ANALYSIS AND DESIGN OF TRANSMISSION TOWER USING STAAD.Pro V8i

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Abstract: The design process of structural planning and design requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering beside the knowledge of practical aspects such as recent design codes, bye laws, backed up by ample experience, intuition and judgment. The purpose of standards is to ensure and enhance the safety, keeping careful balance between economy and safety. In this, tower is one of the steel structure which is getting progressed especially the transmission tower. Safety is the foremost thing which should be kept in mind in order to provide a comfort zone for the surrounding beings. Therefore, the transmission tower has to be constructed with a proper care and maintenance. By normal designing and analysis of the tower it requires a more time so we adopt different softwares to obtain the results. So, analysis and designing of a transmission tower is done by "STAAD.Pro V8i".

Keywords: - *Transmission tower, ASCR Conductor, Earth wire.*

I. INTRODUCTION

Transmission Tower

Tower is a tall structure, whose height is greater than its width. As they are greater in height various functions can be achieved. They can be of many types, clock towers, castle, bridge, transmission tower, light house, signals towers etc. Transmission tower is a tall structure which is used to support an overhead power line. These towers are constructed for transmitting the electricity from generation station to sub-stations. They are used in high voltage AC and DC systems, and they are wide variety of shapes and sizes. The major typical height ranges from 15 to 55 meters (49 to 189ft).They are also known as Power tower /Cellular phone tower / Electric tower depending upon the purpose they serve. The materials are used to construct the transmission tower is ISA (Indian Standard Angle) sections. The Dimensions for angle sections are according to steel table. For equal angle sections the size varies from minimum 20X20X3 to maximum 200X200X25. For unequal angle sections the size varies from minimum 30X20X3 to maximum 200X150X18. Providing bracings like K bracings, X bracings and KX bracings are used to here to reduce the total weight of tower. During design of transmission tower the following procedures to be considered in mind. The minimum ground clearance of the lowest conductor point above the ground level. The length of the insulator string. The minimum clearance to be maintained between conductors and tower. The location of ground wire with respect to outer most conductors. The mid span clearance required from considerations of the dynamic behaviour of conductor and lightening protection of the line. To determine the actual transmission tower height by considering the above things, we have divided the total height of tower in four parts. Minimum permissible ground clearance (H1).Maximum sag of the conductor (H2).Vertical spacing between top and bottom conductors (H3).Vertical clearance between ground wire and top conductor (H4).

Transmission line should be stable and carefully designed so that they do not fail during natural disaster. In planning and design of a transmission line, a number of requirements have to be met from both structural and electrical point of view. From the electrical point of view, the most important requirement is insulation and safe clearances of the power carrying conductors from the ground. The cross section of conductors, the spacing between conductors and the location of ground wires with respect to the conductors will decide the design of towers and foundations. The design of transmission tower is generally based on minimum weight of tower. The tower is modelled as a jointed space truss, steel angle sections of different grades are generally used for towers.

II. Transmission tower configuration

Reliability level	2
Wind zone	2
Terrain category	2
Wind speed, V_b	39m/s
Meteorological reference wind speed, V_R	28.36m/s
Design wind pressure, P_d	59.58kg/m^2 or 0.5891 kN/m^2
Ground clearance, h_1	7.00m
Maximum sag of the lower most conductors wires, h_2	6.7m
Vertical distance between conductor wires, h_3	9.8m
Vertical distance between conductor and ground wire, h_4	8.5m
Base width of the tower, b	4.00m
Length of each cross arms	3.2m

III. Properties of Conductor Wire

Type of conductor	ASCR conductors
Voltage	220kV
Conductor size	6.54/3.18 + 7/3.18mm
Area of the conductor (for all strands)	475.379mm^2 or 4.7537cm^2
Weight of the conductor(w)	1.62kg/m
Ultimate tensile strength	13316kg or 130.30kN
Coefficient of linear expansion(α)	19.3X10^{-6} per^{o}c
Modulus of Elasticity (E)	0.7036X10^6 kgf/cm^2
Diameter of the ASCR wire	28.62mm

IV. Properties of Earth Wire

Type of earth wire	Galvanized steel
Size of the earth wire	7/3.15mm
Configuration	One continuously to run horizontally on thetop of the towers and conductors
Overall diameter	9.45mm
Weight of conductor	0.426kg/m
Ultimate tensile strength	58.4kN or 5955.14 kg
Ruling design span	350m
Area of cross- section	545.5mm^2
Coefficient of linear expansion	11.5X10^6/^{o}c
Modulus of elasticity	1.933X10^{6}kgf/cm^2

V. Modelling

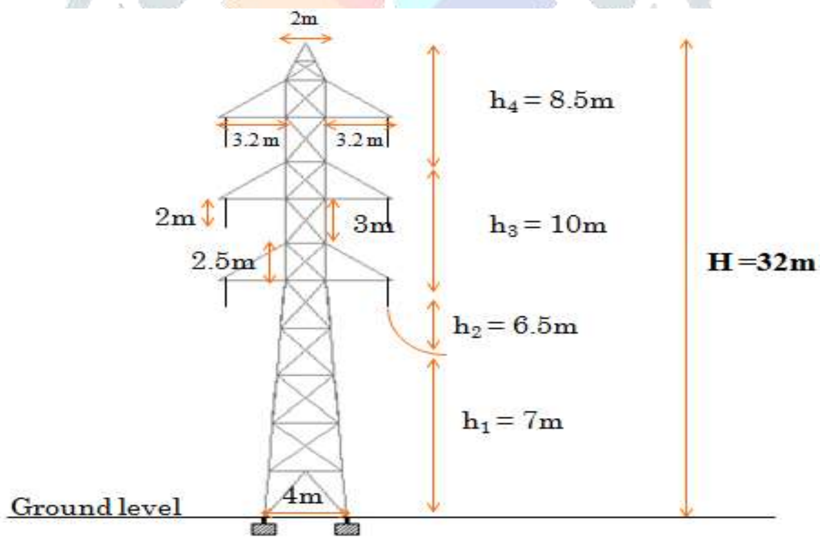

Fig 1.1: Geometric Dimension of Tower

VI. Wind Load and Calculations of Wind loads

A. Wind loads on conductor wire

$$F_{WC} = P_d * C_{dc} * L * d * G_C$$

At Height	Drag coefficient (C_{dc})	Gust response factor (G_C)	Span (L) m	Diameter (d) m	Force, F_{WC}
14 m	1.2	1.851	175	28.62*10^{-3}	6.49
19.5m	1.2	1.983	175	28.62*10^{-3}	6.959
25m	1.2	2.055	175	28.62*10^{-3}	7.211

B. Wind loads on earth wire

$$F_{WG} = P_d * C_{dG} * L * d * G_G$$

At Height	Drag coefficient, (C_{dG})	Gust response factor (G_G)	Span, L (m)	Diameter, (d) m
32	1	2.14	175	$9.45*10^{-3}$

C. Wind loads on Insulator strings

$$F_{wi} = P_d * C_{di} * G_i * A_i$$

At Height	Drag coefficient (C_{di})	Gust response factor (G_i)	Area 50% insulator projected A_i	Force, F_{wi}
16	1.2	2.088	0.0186	0.027
21.5	1.2	2.22	0.0186	0.029
27	1.2	2.27	0.0186	0.030

D. Panel loads

Panel number	Solidity ratio	Drag coefficient (C_{dt})	Area(A_e) m^2	Gust response factor (G_T)	Force, $F_{WT} = P_d * C_{dt} * A_e * G_T$
1	0.095	3.6	0.8616	2.32	4.201
2	0.18	3	1.466	2.295	5.893
3	0.21	2.86	3.789	2.27	14.364
4	0.18	3	1.466	2.24	5.752
5	0.21	2.86	3.789	2.215	14.016
6	0.18	3	1.466	2.158	5.542
7	0.26	2.66	2.3024	2.088	7.467
8	0.23	2.78	2.3904	1.9984	7.7543
9	0.21	2.86	2.483	1.92	7.961
10	0.19	2.95	2.5799	1.92	8.531
11	0.13	3.25	2.0906	1.92	7.435

E. Lateral force in each panel

Wind loads on panel for different conditions;

1. Normal operating conditions.
2. Top conductor broken wire conditions.
3. Earth wire in broken conditions.

Lateral force	Under the different conditions		
	Condition 1	Condition 2	Condition 3
P_A	6.267	6.267	3.1335
P_B	5.893	5.893	5.893
P_C	21.605	10.803	21.605
P_D	5.752	5.752	5.752
P_E	21.004	10.502	21.004
P_F	5.542	5.542	5.592
P_G	13.984	6.992	13.984
P_H	7.75433	7.7543	7.7543
P_I	7.961	7.961	7.961
P_J	8.531	8.531	8.531
P_K	7.435	7.435	7.435

VII. Results and discussions

Axial forces and deflections acting in the tower

7.1 Axial forces acting in the tower

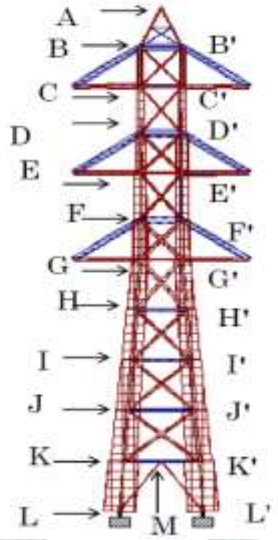

Fig 2.1: Axial Forces

Table 7.1 Axial Forces of vertical members

Vertical members				
Beam name	Beam number	Load combinations		
		CONDITION 1 (L/C 5)	CONDTION 2 (L/C 6)	CONDITION 3 (L/C 7)
A $A_{(middle)left}$	406	6.086	6.045	3.953
$A_{(middle)left}$ B	10	5.686	5.568	3.825
BC	98	7.114	8.298	4.832
CD	94	23.612	21.426	19.448
DE	90	48.219	38.633	42.417

EF	86	82.029	62.455	74.332
FG	6	118.357	87.308	109.215
GH	28	156.345	113.288	146.16
HI	27	192.603	135.326	178.523
IJ	26	228.999	156.373	207.434
JK	25	257.454	174.622	231.008
KL	2	290.887	197.585	260.104
LM	81	0.876	0.878	0.876
ML'	82	0.92	0.912	0.919
K'L'	4	289.901	196.888	259.161
J'K'	33	256.323	173.794	229.931
I'J'	34	227.612	155.336	206.125
H'I'	35	191.311	134.16	177.027
G'H'	36	156.14	112.803	145.798
F'G'	7	118.18	87.08	109.085
E'F'	87	82.09	62.498	74.573
D'E'	91	53.851	42.26	48.031
C'D'	95	30.086	24.816	25.845
B'C'	99	12.659	11.324	10.306
$A_{(middle)}$B'	12	5.617	5.732	3.728
A $A_{(middle)\ right}$	408	6.074	6.114	3.914

Table 7.2 Axial Forces of Horizontal Members

Horizontal members				
Beam name	**Beam number**	**Load combinations**		
		CONDITION 1 (L/C 5)	**CONDTION 2 (L/C 6)**	**CONDITION 3 (L/C 7)**
$A_{(middle)}$ left to $A_{(middle)}$ right	412	-0.371	-0.379	0.036
BB'	16=334	-5.629	-5.608	-4.441
CC'	360	0.041	0.177	0.673
DD'	364	-11.881	-9.826	-10.702
EE'	366	-13.386	-10.088	-11.565
FF'	367	0.875	-0.915	0.908
GG'	14=326	-24.648	-17.297	-22.556
HH'	322=325	-31.226	-22.296	-29.133
II'	321=324	-30.409	-20.968	-27.832
JJ'	320=323	-33.851	-22.943	-30.428
KK'	46=74	-17.672	-11.99	-15.832

Table 7.3 Axial Forces of Bracings

Bracings of 2D face of tower				
Beam name	**Beam number**	**Load combinations**		
		CONDITION 1 (L/C 5)	**CONDTION 2 (L/C 6)**	**CONDITION 3 (L/C 7)**
JK	49=182	26.232	17.842	23.527
	50=181	25.977	17.578	23.266
IJ	52=183	22.111	15.101	19.999
	51=184	21.939	14.914	19.824
HI	54=185	25.122	17.658	23.33
	53=186	24.956	17.487	23.162
GH	55=188	28.459	20.871	26.748
	56=187	28.341	20.754	26.629
FG	101=102	29.119	21.428	26.855
	206=205	29.564	21.707	27.269
EF	103=104	15.626	11.83	14.061
	208=207	15.53	11.731	13.965
DE	105=106=519	11.087	8.831	9.757
	210=209	11.83	9.232	10.501
CD	107=108	4.892	4.342	4.011
	212=211	4.315	3.904	3.455
BC	109=110	1.449	1.609	1.087
	214=213	2.18	1.786	2.949
$A_{(middle)}$ to B	414	0.401	0.407	-0.01
	413	0.395	0.406	-0.017

Table 7.4 Axial Forces of Cross Arms

CROSS ARMS				
Beam name	**Beam number**	**Load combinations**		
		CONDITION 1 (L/C 5)	**CONDTION 2 (L/C 6)**	**CONDITION 3 (L/C 7)**
AT LEFT G				
	515	-1.083	-1.903	-1.571
	437	-0.408	0.707	0.318
	485	-0.279	0.377	0.116
	402	0.412	1.078	0.802
AT RIGHT G				
	433	1.46	1.666	1.793

	483	0.124	0.653	0.492
	398	0.945	1.441	1.308

7.2 Deflection at panel joints

Table 7.5 Relative Displacements

Node name	Node number	Load combinations		
		CONDITION 1 (L/C 5)	CONDITION 2 (L/C 6)	CONDITION 3 (L/C 7)
A	13	0.098	0.064	0.09
B	10	-0.008	-0.01	-0.007
C	47	-0.04	-0.029	-0.04
D	43	0.043	0.035	0.041
E	39	0.016	0.018	0.019
F	35	0.355	0.25	0.336
G	6	-0.42	-0.304	-0.385
H	21	-0.484	-0.319	-0.437
I	20	0.061	0.053	0.059
J	19	-0.028	-0.037	-0.026
K	18	0.029	0.026	0.028
L	4	0.239	0.156	0.207
M	31	0.305	0.204	0.288
L'	3	0.276	0.181	0.241
K'	26	-0.306	-0.198	-0.274
J'	27	-0.359	-0.253	-0.339
I'	28	-0.213	-0.135	-0.2
H'	29	0.482	0.321	0.436
G'	7	-0.496	-0.347	-0.456
F'	36	0.213	0.137	0.201
E'	40	-0.019	-0.018	-0.018
D'	44	0.027	0.015	0.024
C'	48	0.049	0.031	0.044
B'	11	-0.094	-0.089	-0.096

VIII. Conclusions

Continues demand due to increase in population in all sector leads to requirement of efficient consistent and adequate amount of electric power supply. Which can only fulfil by using the transmission tower. After the analysis it is inclusive of dead load + live load + wind load under normal operating condition. The maximum nodal displacement is found to be at the top node (13) and displacement is 175.255 mm for normal operating condition. As per the design concern all the sections considered are found safe against the critical load combination. The quantity of steel required is estimated as 5.9 tonnes (58.06kN). For further studies, Attempts can be made to analyse and design the models with good aesthetical appearance. Analysis of transmission line tower can be done by applying dynamic loads. The quantity of steel required can be optimized by using different bracings. The cost of construction can be compared for different bracing systems.

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