Analysis and Design of 220kV transmission line tower with hot rolled and cold formed section

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Abstract *:* The metal structures which keep the transmission line off the ground are power transmission towers. Generally most of transmission tower have been fabricated from hot-rolled steel angles. But availability of thinner hot-rolled sections is limited therefore hot rolled steel can be replaced with the cold formed steel. In his report an attempt is made that 220kV transmission line tower is analyzed and design using STAAD-Pro Vi8. In this study, the towers are designed in four wind zones from II to V with different steel sections such as hot rolled and cold formed. The towers are modeled using constant parameters such as height, bracing system and base width and the loads are calculated from IS: 802 (1995). Hot rolled sections are design according to IS 800: 2007 using limit state method whereas cold formed sections are design according to IS 801:1975 using working state method. The obtained results are compared for deflections in different wind zones and it is observed that deflection in cold formed steel is more as compared to hot rolled steel.

Keywords : Transmission tower, hot rolled steel, cold formed steel, STAAD-Pro Vi8.

INTRODUCTION

Transmission tower structures help facilitate the transportation of energy from the generating source to the substations where power is distributed. In India, development of electric power over the years has been unparalleled. The increasing demand for electric 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. Cold-formed angles are more readily available in thinner & smaller sections. They provide a feasible alternative for more economical structures. Unlike hot-rolled sections, cold-formed angles are available in more varieties of shapes. Transmission tower with cold-formed can be used to provide stiffening lips to prevent local buckling of thin wide elements & to optimize shapes. Ch. Sudheer et.al.[2] studied analysis and design of 220kv transmission line tower in different zones I & V with different base widths. The obtained results were compared with respect to deflections, stresses, axial forces and weight of towers. C. Preeti[3] studied more cost effective transmission tower by changing the geometry (shape) and behavior (type) using STAAD-Pro.

In the present work a 220kv transmission line tower is modeled using STAAD-Pro. The towers are designed in four wind zones II to V by using hot rolled and cold formed steel sections.

TRANSMISSION TOWER GEOMETRY

The following parameters for transmission line and its components are assumed as follows:

Transmission line voltage	= 220kv
Tower type	= Suspension tower
No. of circuits	= 2
Angle of line deviation	= 0^0 - 2^0
Tower configuration	=Vertical conductor configuration
Bracing Pattern	= Warren type
Cross arm	= Pointed
Max. Temperature	= 75^0
Every day temperature	= 32^0
Min. Temperature	= 0^0
Insulator type	= I- string
Height of tower	= 34008 mm
Base width of tower	= 6600 mm
Terrain category	= 2
Reliability level	= 1
Number of insulator discs	= 14
Size of insulator discs	= 255 X 145 mm
Length of insulator string	= 2340 mm

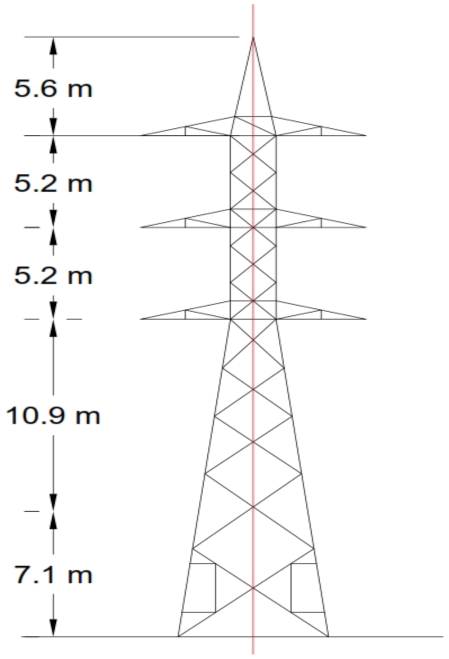


Figure 1: Transmission tower geometry

Table 1: parameters of conductor

PROPERTY	CONDUCTOR
Material	Aluminum conductor steel reinforced (ACSR)
Nominal size	ZEBRA
Stranding	(54+7) / 3.18
Diameter (mm)	28.620
Area (mm)	484.500
Weight (kg/m)	1.621
Ultimate strength (kg)	13288.000
Modulus elasticity (kg/mm^2)	7034.000
Alpha(per deg C)	1.93E-05

Table 2: parameters of ground wire

PROPERTY	GROUND WIRE
Material	Galvanized steel strands wire (GSSW)
Nominal size	-
Stranding	7 / 3.66
Diameter (mm)	10.980
Area (mm)	73.650
Weight (kg/m)	0.583
Ultimate strength (kg)	6972.000
Modulus elasticity (kg/mm^2)	19330.000
Alpha(per deg C)	0.11E-04

SAG TENSION FOR CONDUCTOR AND GROUND WIRE

Indian standard codes of practice for use of structural steel in over-head transmission line towers have prescribe following conditions for the sag tension calculations for the conductor and the ground wire:

1. Maximum temperature (75^0 C for ASCR and 53^0 C for ground wire) with design wind pressure (0% and 36%).
2. Every day temperature (32^{0}C) and design wind pressure (100%, 75% and 0%).
3. Minimum temperature (0^{0}C) with design wind pressure (0% and 36%).

IS 802: Part 1: Sec 1: 1995 states that conductor/ ground wire tension at every day temperature and without external load should not exceed 25% (up to 20kV) for conductors and 20% for ground wire of their ultimate strength. Sag tension are calculated by using the parabolic equations as discussed in the IS: 5613: Part 2: Sec1: 1989 for both the conductor and ground wire.

Table 3: Sag tension for conductor (ASCR)

Temp (deg c)	Wind (kg/m^2)	Snow (mm)	CONDUCTOR		
			Tension (kg)	Sag (m)	F.O.S.
0.00	0.00	0.00	473.58	6.09	3.26
32.00	78	0.00	4326.71	5.73	3.07
32.00	0.00	0.00	3322	7.47	4
32.00	104	0.00	4786.76	5.1855	2.776
75.00	0.00	0.00	2693.82	9.21	4.93

Table 4: Sag tension for ground wire

Temp (deg c)	Wind (kg/m^2)	Snow (mm)	GROUND WIRE		
			Tension (kg)	Sag (m)	F.O.S.
0.00	0.00	0.00	1605.86	5.56	4.34
32.00	96	0.00	1881.08	4.75	3.706
32.00	0.00	0.00	1394.4	6.40	5
32.00	128	0.00	2126.18	4.2	3.28
53.00	0.00	0.00	1282.36	6.96	5.44

LOADING CALCULATION

The self- supporting towers are rigid in both the directions and it is subjected to two types of loads i.e. wind loads acting transversely and longitudinal horizontal loads.

A. Transverse loads:

Force due to wind on various elements of transmission lines is obtained by multiplying pressure with the projected area of that element.

Wind on wire: $F_{wc} = P_d. L. d. G_c. C_{dc}$

Wind on Insulator: $F_{wi} = P_d. A_i. G_i. C_{dt}$

Due to deviation $F_{wd} = 2. T. \sin (\phi / 2)$

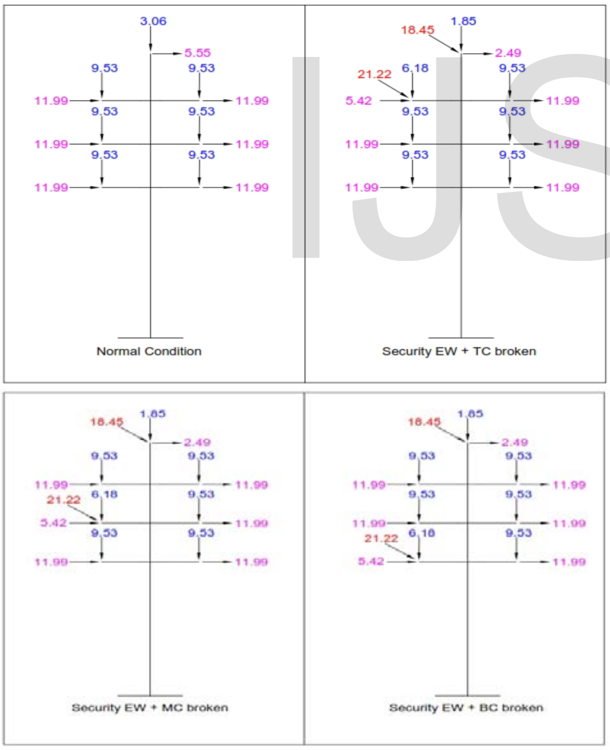
B. Longitudinal Loads:

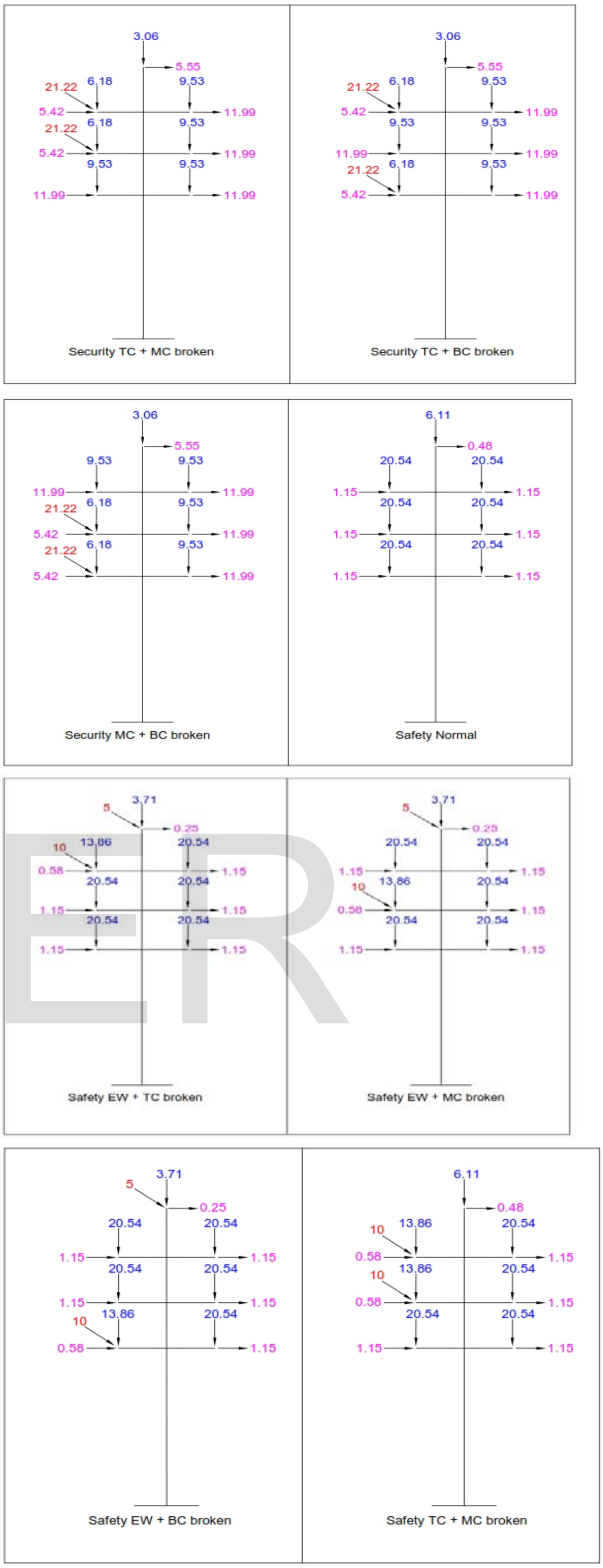
Longitudinal loads are mainly caused due to broken wire condition, and these loads have much more effect on the design of the tower than any other load. The unbalanced pull due to broken conductor, in case of supports with suspension strings, may be assumed equal to 50 percent of the maximum working tension of the conductor. For the ground wire broken condition, 100 percent or such percentage of ground wire tension, for which the ground wire clamp is proportioned and whichever is less should be considered for the purpose of design of tower.

$LR = 0.5 * T. \cos (\phi / 2)$

LOADING COMBINATIONS

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 below:





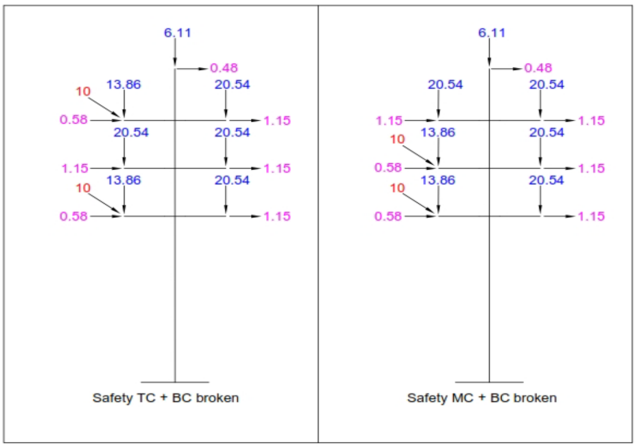


Figure 2: Line diagram for transmission line tower

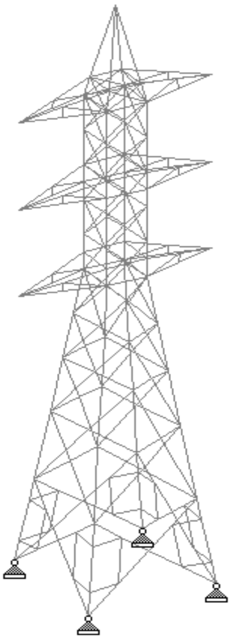


Figure 3: Model of transmission line tower in STAAD-Pro

MODELLING APPROACH

The STAAD- Pro V8i has been used for analysis and design. In this study tower is modeled as a 3D space by considering tower as a truss. Transmission tower of angle section of hot rolled members are used with mild steel of grade 250 N/mm^2 and the channel sections of cold formed members are used with steel grade of 353 N/mm^2. Wind load considered is acting in X and Z directions. Loads and Load combinations are considered for different wind zones from II to V as per IS 802 are used in linear static analysis.

RESULTS AND DISCUSSION

The deflection obtained from STAAD-Pro at different height of transmission tower with hot rolled section and cold formed sections.

Table 5: Deflection for tower in wind zone II

	Height	Deflection of HRS mm	Deflection of CFS mm	Permissible deflection mm
Base of Leg	0	0	0	0
Bottom cross arm	18.008	25.37	35.41	180
Middle cross arm	23.208	31.80	44.48	232
Top cross arm	28.408	38.33	53.26	284
Ground wire arm tip	34.008	43.99	61.49	340

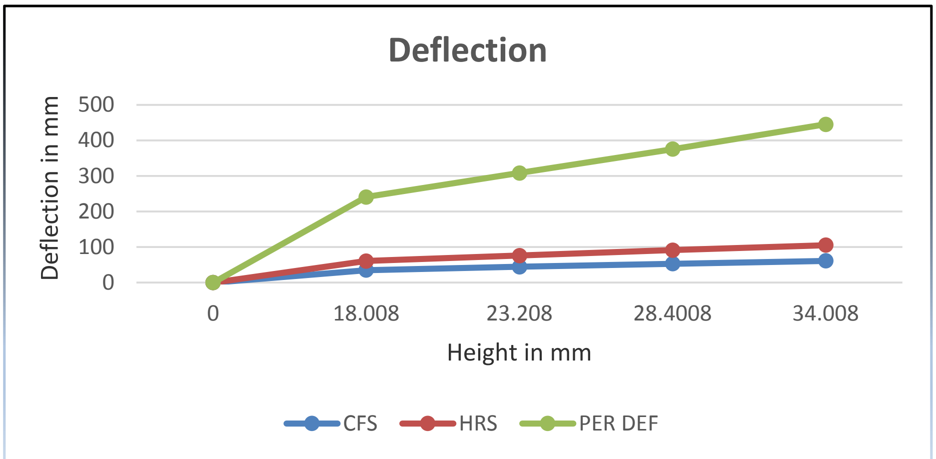


Figure 4: Deflection of tower in wind zone II

Table 6: Deflection for tower in wind zone III

	Height	Deflection of HRS mm	Deflection of CFS mm	Permissible deflection mm
Base of Leg	0	0	0	0

Bottom cross arm	18.008	26.42	37.44	180
Middle cross arm	23.208	33.17	47.22	232
Top cross arm	28.408	40.00	56.62	284
Ground wire arm tip	34.008	46.02	65.51	340

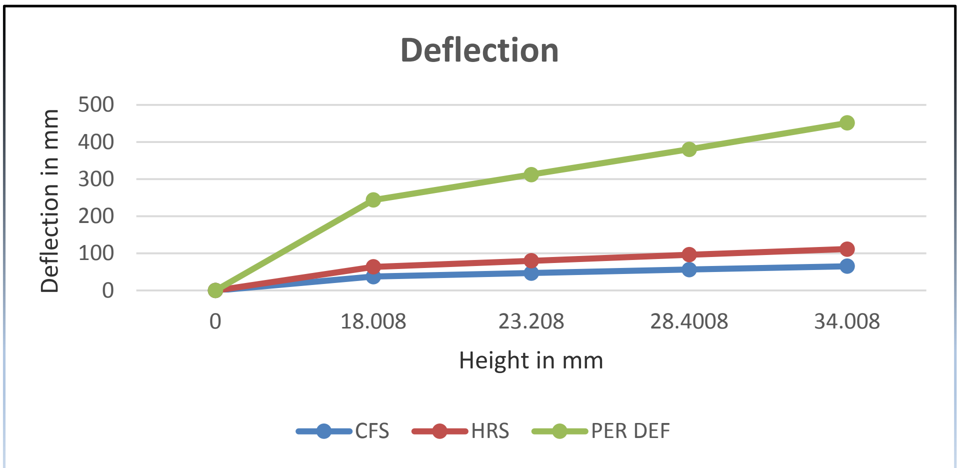


Figure 5: Deflection of tower in wind zone III

Table 7: Deflection for tower in wind zone IV

	Height	Deflection of HRS mm	Deflection of CFS mm	Permissible deflection mm
Base of Leg	0	0	0	0
Bottom cross arm	18.008	26.42	39.34	180
Middle cross arm	23.208	33.27	49.71	232
Top cross arm	28.408	40.13	59.66	284
Ground wire arm tip	34.008	46.23	69.16	340

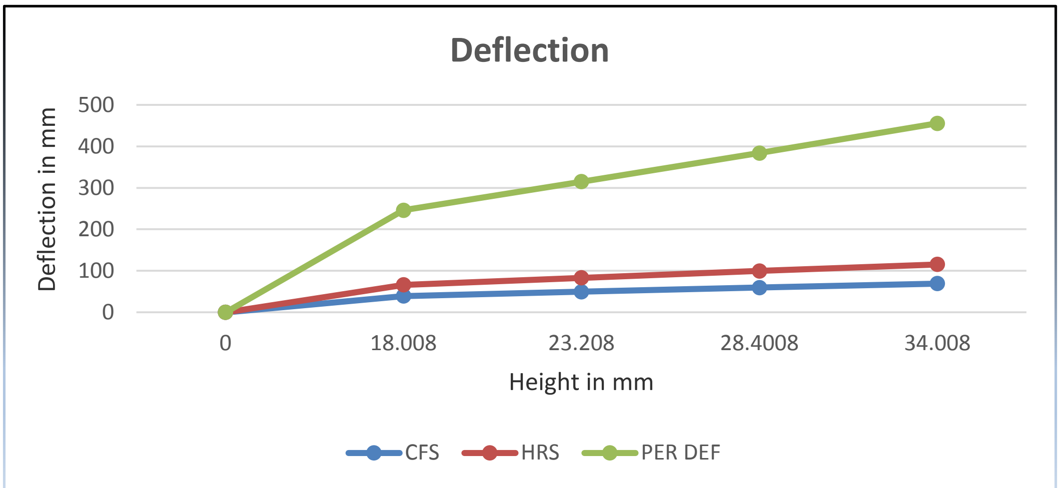


Figure 6: Deflection of tower in wind zone IV

Table 8: Deflection for tower in wind zone V

	Height	Deflection of HRS mm	Deflection of CFS mm	Permissible deflection mm
Base of Leg	0	0	0	0
Bottom cross arm	18.008	26.82	42.72	180

Middle cross arm	23.208	33.70	54.05	232
Top cross arm	28.408	40.67	65.02	284
Ground wire arm tip	34.008	46.84	75.54	340

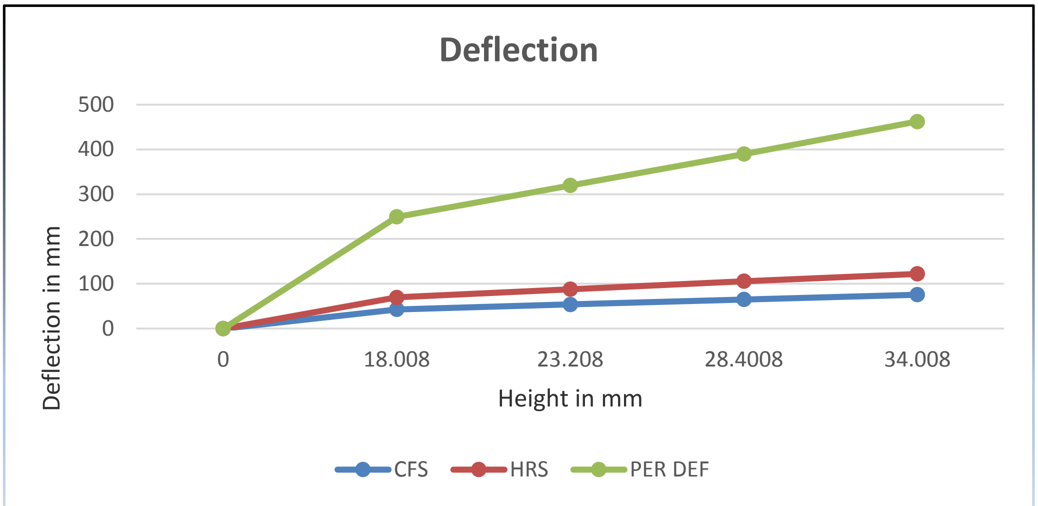


Figure 7: Deflection of tower in wind zone V

Tables and graphs shows the deflection result for wind zone II to V. From above tables and graphs it is concluded that deflection of the tower increases with height. Deflection of tower using cold formed sections is slightly greater than tower using hot rolled sections but both deflections are within permissible values.

CONCLUSIONS

The transmission towers of hot rolled sections and cold formed sections with four wind speeds are design and analyzed using STAAD-Pro V8i software. From preceding results and discussions following conclusions can be made: Tower model is pin jointed space 3D structure. Deflection is maximum at ground wire tip and minimum at leg base. Within the permissible limit transmission tower of cold formed sections have 39.8%, 42.3%, 49.6% and 61.2% increased in deflection as compared to hot rolled sections for wind zones II, III, IV and V respectively.

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ABBREVIATION

kV	Kilo Volt
HRS	Hot Rolled Steel
CFS	Cold Formed Steel
Max	Maximum
Min	Minimum
EW	Earth wire
TC	Top Conductor
MC	Middle Conductor
BC	Bottom Conductor