Analysis and Design of Transmission Tower Using Staad-Pro

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***Abstract*- A transmission tower, also known as an electrical power tower or utility pole, is a tall structure used to support overhead power lines for the transmission of electrical energy. Transmission towers play a critical role in the reliable and efficient transmission of electricity from power generation plants to distribution networks and ultimately to consumers.**
This abstract provides an overview of transmission towers, including their purpose, types, components, and key considerations in their design and construction. Transmission towers are designed to withstand various environmental and loading conditions, such as wind, ice, and seismic forces while maintaining the integrity and stability of the overhead power lines. Different types of transmission towers, such as lattice towers, tubular towers, and pole towers, are used based on factors such as voltage level, span length, and terrain conditions. Analysis of this transmission tower is administered using STAAD PRO The present work describes the analysis and design of a transmission line tower of 31 meters in height and 220KV double circuit viz. various parameters
The components of a transmission tower typically include tower legs, cross-arms, insulators, and hardware for attaching conductors and ground wires.
***Keywords:* Transmission towers, Geometry of the tower, Self-supporting tower, Configuration of the tower, unit load, deflection, design.**

I. INTRODUCTION:

STAAD.Pro is a popular structural analysis and design software used by engineers for designing and analyzing various types of structures, including transmission towers. Here's a general overview of the steps to use STAAD.Pro for designing a transmission tower. Define the materials and loads: Specify the material properties of the transmission tower, such as the material type and properties of the steel or concrete used. Define the loads acting on the tower, including dead loads (e.g., self-weight of the tower), live loads (e.g., wind loads, ice loads), and other applicable loads. Analyze the structure: Perform structural analysis using STAAD.Pro to determine the internal forces and displacements of the transmission tower under the applied loads. This analysis helps to ensure that the tower can safely resist the loads and remain stable. Generate design reports: Use STAAD.Pro to generate design reports that document the design calculations, analysis results, and other relevant information. It's important to note the specific steps and procedures for designing a transmission tower using STAAD.Pro may vary depending on the design requirements, project specifications, and applicable codes and standards. It's recommended to consult with a qualified structural engineer who is experienced in using STAAD.Pro and familiar with transmission tower design to ensure accurate and safe design results.

II. METHODOLOGY

The methodology for designing a transmission tower using STAAD Pro typically involves the following steps: Create a 3D model of the transmission tower in STAAD Pro, defining the geometry of the tower including the type of tower (e.g., lattice or tubular), member sizes, connection details, and support conditions. STAAD Pro provides various tools for creating and modifying the geometry of the tower model.

Run the analysis in STAAD Pro to calculate the internal forces, moments, and displacements in the tower members under the applied loads. STAAD Pro uses advanced algorithms to perform various types of analyses, such as linear or nonlinear static analysis, response spectrum analysis, time history analysis, or buckling analysis, depending on the project requirements.

After obtaining the analysis results, use STAAD Pro's design modules to design the tower members for strength, stability, and serviceability requirements as per the applicable design codes and standards. STAAD Pro provides built-in design codes for various international standards, such as AISC, Eurocode, and IS, among others.

The design modules in STAAD Pro can automatically generate member design reports, including detailed calculations for verification. Once the design is finalized, perform post-processing tasks in STAAD Pro, such as generating construction drawings, connection details, and fabrication files, to aid in the construction and fabrication of the transmission tower.

III. Transmission Line Components:

3.1. Transmission Line Tower

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.

- Transmission Line Voltage: 220 kV (A.C.)
- Right of Way (recommended): 35, 000 mm
- Angle of Line Deviation: 0 to 2 degree

- Terrain Type Considered: Plain
- No. of Circuits: Single Circuit
- Tower Configuration: Vertical Conductor
- Bracing Pattern: Pratt system
- Cross Arm: Point

- Return Period: 50 years
- Wind Zone: 3
- Basic Wind Speed: 50 m/s
- Design Wind Pressure: 793 N/sqm
- Tower Type: Self-Supporting, Type "A"
- Tower Geometry: Square Base Tower
- Inclination of the tower legs: 70 (with vertical)

- Insulator Type : I String
- Number of Insulator Discs: 15
- Size of Insulator Disc: 255 × 145 mm
- Length of Insulator String: 2,500 mm
- Creep Effect: Not Considered
- Shielding Angle :30^0

3.2. 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. The properties of the conductor considered hereare tabulated in Table1.

Table 1: Conductor mechanical and electrical properties.

Conductor material	ACSR
Code name	Panther
Conductor size	30/7/3.00 mm
Area of the conductor (for all strands), A	2.6155 cm2
Overall diameter of the conductor (d)	21 mm
Weight of the conductor (w)	0.973 kg/m
Bearing strength of the conductor (UTS)	9130 kg
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

3.3. 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. The earthwire considered for transmission line has the following properties as mentioned in Table 2.

Table 2: Earth wire mechanical and electrical properties

Material of earthwire	Galvanized steel
No.of earthwire	one
Stranding/wire diameter	7/3.15mm
Total sectional area	54.55mm2
Overall diameter	9.45 mm
Approximate weight	428kg/km
Calculated D.C. resistance at 20˚C	3.375ohm/km
Mini UTS	5710 kg
Modulus of elasticity	19361 kg/mm2
Coefficient of linear expansion	11.50 × 10-6/˚C
Maximum allowable temperature	53˚C

3.4. 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 the current 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.

IV. Sag tension for conductor and ground wire

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

- Maximum temperature (75°C for ASCR and 53°C for ground wire) with design wind pressure (0% and 36%).
- Every day temperature (32°C) and design wind pressure (100%, 75% and 0%).
- Minimum temperature (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 220 kV) for conductors and 20% for ground wires of their ultimate tensile strength. Sag tensions are calculated by using the parabolic equations as discussed in the I.S. 5613: Part2: Sec: 1: 1989 for both the conductor and ground wire. In this paper, the consideration of the sag of ground wire as 90% the sag of the conductor at 0°C and 100% wind condition. The sag tension values are mentioned in the Table 3.

Table 3. Sag tension for conductor (ASCR)

Temperature variation°C	0			32		75
Wind variation %	0	0.36		0.75	1.0	0
Tension (kg)	2282.5	3733	3246.24	3108.30	3416.27	2367.23

All tension values are giving F.O.S < 4.

So, we consider the minimum tension(tension for F.O.S = 4.) to find the maximum sagging in all condition.

So, sagging $=wl^2/8T_2$ = 0.937 X 320^2/ 8X2282.5 = 5.46M

By increasing 4% of calculated sag we get= 5.46 × 4%= 5.70 m.

V. Height of tower:

h1 = minimum permissible ground clearance = 7.1 m (cl=13.1, IS: 5613.2.1)

h2 = sag (maximum) = 5.46 × 1.04 (increase by 4%) = 5.7 m

h3 = minimum clearance between two conductor = 4.9× 2 m. = 9.8m (cl=7.3.1.1, IS: 5613.2.1)

h4 = vertical distance between earth and top conductor = 8.4 (cl=13.2, IS: 5613.2.1)

Total H = (h1 + h2 + h3 + h4)= 31 m

The dimension of the tower is shown in the Fig 1

towers are calculated separately by developing excel programs by following Indian Standards. For finding the drag coefficients for the members of triangul derived from Table 30 –IS-875 (part 3)-1987 in the similar fashion as prescrib 1995.

VI. Wind loads on tower:

Wind loads on all the towers are calculated separately by developing excel pro Indian Standards. For finding the drag coefficients for the members of triangul derived from Table 30 –IS-875 (part 3)-1987 in the similar fashion as prescrib 1995.

5.1. Design Wind Pressure

To calculate design wind pressure on conductor, ground wire, insulator and panels:$Pd=0.6\times Vd^2$ (3)

Where,Pd = design wind pressure in N/m2

Vd = design wind speed in m/s

To calculate design wind pressure ,Vd = VR× K1×K2 (4)

VR = 10min wind speed (or) reduced wind speed

VR = Vb/k0 (5)

Vb = basic wind speed

K0 =1.375 [conversion factor]

K1 = risk coefficient

K2 = terrain roughness coefficient.

5.2. Wind Loads on Conductor/Ground Wire

To calculate wind loads on conductor and ground wire, Fwc= Pd×Cdc×L×D×GC (6)

Fwc = wind load on conductor

Pd = design wind pressure

Cdc = drag coefficient for ground wire=1.2 drag coefficient for conductor = 1.0
L = wind span
d = diameter of conductor/ground wire
Gc = gust response.

5.3. Wind Load on Insulator

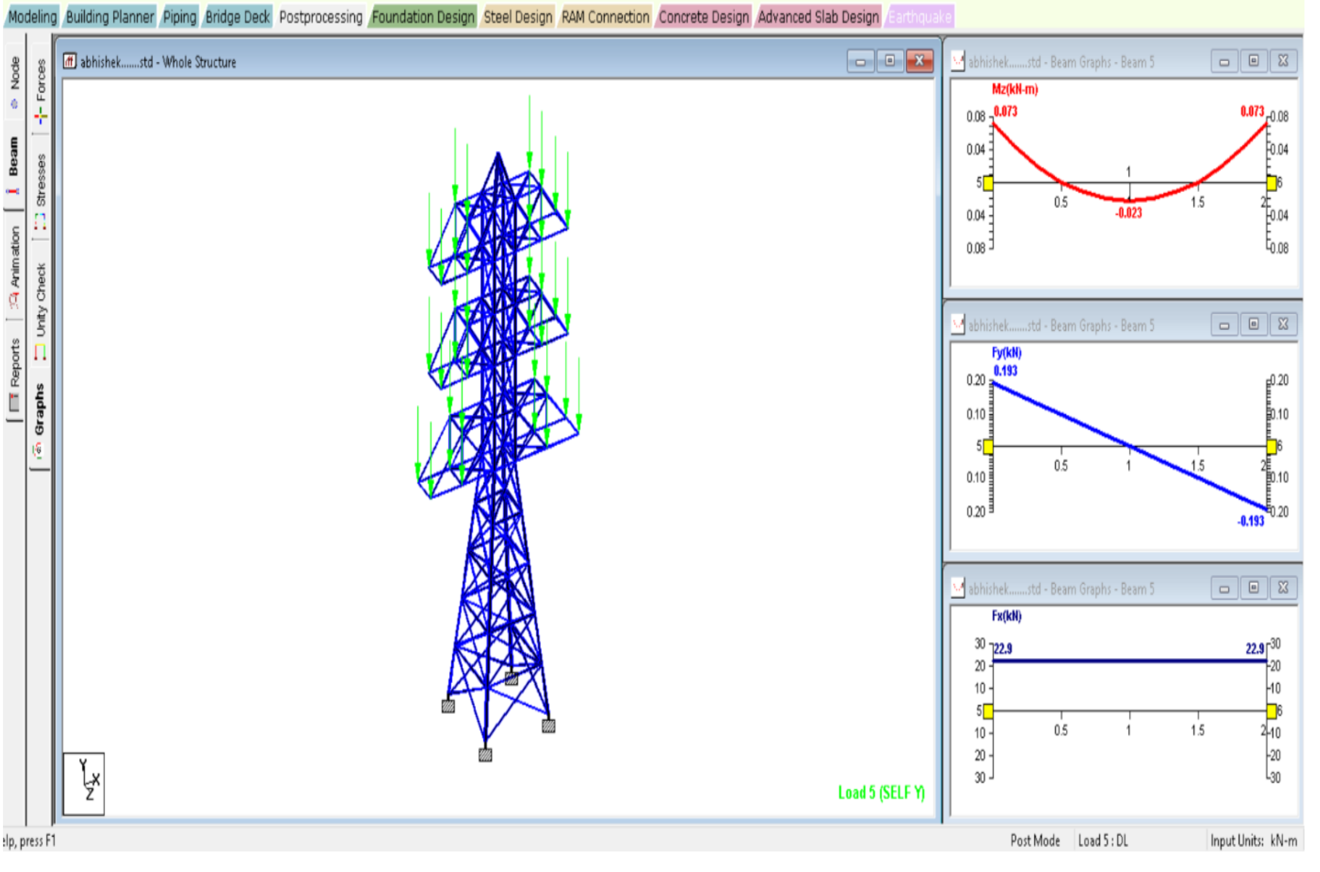
To calculate wind load on insulator, Fw=Pd×Cdi×AI×GI (7)
where,AI = 50% area of insulator projected parallel to the longitudinal axis of string
GI = gust response factor for insulator
Cdi = drag coefficient, to be taken as 1.2150 mm
GT = gust response factor for towers

VII. ANALYSIS OF TOWER

There are four types of angle are used in the this tower.
1- ISA 200*200*25 (For main legs)
2- ISA 100*100*8 (For diagonal bracing)
3. ISA 130*130*10 (for horizontal bracing)
4- ISA 90*90*12 (For cross arm)

Data Input for Analysis with STAAD.pro STAAD.pro requires data input in some form like graphicalor text. The following data was fed to STAAD.pro graphically:
1.Member lengths and locations
2.Mutual Connectivity of members
3.Supports
4.Assigning type and properties of members
5.Assignment of loads due to wind and cables
Grouping of members Following data were inserted as text:
1.Load Combinations
2.Load List for Analysis
3.Desired analysis results like Nodal displacements, Support reactions etc.

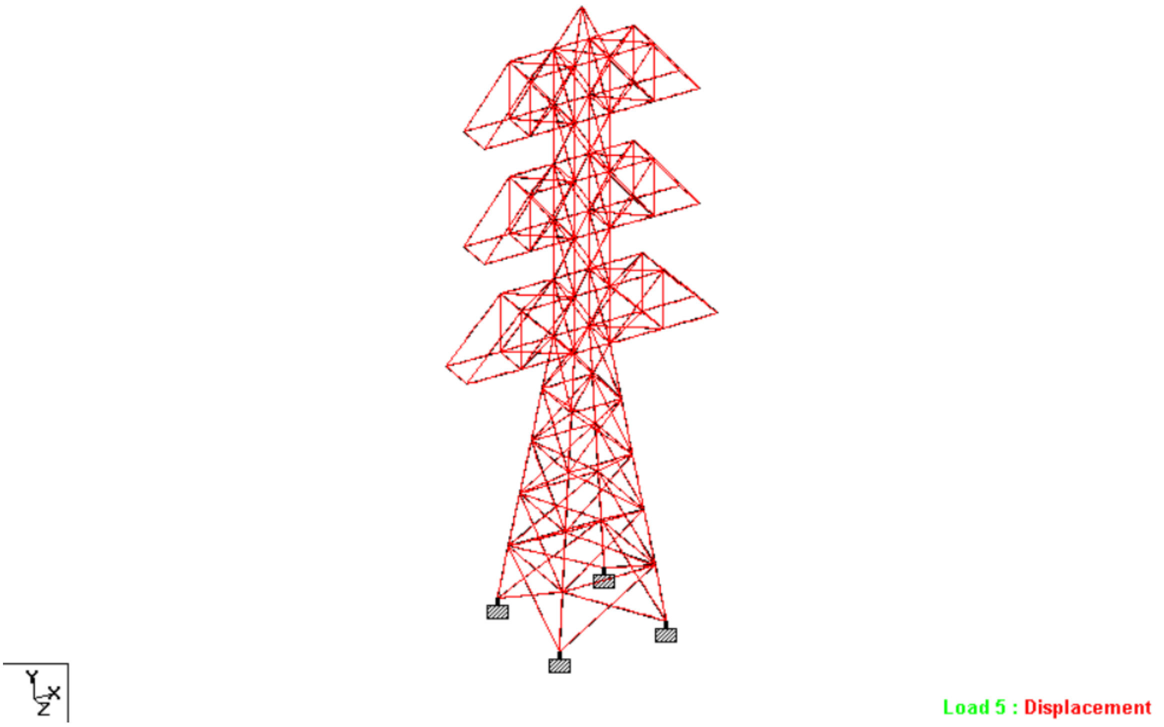
Wire Load (Bending moment and shear force diagram) :



Summary of member end forces

	Beam	Node	L/C	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kN˙m)	Bending My (kN˙m)	Bending Mz (kN˙m)
Max Fx	27	24	10:GENERATE	**189.156**	0.372	0.001	-0.000	-0.052	-0.764
Min Fx	44	24	7:GENERATEI	**-76.820**	1.460	0.000	0.000	0.026	1.005
Max Fy	84	1	10:GENERATE	59.765	**3.191**	0.723	-0.009	-1.678	3.918
Min Fy	74	2	7:GENERATEI	59.647	**-3.192**	0.723	-0.009	1.678	3.918
Max Fz	57	15	8:GENERATEI	30.205	1.601	**0.739**	0.002	-1.991	1.263
Min Fz	81	11	10:GENERATE	30.163	1.601	**-0.740**	-0.002	1.992	1.262
Max Mx	83	12	8:GENERATEI	18.132	2.473	-0.666	**0.012**	2.848	1.621
Min Mx	55	16	10:GENERATE	18.165	2.473	0.666	**-0.012**	-2.848	1.621
Max My	83	12	10:GENERATE	56.604	2.410	-0.723	0.009	**2.945**	1.420
Min My	55	16	8:GENERATEI	56.638	2.410	0.723	-0.009	**-2.945**	1.420
Max Mz	74	2	7:GENERATEI	59.647	-3.192	0.723	-0.009	1.678	**3.918**
Min Mz	23	20	16:GENERATE	100.521	0.391	0.009	0.000	-0.003	**-0.776**

Summary of Node Displacement :



Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	46	7:GENERATEI	**35.865**	-3.992	0.002	36.086	0.000	0.000	-0.002
Min X	46	9:GENERATEI	**-36.230**	-4.008	0.000	36.451	-0.000	0.000	0.002
Max Y	81	1:EQX	14.945	**6.361**	-0.011	16.242	0.000	-0.000	-0.001
Min Y	81	9:GENERATEI	-25.056	**-16.120**	-0.242	29.794	0.000	0.000	0.001
Max Z	46	8:GENERATEI	-0.181	-4.000	**36.223**	36.444	0.002	0.000	-0.000
Min Z	46	10:GENERATE	-0.184	-4.000	**-36.221**	36.441	-0.002	0.000	0.000
Max rX	71	8:GENERATEI	-0.346	-2.628	25.662	25.798	**0.002**	-0.001	0.000
Min rX	78	10:GENERATE	0.117	-2.711	-25.647	25.790	**-0.002**	-0.001	-0.000
Max rY	76	10:GENERATE	-0.560	-3.381	-31.437	31.623	-0.001	**0.002**	0.001
Min rY	75	8:GENERATEI	-0.437	-3.339	31.960	32.137	0.001	**-0.002**	0.001
Max rZ	75	9:GENERATEI	-25.872	5.661	0.280	26.485	0.000	-0.000	**0.002**
Min rZ	82	7:GENERATEI	25.633	5.548	-0.279	26.228	-0.000	-0.000	**-0.002**
Max Rst	46	9:GENERATEI	-36.230	-4.008	0.000	**36.451**	-0.000	0.000	0.002

Design Result :

The design was finally performed by STADD.PRO and the result obtained are tabulated as below ;

BEAM	ANALYSIS PROPERTY	RATIO	A_X CM^2	I_Z CM^4	I_Y CM^4	I_X CM^4
9	ISA 200*200*25	0.833	27.66	152.421	594.142	13.248
10	ISA 200*200*25	0.886	27.60	152.421	594.142	13.248
11	ISA 200*200*25	0.883	27.60	152.421	594.142	13.248
29	ISA 130*130*10	0.125	12.20	29.690	117.771	2.603
30	ISA 130*130*10	0.070	21.10	98.444	386.970	7.033
31	ISA 130*130*10	0.047	29.90	195.953	763.624	14.352
179	ISA 100*100*8	0.041	29.90	195.953	763.624	14.352
182	ISA 100*100*8	0.049	19.10	73.375	286.643	6.367
184	ISA 100*100*8	0.266	6.840	9,363	37.294	0.821
270	ISA 90*90*12	0.126	19.10	73.375	286.643	6.367
274	ISA 90*90*12	0.178	27.60	152.421	594.142	13.948
292	ISA 90*90*12	0.057	19.10	73.375	289.643	6.367

VIII. CONCLUSION

In conclusion, utilizing STAAD.Pro for the analysis and design of transmission towers offers several advantages. The software provides accurate structural analysis capabilities, allowing engineers to model and analyze complex tower structures under various loads and conditions. The automated design optimization features aid in optimizing the design for cost-effectiveness and compliance with design codes and standards. The user-friendly interface and advanced modeling tools enhance productivity, while the visualizations and documentation capabilities aid in better understanding, communication, and compliance. Overall, STAAD.Pro is a powerful tool that facilitates efficient and reliable analysis and design of transmission towers, leading to safe and cost-effective structures..

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