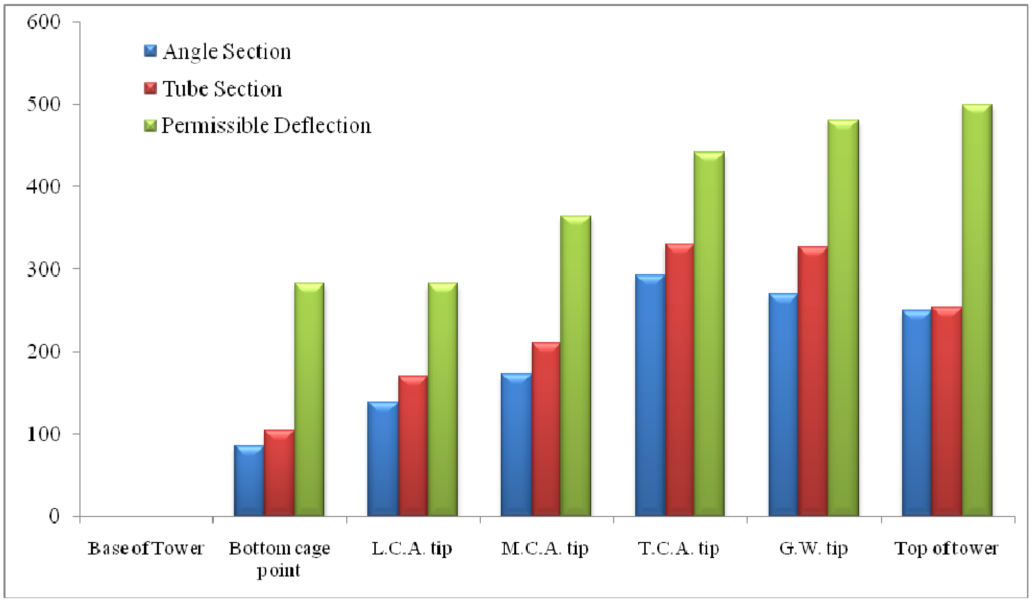


Fig. 6: Comparisons of maximum deflection in various components of three legged tower towers

4.3. Comparison of designs

The triangular towers, the steel saving in 400kV double circuit steel transmission line tower with tube section is 4.3 tones compare with angle sections. Tube sections are more economical that angle sections.

Table 8: Maximum Section Properties

Sr. No.	Different Components	Angle Section	Tube Section
1	Leg (Away from cross arm)	200x200x18	200x200x7.25
2	Leg (Near from cross arm)	200x200x25	200x200x10
3	Main Members	130x130x8	100x100x4
4	Secondary Members	200x200x12	125x125x8
5	Cross Arms	100x100x6	75x75x5
6	Diaphragm	80x80x6	60x60x3.2

Table 9: Comparisons of Steel Weight

Sr no	Tower Configuration	Steel Weight (Tone)	Steel Saving in Tone	Steel Saving in %
1	Three Legged Tower (Angle Section)	21.1	0.0	0 %
2	Three Legged Tower (Tube Section)	16.8	4.3	20.6 %

5. CONCLUSION

The axial forces are also increased in all members in three legged tower with angle sections as compared to three legged tower with tube sections during all components. Triangular tower with tube section, deflection is found to increase in normal condition compare with angle sections but within permissible limit. A saving in steel weight of 20.6% resulted when using a three-legged tower tube section compared with an angle sections.

REFERENCES

1. V. G. Rao, Optimum design for transmission line towers, Computers & Structures, Vol. 57, 1995, 81-92.
2. C. J. Patel and H. S. Trivedi, Weight compression in transmission line tower on the based on changing base width, Proceedings of International Conference on ISIWSE-2010, Aurangabad, Maharashtra, India, Vol. 1, 2010, 28-37.
3. J. S. David and A. C. Palmer, Optimal design of transmission towers by dynamic programming, Computers & Structure, Vol. 2, 1992, 455-468.
4. D. Tupe, Analysis of communication towers with different types of brace systems, post graduation thesis, Department of Applied Mechanics, Government College of Engineering, Aurangabad, MH, India, 2008.
5. A. Gupta, Analysis and economical design of transmission line towers of different configurations, doctoral diss., Delhi College of Engineering, Delhi, India, 2003-05.
6. V. Lakshmi and M. V. R. Satyanarayana, Study on performance of 220 kV M/C MA tower due to wind, International Journal of Engineering Science and Technology (IJEST), Vol. 3, Issue 3, March 2011.
7. B. 0. Kuzmanovi, N. Willems and F. M. Thomas, Automated design of three legged transmission line towers, Computers & Structures, Vol. 1, 1997, 171-182.

8. Y. M. Ghugal and U. S. Salunkhe, Analysis and design of three and four legged 400kV steel transmission line towers: comparative study, International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Vol. 04, No 06 SPL, Oct 2011, 691-694.
9. Manual of Specifications & Standards, HVPNL 400 kV PPP-1 transmission project, Jhajjar Power, May 1991.
10. IS: 802 (Part 1/ Sec 1) 1995, Use of structural steel in over head transmission line towers – code of practice (materials, loads and permissible stresses), section1 – materials and loads.
11. IS: 5613 (Part 3/ Sec 1) 1989, Code of practice for design, installation and maintenance for overhead power lines, part 3 - 400 KV lines, section 1 - design, 1989.
12. IS: 875 (Part3) 2005, Code of practice for design loads (other than earthquake) for buildings and structures, part 3- wind loads, 2005.
13. P. C. Punmia, Ashok Kumar Jain and Arun Kumar Jain, Comprehensive design of steel structures (Laxmi publications (P) Ltd, Mumbai, 2003) 456-586.
14. Mohammed S. Al-Ansari, "Building Response to Blast and Earthquake Loading", International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 2, 2012, pp. 327 - 346, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
15. Esmaeil Asadzadeh, Prof.Mrs. A. Rajan, Mrudula S. Kulkarni and Sahebaliasadzadeh, "Finite Element Analysis for Structural Response of Rcc Cooling Tower Shell Considering Alternative Supporting Systems", International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 1, 2012, pp. 82 - 98, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316

APPENDIX

Abbreviations

kV	Kilo Volt	L	Longitudinal
G.W.	Ground wire	T	Transverse
NC	Normal Condition	W.C.	Wind load on conductor
BWC	Broken Wire Condition	L.C. A.	Lower cross arm
b/w	Between	M.C. A.	Middle cross arm
Max	Maximum	U.C. A.	Upper cross arm
Min.	Minimum	WL	Wind Load
B.W.C.L.B.	Broken wire condition left bottom		
B.W.C.L.M.	Broken wire condition left middle		
B.W.C.L.T.	Broken wire condition left top		
B.W.C.L.G. W.	Broken wire condition left ground wire		

APPENDIX

A 2. Point Load on Each Node Joint of Three Legged Tower Panel

Group No.	Name	Total Area of Provided	Height	Solidity Ratio	Design Wind Pressure (pz)	C_{dt} (Drag Coefficient)	Gust Response Factor for Towers (GT)	Panel Load due to Wind $F_{Wt} = P_d X A_e X G_T X C_{dt}$	Distribute for Each Joint	Point Load on Each joint (Longitudinal Direction) KN	Point Load on Each Joint (Transverse Direction) KN
1	Base leg	7.74	8	0.12	681.3	3.33	1.70	29844.1	22	1.4	1.4
2		6.00	14	0.15	681.3	3.23	1.76	23238.6	22	1.1	1.1
3		5.04	19	0.18	681.3	3.20	1.84	20208.5	22	0.9	0.9
4		4.91	24.2	0.20	681.3	2.90	1.90	18436.3	22	0.8	0.8
5		3.61	28.2	0.23	681.3	2.80	1.94	13351.6	11	1.2	1.2
6	Cage leg	1.68	30.1	0.25	681.3	2.78	1.96	6247.3	11	0.6	0.6
7		1.66	33.15	0.17	681.3	3.1	2.00	6876.1	10	0.7	0.7
8		1.61	36.2	0.17	681.3	3.1	2.03	6811.2	10	0.7	0.7
9		1.45	37.9	0.29	681.3	2.5	2.05	5009.9	11	0.5	0.5
10		1.62	41	0.18	681.3	3.2	2.08	7332.1	10	0.7	0.7
11		1.57	44.1	0.19	681.3	3.3	2.09	7390.9	10	0.7	0.7
12		1.25	45.7	0.33	681.3	2.5	2.10	4435.5	11	0.4	0.4
13		1.43	48	0.29	681.3	2.5	2.13	5085.2	10	0.5	0.5
14		1.30	50	0.32	681.3	2.5	2.13	4690.8	11	0.4	0.4
15	Lower cross arm	1.08	30.1	0.39	681.3	2.2	1.96	3611.2	8	-	0.5
16		1.08	30.1	0.51	681.3	2.0	1.96	2513.1	8	-	0.3
17		1.08	30.1	0.94	681.3	2.0	1.96	1574.5	7	-	0.2
18	Middle cross arm	1.08	37.9	0.43	681.3	2.0	2.05	3143.9	8	-	0.4
19		1.08	37.9	0.41	681.3	2.0	2.05	2426.9	8	-	0.3
20		1.08	37.9	1.03	681.3	2.0	2.05	1523.9	7	-	0.2
21	Upper cross arm	1.08	45.7	0.45	681.3	2.0	2.10	3095.5	8	-	0.4
22		1.08	45.7	0.57	681.3	2.0	2.10	2399.9	8	-	0.3
23		1.08	45.7	1.10	681.3	2.0	2.10	1498.2	7	-	0.2
24	ground wire cross arm	1.08	50	0.69	681.3	2.0	2.13	3893.2	4	-	0.48