www.mazedan.com
Available online at
www.mdl.mazedan.com
MJCEA
www.mazedan.com/mijcea

A STUDY ON DESIGN AND ANALYSIS OF GANTRY STRUCTURE FOR SUBSTATION USING STAAD PRO

MAZEDAN JOURNAL OF CIVIL ENGINEERING & ARCHITECTURE
e-ISSN: 2582-9564
Article id- MJCEA0601002
Vol.-6, Issue-1
Received: 5 May 2025
Revised: 20 Jun 2025
Accepted: 3 Jul 2025

MR. VINIT P SANGALE*, & PROF. SACHIN U PAGAR.

DOI: https://doi.org/10.5281/zenodo.16907994

Citation: Sangale, V. P. & Pagar, S. U. (2025). A Study on Design and Analysis of Gantry Structure for Substation Using STAAD Pro. *Mazedan Journal of Civil Engineering & Architecture*, 6(1), 4–7.

Abstract

In this analysis & design of Gantry Structure for Switchyard loading & analysis is govern for dead, live, Wind & Electrical loads i.e. Normal Condition and Short circuit condition load as per different location, height, size of Tower structure & Capacity of Overhead cables in kV. Generally whole structures design as a conventional sections like angle, etc. Main reason is whole structural members sections are all sections locally available, easy to construct, transport & economical. Here, involves all study to resolves & enhance more efficiency of structures. Trying to design Structure economically by selecting proper Bracing system. In order to properly plan and design a structure, it is necessary to have not only imagination and conceptual thinking, but also a solid understanding of the science of structural engineering, as well as practical knowledge of recent design codes and regulations, all supported by ample experience, intuition, and judgment, with the goal of ensuring safety while maintaining a careful balance between economy and safety.

Keywords: Design, Gantry Structure, Loading, Overhead cables, Design codes and regulations, Economy, Safety.

1. INTRODUCTION

Gantry Structure in Switchyard mean a latticed beam supported by two latticed towers. The gantry structures can be designated according to their position in switchyard, such as line gantry, bus gantry and transformer reactor Gantry. They required for the distribution of power from Switchyard to across the country. As a result, more power stations are being built and placed in strategic locations. System interconnections are also growing in order to increase accuracy and efficiency. Any natural disaster can cause transmission lines to fail if they are not planned appropriately. As a result, it must be stable and well-designed to avoid failure in the event of a natural disaster. It must also meet all applicable national and international regulations. A transmission line's structural and electrical aspects should be considered during planning and design. Insulation and safe clearances of power carrying cables from the ground are the most critical requirements from an electrical perspective.

Gantry Structures account for almost 20-40% of the total cost of a Substation. The choice of an optimal form, as well as the appropriate sort of bracing system, goes a long way toward producing a cost-effective Gantry structure design. Electricity is the primary source of power for industry, businesses, and homes. Because of infrastructure development, the demand for energy is increasing due to rapid growth in the industrial region. As cost of electricity is less compare to fuel, now a days, rail transportation is also shifted from fuel-powered engines to electric engines. As a result, it is necessary to transfer the high voltage to the area in demand, which necessitates the construction of substations and hence Gantry structures.

Electrical power has emerged now an in comfort, safety and welfare of humanity in the 21st century. In every developing or developed country, consumption of electricity has prevailed to rise. The rate of increment is superabundant in case of developing nation like INDIA. Which increases number of electric-power stations and their capacities and subsequent increment in number of transmission lines from electricity-generating stations to sub-stations and then to subsequent load centers, resp.

Though Substation are major parts of electrical engineering, designing of those supporting structures like towers, foundation etc. requires the direct liaison of civil engineers-structural and geotechnical. A principal job thus comes on to the structural engineer, not only to make design economical, but also safer and more reliable. Structurally the Gantry structure should be well enough to withstand loads like wind load, electric load and self-weight as well as in all weather conditions.

The goal of every designer is to design the best (optimum) systems. But, because of the practical restrictions this has been achieved through intuition, experience and repeated trials, a process that has worked well.

In this study, a Gantry tower at 765kV Substation is modelled using STADD Pro - Connect edition. The towers are designed for wind zones IV with constant base width.

Sapkal College of Engineering College Anjaneri, Maharashtra, India
*Corresponding author email-vinitpsangle@gmail.com

Problem Statement

A Gantry Structure with beam at 765kV Substation which is situated in wind zone IV is selected for the study. Design, analysis and optimization are carried out using STAAD Pro. Software.

Objectives

There are 3 sets of coils wound around n-number of poles inside the stator; each set of coils is switched sequentially based on hall sensor feedback to rotate the motor [7].

2. METHODOLOGY

Input

- Total height of Structure: 45m
- C/C distance between Towers: 15m
- Bottom to Girder/Beam Centre level: 39m
- Wind Speed - 47 m/s
- Seismic Zone-II

3. MODELLING APPROACH

STAAD Pro-Connect Edition is a comprehensive and integrated finite element analysis and design offering, including a state-of-the-art user interface, visualization tools, and design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, wind, earthquake, and moving loads. STAAD Pro-Connect edition provides FEM analysis and design for any type of project including towers, culverts, plants, bridges, stadiums and marine structures. The STAAD Pro-Connect edition has been used for analysis and design. In this study tower is modeled as a 3D space by considering tower as a truss. Wind load considered is acting in X and Z directions. Loads and Load combinations are considered for wind zone II as per IS: 802 (Part 1/Sec 1):1995. is used in analysis.

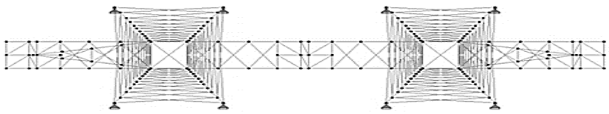

Figure 1 Top View of Gantry Structure

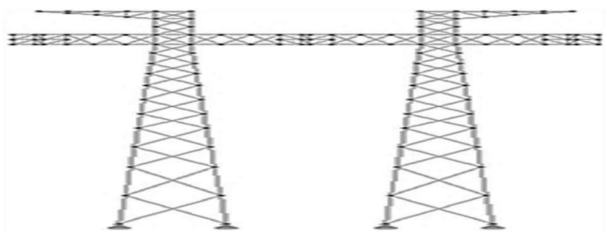

Figure 2 Elevation of Gantry Structure

4. LOADING AND LOAD COMBINATIONS

Load Calculations

- According to IS:5613(Part-2/Sec-I)-1985, 3 types of loads act on Gantry Structure is same as transmission tower in which 3 different considerations namely, Reliability Considerations, Safety Consideration and Security Consideration. These loads are calculated as per formula mentioned in clauses 9, 12 and 13 of IS:802(Part-1/Sec-I)-1995.

Load Combinations

Loading combination is used as per clause 13 for all the 3 conditions reliability, safety and security conditions. In this work, seven different loading combinations were considered as shown below:

- Reliability Consideration Normal condition
- Security Consideration Normal condition
- Safety consideration normal consideration
- Security Consideration Top Conductor Broken

Wire Condition

- Safety Consideration Top Conductor Broken Wire Condition
- Security Consideration Ground-wire Broken Wire Condition
- Safety Consideration Ground-wire Broken Wire Condition.

Design Parameters

The design and fulfilling code-check of each member of tower analyzed in STAAD.PRO v8i are formed on the allowable stress design method basis, accordingly IS:802(Part-1/ Sec-1).

In this work, Indian Steel Angle Sections are taken for the analysis of Gantry structure. The Table I shows the sections used in this analyzation.

Table 1 Steel Sections used in Tower

1.Main Leg	ISA200x200x25 mm
	ISA 150X150X16 mm
	ISA 75x75x5 mm
2.Bracing	ISA 100X100X8 mm
	ISA 90x90x6 mm
	ISA 150x150x16 mm
	ISA 65x65x5 mm
3.Secondary Bracing	ISA 45x45x5 mm

Table 2 Steel Sections used in Girder/ Beam

1.Main Member	ISA 150x150x16 mm
	ISA 130x130x12 mm
2. Bracing	ISA 90x90x6 mm
	ISA 75x75x5 mm

The Parameters used for analysis of Tower are given below in Table III.

Table 3 Gantry Structure Parameters

Tower Type	Gantry Structure
Transmission line voltage	765kV
Angle of line deviation	0 Degree Cel.
Terrain type	Category -1
Conductor material “ACSR”	Zebra 28.62mm Dia.
Basic Wind Speed	47 m/s
Max. Temperature of Conductor	75 Degree Cel.
Max. Temperature of Ground wire	53 Degree Cel.
Everyday Temperature	32 Degree Cel.
Minimum Temperature	-18 Degree Cel.
Design Period	50 Years
Type of Insulator	String Type

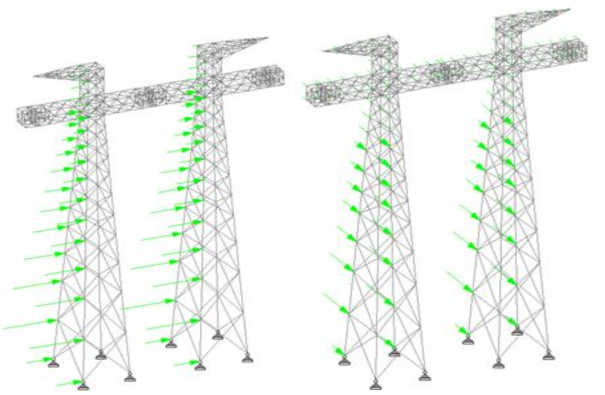

Figure 3 Wind load acting on XX and XB Bracing systems

5. BRACING SYSTEM

There are ten types of bracing systems for a lattice tower configuration. Those ten types are as follows:

1) Single diagonal bracings: this is the simplest form of bracing. The wind shear at any level is shared by the single diagonal of the panel. Such bracing is used for towers up to 30m height.

2) X-X bracing: this is a double diagonal system without horizontal bracing, used for towers up to 50m height. Itis a statically determinate structure.

3) X-B bracing: this is a double diagonal system with horizontal bracings. Such bracings are quite rigid and may be used for towers up to 50m height. The structure is statically indeterminate. The horizontal members are redundant members and carry only nominal stresses.

4) K-bracing: such a bracing gives large head room, and hence K-bracing can be used in lower panels where large head room is required. The structure is statically determinate. Such bracing can be used for towers of 50 to 200m height. In most of the transmission line towers, the lower panels is either K- or Y- braced and upper panels are X-braced or XB- braced.

5) XB bracing: this is a combination XX and XB bracing where horizontal members are provided only at the level of crossing of diagonals. The structure is statically indeterminate. However, the length of the diagonal is reduced. The system is suitable for towers 50 to 200m height.

6) W-bracing: this system uses a number of overlapping diagonals. The system is statically indeterminate. However, the effective length of diagonals is reduced the system is quite rigid and may be used for towers of 50 to 200m height.

7) Y-bracing: this system gives larger head room can be used for lower panels. The system is statically determinate. In most of the transmission line towers, lower panels are either Y- braced on k-braced and upper panels are X-B braced or X-braced.

8) Arch bracing: such a bracing can be adopted for wider panels. This system also provides greater head room. The system is statically determinate.

9) Subdivided V-bracing: such a bracing are used for tall towers of communication systems, radio and TV transmission etc.; for heights between 50 to 200m.

10) Diamond lattice system: A typical diamond lattice system is used for towers of 100 to 200m height. The base width is kept at 1/5 to 1/6 of the height. Rigid horizontal diaphragms are used at top and at intermediate sections, preferably at intervals of 25 to 30m, to increase the torsional stiffness of the cross-arm.

As Our Gantry height is above 30 and below 50, we have selected these bracing systems for analysis. i.e.

- X-B System
- X-X System

6. RESULT AND DISCUSSION

In this present work, the nodal displacements due to seven different load cases, were computed for two different types of bracing system as said above at specified points: base of leg, cross-arm points and topmost point of the transmission tower using the software STAAD Pro. Connect edition. Since seven different load combinations give different nodal displacements in mm.

Table 4 Displacements in XX and XB Bracing

Location	XX – Bracing			XB - Bracing		
	X	Y	Z	X	Y	Z
Base	0	0	0	0	0	0
At Beam/ Girder	83.03	-25.72	90.481	81.351	-25.143	87.476
Topmost Point	1.943	-5.375	184.065	1.871	-5.271	177.358

Along height, Displacement is also increasing along three directions of the tower till Cross Arm Point. But displacement along y-direction at the topmost point in is found to be less i.e. -5.375 mm for XX-bracing and -5.271 mm for XB-bracing, but along x direction, displacement is same because of same load applied. As the wind load acting along Z-direction is dominant, the displacement is found to be higher than other direction.

Table 10, the total amount of steel used in XX-bracing system is found to be 905.784 kN and in XB-bracing system, it is found to be 790.326 kN. It is observed that the amount of steel required in XX-bracing system is found to be much higher i.e. 115.458 kN higher amount than XB-bracing system.

Table 5 Weight summary comparison between XX & XB Bracing

Steel Sections used	XX–Bracing System		XB-Bracing system	
	Length	Weight	Length	Weight
Tower				
ISA 200X200X25	130.56	94.377	130.56	94.377
ISA 100X100X10	142.87	20.962	142.87	20.962
ISA 100X100X8	607.93	71.919	862.58	102.044
ISA 200X200X20	124.53	73.089	124.53	73.089
ISA 90X90X6	219.45	17.701	282.39	22.777
ISA 150X150X16	170.01	59.684	170.01	59.684

ISA 75X75X5	93.51	5.222	93.51	5.222
ISA 65X65X5	249.80	11.993	266.60	12.800
Total Weight	354.948		390.955	
Beam				
ISA 150X150X16	52.00	18.255	52.00	18.255
ISA 90X90X6	427.77	34.504	461.37	37.214
ISA 75X75X5	194.98	10.889	228.58	12.766
ISA 130X130X12	64.00	14.700	64.00	14.700
Total Weight	78.349		82.935	

7. CONCLUSIONS

The nodal displacement in XX-bracing system is quite higher in z-axis (transverse direction) as compared to XB-bracing system. i.e. 184.065 mm & 177.358 mm. Also, at the Girder/Beam displacement is significantly higher in z-direction only. i.e. 90.481 mm & 87.476 mm for XX and XB Bracing resp.

The displacement in y-axis (axial direction) and x-axis (longitudinal direction) has very lesser discrepancies in both bracing systems. The nodal displacements in x-direction and z-direction at base of legs, at Cross arm point and topmost point of tower is found to be continuously increasing but in y-direction, it is found that nodal displacement is increasing up to cross-arm point and it is decreased to 5.375 mm at top.

The material i.e. quantity of steel required in XX-Bracing system is found to be lesser by 10.15 % in Tower and In Girder/Beam 5.88% as compared to XX-bracing system.

XX-bracing system is found to be optimum and economical in design of Gantry structures in cost of material with allowable deflection in comparison to XX & XB Bracing system, however if required, in worst case of displacement one can go for XB for its strength and displacement control.

REFERENCES

[1] T. Raghavendra, "Computer Aided Analysis and Structural Optimization of Transmission Line Tower", International Journal of Advanced Engineering Technology E-ISSN 0976-3945.

[2] Panchal, "Dynamic Analysis of Transmission Line Towers", International Conference on Civil Engineering and Applied Mechanics (ICCEAM) 2014, Paris, France, Report No: IIIT/TR/2014/-1.

[3] May Chaw Su Kyi, Dr. Kyaw Lin Htat, "Evaluation of Steel Lattice Transmission Tower with Different Wind Loads", ISSN 2319-8885 Vol.03, Issue.08, May-2014, Pages:1563-156.

[4] Lingampally Srikanth and Dr D Neelima Satyam, "Dynamic Analysis of Transmission Line Towers", International Conference on Civil Engineering and Applied Mechanics (ICCEAM) 2014, Paris, France, Report No: IIIT/TR/2014/-1.

[5] Xing Fu and Hong-Nan Li, "Dynamic Analysis of Transmission Tower-Line System Subjected to Wind and Rain Loads", J. Wind Eng. Ind. Aerodyn 157(2016)95-103.

[6] Gopi Sundam Punse. "Analysis and Design of Transmission Tower". International Journal of Modern Engineering Research (IJMER), ISSN: 2249–6645, Volume 4, Issue 1, Jan. 2014

[7] Vikas G. ahlawat, Er. Sumit Kumar, & Yogesh Kaushik. (2015). "Analysis and Design of a 25-Metre-Tall Steel Transmission Tower". International Journal of Engineering Technology, Management and Applied Sciences, 32-35.

[8] N. Mahesh, & V. Ranga Rao. (2017). "Design & Estimation of Electric Steel Tower". International Journal of Civil Engineering and Technology (IJCIET), 646-652.

[9] Patil B.Y, Prof. Upase K.S., & Prof. Hamne A. A. (2020). "Design and Analysis of Transmission Line Tower using Staad-Pro". International Journal for Scientific Research & Development, 11-13.

[10] Anshu Kumar Pal, M. Suneel, & P V Rambabu. (2019). "Comparative Analysis of Transmission Tower using XX and XBX Bracing Systems in Different Wind Zones'. International Journal of Recent Technology and Engineering (IJRTE), 56-61.

[11] Yasaswini, S. V. N. L. Lalitha, & Shefali Talati. (2016). "Multi Voltage Multi Circuit Transmission Tower Design to Reduce Right of Way". Indian Journal of Science and Technology, 1-7.

[12] Y. M. Ghugal, 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 691 ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, pp 691-694.

[13] V. Lakshmi1, A. Rajagopala Rao "Effect of Medium Wind Intensity On 21M,132kV Transmission Tower" ISSN: 2250–3676 Volume-2, Issue-4, 820-824

[14] F. Albermani, M. Mahendran and S. Kitipornchai "Upgrading of Transmission Towers Using a Diaphragm Bracing System" International Journal of Civil and Structural Engineering Volume2, No2, 2008.

[15] G. Visweswara Rao "Optimum Designs for Transmission Line Towers" Computer & Structures vol.57. No.1. pp.81-92, 1995.