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Analysis and Design of Transmission Tower Using STAAD.PRO

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Abstract: Formulation of transmission towers is tendered in a perspective of confronting high voltage transmitting conductors and insulators to stand in need of altitude from the ground level. For the same purpose a transmission tower is replicated with similar context of height 49m and fetching a 220KV double circuit conductor, maneuvered with STAAD PRO. The contemplations from both structural and electrical fields are viewed in designing transmission line towers, for safe and economic aspects. According to IS 800-2007, the wind forces are much prominent on the tower, conductors and insulators, besides the self-weight. This work is focused in optimizing the transmission tower with employing the 'X' and 'K' bracings, and by varying the sections, examined using Static analysis. The upshots of using 'X' bracing to 'K' bracing are the appraisable reduction in the weight of the structure by 6% and having the displacement values supplemented.

Keywords: *Transmission line Tower, Insulator, Conductor, 'X'& 'K' Bracings, Dynamic Analysis, Optimized*

1. Introduction

Design variables encompass joint coordinates in conjunction with member areas which are consecutively accounted as dependent design variables, according to Hooke & Jeeves method. The K bracing has got massive weight shrunk compared to that of an X bracing analyzed with dynamic and tornado loads with varying sections of pipe, angular and tubular, a substantial weight of 14% is lowered [1]. With increase in the population rate the demanded necessity of power supply saw an upsurge, and in view of the same ambition a self-supported 220KV and 110KV are modeled, where the primary members are much prior in transferring loads than the secondary members. In the design of transmission tower, tube sections unable to afford proper economy [2]. And on basis of trial and error the most favorable geometric tower configuration is adopted. The analysis and design is performed in STADD.PRO for a 220 KV self-sustaining transmission tower with fixed height, clearances, length and type of conductor as inputs. Conservation of steel area up to 45% is achieved; when 'X' Bracing system is compared to that of 'K' bracing [3]. Considering the aspect of bracings, the tapered model is found to be effective to that of inclined, as they result in complexity with application of lateral and diagonal wind loads, primarily for the tall structures. Till a height of 50m the secondary members are demonstrated to be economical, and diaphragm bracings are used to bring up higher bearing members [4]. A stable electrical power system can be attained via transmission tower, where the ultimate strength is ranked via non-linear dimension and property of the material. In Perth metropolitan model, the wind loads are the deciding factor where the main governing factor for the failure is displacement, while the seismic loads also affect the structure in terms of displacement much higher than the design forces [5]. Weight dominance is arrived by the algorithm in using Particle Swarm Optimization technique, by which 7.4% coherent value compared to STAAD pro though the type of tower maters [6].Unique transmission tower displays fewer forces when analyzed with that of Northridge than Koyna tornado motion of ground, with continuous examination of wind as an equivalent static method [7]. In shortage of required right of way, the base width of tower is restricted for usage of unalike sized sections. Generally by using 5 to 6mm sized members, the weight came down for all the sections [8]. STAAD pro is used to analyze the tower of 35m tall approach of tornado loads, if the tower peer equivalent to resonance it may get affected at a height 27m, whereas 190mm deformation is observed in X-Direction and 60mm in Y-Direction at the peak of the tower [9]. Multiple bottom base widths ranging from 1/4 to 1/6 of the tower height with seismic zone I and zone V regions are considered for designing of transmission towers with 220KV capacity [10]. Linear static analysis and p-delta analysis is enlisted for a circuit of 400KV, resulting untangled displacement values for the latter case. Analyzed with members containing different sections of IS tubular and angle sections, with over twenty two percent steel saving in the latter case [11]. When analyzed with IS:1893 Zone III data of seismic region, special forces prevailed when conductors have oriented to the tower direction, acceleration response is good for the triangular bases with 12% weight reduction compared to squared ones and 5% fundamental frequency is gained with deflections in control [12].

2. Methodology

A Double Circuit Transmission line tower carrying 220KV power capacity is analyzed and designed in STAAD.PRO. The total height of tower is 49m which is determined according to IS 5613(part 2/ sec 1):1995.Two towers are modeled by using 'X' and 'K' Bracings by using Indian angle sections with different sectional properties in the tower elements. In order to design optimized transmission tower with varying sections, IS: 802 (Part 1/ Sec 1): 1995 has been followed.

2.1 Transmission Tower Dimensions

According to the Electrical Rule, 77(4) 1956, (a) The minimum gap above the ground to the bottom most point of the conductor, (b)The peak sag is equal from all the sections of very next tower in plain country. (c) With considering high earthquake conditions and wind should be followed, (d) the vertical distance between conductor and top most wire is commanded by shied angle. By considering all the above necessities the total height of the tower is resolved. The modeled transmission tower is shown in fig 1.

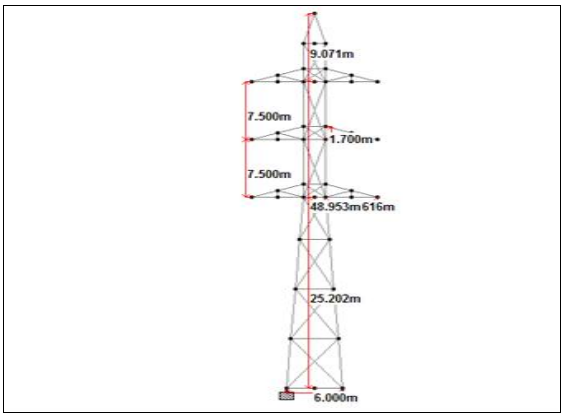

Figure 1 *Transmission Tower*

Table 1: *Transmission Tower Dimensions*

Description	Lengths
Total Height (H)	49m
Ground clearance (h1)	7.01m
Maximum sag of the lower most conductors wire (h2)	18.192m
Vertical distance between conductor wires (h3)	7.5m
Vertical distance between conductor and ground wire (h4)	9.071m
Square base width	6.0m
Length of cross arm from edge of hamper	5.616m
Span between the towers	200m
Length of wire between two suspension towers	230m

3. Analysis of Transmission Tower

As per IS 802 (Part1/Sec1):1995, the loads acting on transmission tower and its components can be determined by the following formula.

Wind Load on Tower Fwt = P_d x C_{dt} x A_e x G_T
Wind Load on Conductor and ground wire F_{wc} = P_d x C_{dc} x L x D x $G_{c.}$
Wind Load on Insulator Strings F_{wi} = C_{di} P_d x A_i x G_i

Where,

P_d = Design wind pressure N/m^2
C_{dt} = Drag coefficient for tower
A_e = Total net sectional area of members (m^2)
G_T = Gust response factor for tower
C_{dc} = Drag coefficient for conductor and ground wire
L = Wind span (m)
d = Diameter of cable (m)
G_c = Gust response factor for conductor
C_{di} = Drag coefficient for insulator
A_i = 50% of area of insulator string
G_i = Gust response factor for insulator

Sectional Parameters are given below

Table 2: *Indian Steel Sections for X-Bracing*

LD ISA200X100X10	Horizontal & Inclined bracings
SA ISA200X200X25	Main Vertical Members
SD ISA100X100X12	Cross arms

The tower model is assigned with following parameters shown in table 4 in accordance with I.S. 802: (Part 1/ Sec: 1):1995, I.S. 5613: (Part 2/ Sec: 1):1989.

Table 3: *Indian Steel Sections for K-Bracing*

LD ISA180X180X20	Horizontal, Inclined bracings & Cross arms
SA ISA200X200X25	Main Vertical Members

Table 4: *Transmission Tower Parameters*

Transmission line voltage	220KV
Tower type	Suspension tower
Angle of line deviation	0^o-2^o
No. of circuits	Double circuit
Terrain type	1
Conductor material ACSR	54/3.53 AL+7/3.53
Ground wire GSS	7/3.66
Coefficient of linear expansion (α) in /^{o} C ACSR	19.36x10^-6
Modulus of elasticity (E) in Kg/cm^2 ACSR	0.736x10^6
Coefficient of linear expansion (α) in /^{o} C GSS	11.5x10^-6
Modulus of elasticity (E) in Kg/cm^2 GSS	1.933x10^6
Basic wind speed in m/sec	44

Basic wind pressure in kg/m2	73.07
Maximum Temperature of conductor	73°
Maximum Temperature of Ground wire	53°
Every day temperature	32°
Minimum Temperature	-5°
Terrain Type	Plain
Return Period	50Years
Tower Geometry	Square base
Peak type	Triangular
No. of Insulator Disks	6 No. 255X145mm
Insulator Type	String Insulator
Minimum Width at Base	4.5 m Square Tower

3.1 Design Parameters

The member design and code checking in STAAD.PRO are based upon the allowable stress design method as per to IS: 802 (Part 1/ Sec 1): 1995. It is a method for selecting varying primary and secondary members under consideration of design loads, allowable stresses and design limitations.

4. Results

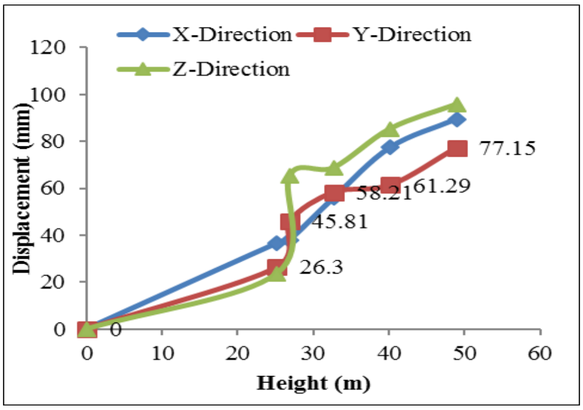

Figure 2 *Height (m) V_S Displacement (mm)*

Figure 2 Ensures that the displacement of tower at specified nodal points with respect to the height of the tower. The displacement values increases rapidly in X-Direction, where wind force is governing at cross arms and peak of tower.

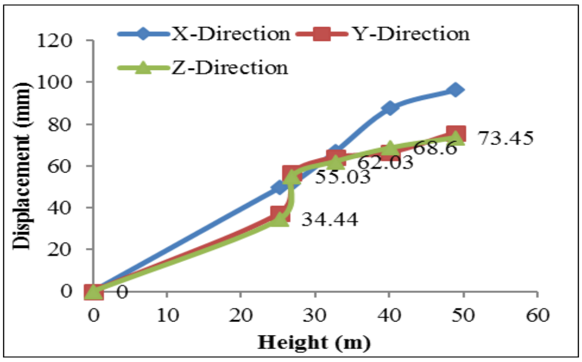

Figure 3 *Height (m) V_S Displacement (mm)*

Figure 3 exemplifies the increase in displacements of the tower. The global X-Direction displacements values are increasing rapidly due to the dynamic load.

Table 5: *Displacements in Tower with X-Bracing*

Node Number	Node Position	Displacement in mm			Maximum permissible displacement in mm (H/100)
		X	Y	Z	
1	Base of leg	0	0	0	0
19	Bottom Hamper Point	36.53	26.3	23.6	252.02
40	1st Cross arm point	38.04	45.81	65.3	269.02
59	2nd Cross arm point	55.82	58.21	68.7	327.02
73	3rd Cross arm point	77.36	61.29	85.3	402.02
70	Top most point of ground wire	89.36	77.15	95.66	489.53

Table 6: *Displacements in Tower with X-Bracing*

Node Number	Node Position	Displacement in mm			Maximum permissible displacement in mm (H/100)
		X	Y	Z	
1	Base of leg	0	0	0	0
19	Bottom Hamper Point	49.56	37.38	34.44	252.02
40	1st Cross arm point	51.60	56.56	55.03	269.02
59	2nd Cross arm point	66.72	64.16	62.03	327.02
73	3rd Cross arm point	87.68	66.51	68.60	402.02
70	Top most point of ground wire	96.45	75.90	73.45	489.53

5. Conclusions

The Displacement value is quiet higher i.e., 96.45mm in X-Direction in case of transmission tower modeled using 'K' Bracing when compared to 'X' Bracing i.e., 89.36mm. The Transmission tower modeled with 'X' Bracing found to be required lesser percentage of steel i.e., 6% when compared to 'K' Bracing. In the design aspect it reveals that by providing unique sectional property throughout the transmission tower leads to uneconomical design. Transmission tower with 'X' Bracing using LD ISA200X200X10, SA

ISA200X200X25, and SD ISA100X100X12 has a total weight of 1182.950 kN. Transmission tower with ‘K’ Bracing using LD ISA180X180X20, SA ISA200X200X25 having a total weight of 1251.296 kN.

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