

## Analysis and Design of an Industrial Tower

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### Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Steel Transmission Towers are often used to transmit power from one location to another using electrical conductors. Transmission line towers elevate heavy electrical transmission conductors to a safe height above the ground. Furthermore, all towers must withstand various natural disasters such as wind, earthquakes, and so on. Because towers must support the weight of above lines, they must be strong. As a result, the design engineer has a lot of responsibility, as he or she must develop not only an economical, but also a safe and trustworthy design that can withstand various loads, including its own. The voltage, circuit count, and kind of transmission line tower are used to classify them. The most common configurations used are rectangular and square. The most prevalent type of broad-based tower is the square type. Different sorts of towers are introduced in this. Transmission towers are often built of steel or galvanized steel. Lattice structures are commonly utilized and have a sleek body made up of polygonal tubular sections with tubular cross arm management for fastening the tension or suspension clamp. The geometric parameters of transmission line tower configuration include the tower's height, base width, top-hamper width, length, and depth of the cross arm. The leg and bracing elements are the main components of the lattice tower. They transport the tower's vertical and shear stresses to its foundation. Secondary or redundant bracing members are utilized to offer intermediate support to primary members in order to

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reduce unbraced length and boost load carrying capability. Rectangular and square configurations are the most common. The most frequent are square-shaped broad-based towers. STAAD PRO V8i was used to construct and analyze a standard steel latticed skyscraper of height 19 meters. On post-processing mode after load analysis The bending moment and shear forces findings were obtained, examined, and updated to meet the requirements.

*Keywords: Transmission line tower; tension or suspension clamp; lattice tower; redundant bracing members.*

## 1. INTRODUCTION

Electric power consumption has continued to climb in every country, developed and developing, with the pace of expansion being faster in emerging countries. Electric power is becoming increasingly vital in community life and the development of numerous economic sectors. As a result, developing countries like India are prioritizing electricity development programmes. In reality, electricity is becoming a more important basic element in the economy.

### 1.1 Transmission tower

A tower (also known as an electricity pylon or other forms) is a tall structure that supports an overhead power line. It is usually made of steel lattice. The conductor subsystem, ground wire subsystem, and one subsystem for each kind of support structure make up a transmission line. They're utilized to keep the Extra High Voltage alive (E.H.V). Mechanical transmission line supports account for a major amount of the line's cost and play a key role in ensuring dependable power transmission. Steel lattice towers are extensively used in the power industry to transmit power through electrical cables from the point of generation to the point of distribution. As towers are critical components of transmission lines, precise prediction of their failure is critical for transmission system dependability and safety. Transmission line towers are said to account for 28-48 percent of a transmission line's overall cost. Transmission line towers are also classed as Barrel, Corset, or Guyed towers based on their shape.

### 1.2 Tower Specification

The top panel is known as the cage, and the bottom panel is known as the body, with legs spreading out to provide better stability against overturning moments. The most common configurations used are rectangular and square. The most prevalent type of broad-based tower is the square type. Electric transmission towers can be anywhere from 10 to 45 meters tall, whereas flood lights in stadiums and big flyover crossings

can be anywhere from 15 to 50 meters tall. Television towers can be anywhere from 100 to 300 meters tall, while radio transmission and communication towers can be anywhere from 50 to 200 meters tall. The number of circuits carried by the tower can be single, double, or multi circuit. The conductor loads will be carried by a cross-arm in the cage part. Heavy compressive forces are applied to the columns and bracing. Transmission line towers are classified by the voltage of the line they carry. In India, the most frequent voltages for power transmission are 110 kV, 220/230 kV, and 440 kV. Steel equal angle sections are commonly used for tower members.

### 1.3 Tower Configuration

Various line configurations are available depending on the transmission system's requirements. The following considerations influence the transmission line tower's configuration:

- a) Assembly length of insulators.
- b) The minimum clearances between conductors and between conductor and tower that must be maintained.
- c) In relation to the outermost conductor, the position of the ground wire or wires.
- d) The mid-span clearance necessary due to the dynamic behaviour of conductors and the line's lightning protection.
- e) The minimal clearance above ground level for the lowest conductor.

Three criteria primarily dictate the tower configuration:

- I. The tower's height.
- II. Base-width.
- III. Maximum hamper width

## 2. LITERATURE REVIEW

Research studies have been done in the field of Transmission Tower. Design and detailed

analysis were done on braced panels, compression members, stiffness etc.

a) (V.G. RAO, OPTIMUM DESIGN FOR TRANSMISSION LINE TOWERS, COMPUTERS AND STRUCTURES, VOL .57, 1992 81-92) [1] To meet certain functional criteria, transmission line towers support electrical power conductors and ground-wires at a suitable height above ground. Transmission line towers are said to account for 28-48 percent of the overall cost of a transmission line.

b) (GUPTA A, ANALYSIS AND ECONOMICAL DESIGN OF TRANSMISSION LINE TOWERS OF DIFFERENT CONFIGURATION 2005) [2] The conductor subsystem, ground wire subsystem, and one subsystem for each type of support structure make up a transmission line.

c) (Y.M. GHUGAL, U.S. SALUNKE, 2011 - ANALYSIS AND DESIGN OF THREE AND FOUR LEGGED 400KV STEEL TRANSMISSION LINE TOWERS) [3] Transmission line towers typically have four legs. Only telecommunications, microwaves, and radio are used on three-legged towers. Constant loading characteristics, including wind forces, are included in this study according to IS: 802 (1995).

d) (V. LAKSHMI AND M.V.R SATYANARAYANA, STUDY ON PERFORMANCE OF 220KV M/C MA TOWER DUE TO WIND VOL. 3 ISSUE 3, MARCH 2011) [4]: High current or Extra High Voltage electric transmission lines are supported by transmission line towers. This has resulted in the requirement for quite substantial supporting structures.

e) (N. Prasad Rao, G.M. Samuel Knight, S.J. Mohan, Lakshmanan, Studies on failure of

transmission line towers in testing, 2010 [5] Because towers are critical components of transmission lines, precise prediction of their failure is critical for the transmission system's reliability and safety. When a system fails, there are significant direct and indirect losses, not to mention the expenses of power outages and litigation. Beam column and plate elements are used to model the tower members.

f) (KAUSHIK YOGESH, AJIT, BHARDWAJ LAL HEERA, ANALYSIS AND DESIGN OF FOUR LEG STEEL TRANSMISSION TOWER USING STAAD.PRO, 2015) [6] A tower is a self-supporting building that stands free of the ground or foundation. Traditional transmission towers' environmental impact is no longer acceptable in developed countries. For financial concerns, currently accessible design solutions with acceptable appearance are not used in underdeveloped nations. Steel angles will continue to be used in underdeveloped nations for classic lattice transmission towers.

### 3. MODEL ANALYSIS

A four-legged transmission tower of height 19 m was designed and analyzed. The tower designed carries both 220 kV and 440 kV power capacity. For section analysis SP 16 was followed and for analysis of transmission tower body IS 802: 1995 (Part 1) was followed. A load of 3.5 kN on 220 kV and 5 kN on 440 kV. The whole structure was designed and analyzed on STAAD-PRO V8i software. The tower was subjected to different loading i.e., Dead Load, Live Load and Wind Load complying with Indian Standard Codes like (IS: 875 part 1 ,1987 - Dead Load, IS: 875 part 2, 1987 - Live Load and IS: 875 part 3 ,1987 - Wind Load) Using this software we have checked the bending moment shear force, deflection of different members.

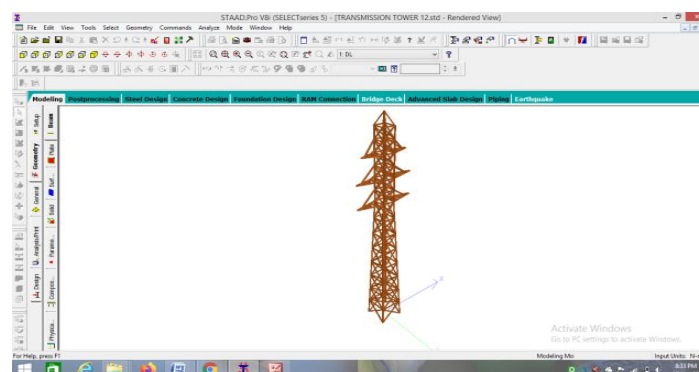


Fig. 1. 3D Rendering view

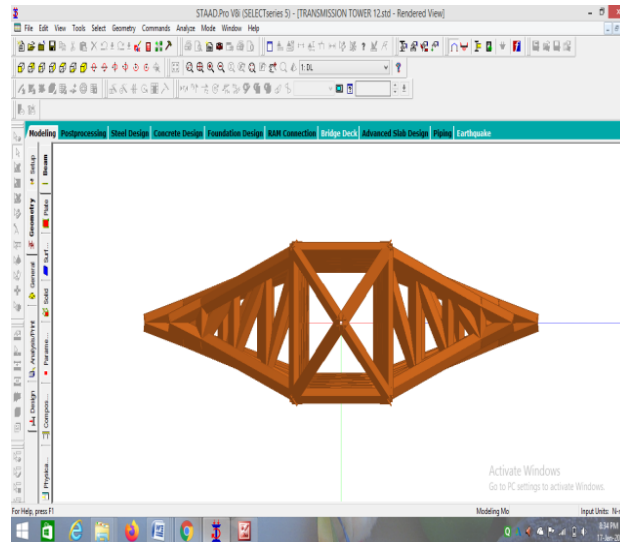


Fig. 2 Top View

### 3.1 Section Analysis

Table 1. Section Database

Members	Section	Material
Column	ISA 100x100x10	Steel
Wings	ISA 100x100x8	Steel
Bracings	ISA 75x75x8	Steel

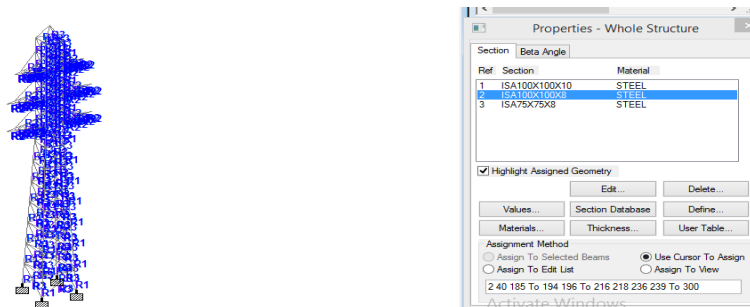


Fig. 3 Assigning different section properties

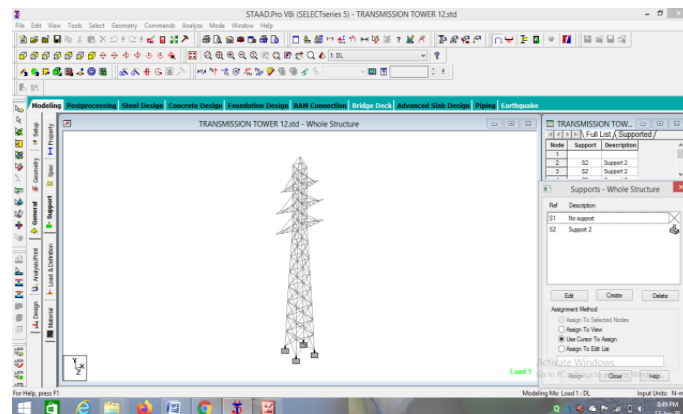


Fig. 4. Assigning fixed support

### 3.2 Load Analysis in Detail on Transmission Tower

#### 3.2.1 Load definition

##### Wind load definition

**Table 2. Wind Definition values**

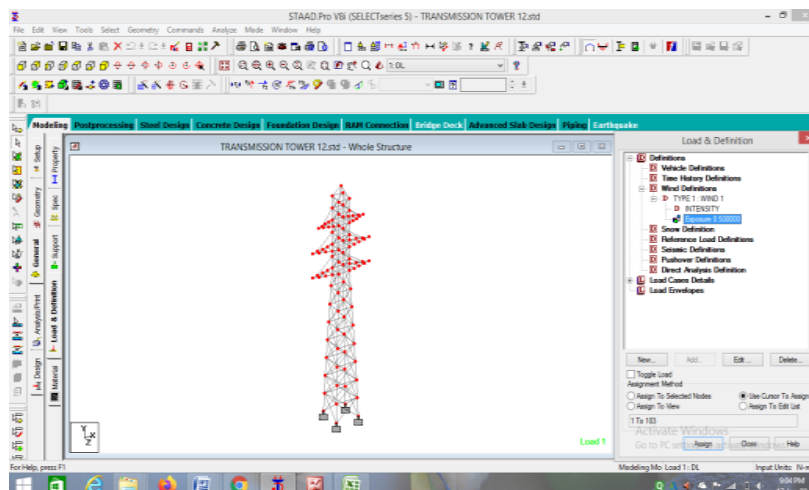
SI No.	Title	values
1	Building category	II
2	Basic wind speed	50 kmph
3	Exposure category	B
4	Structure Type	Trussed Type
5	Height	19 m
6	Width	5 m

##### Intensity

**Table 3. Wind Intensities**

SI no	Intensity	Height
1	9.47E-05	0
2	9.47E-05	4572
3	0.000101	5681.85
4	0.000106	6791.69
5	0.000111	7901.54
6	0.000115	9011.38
7	0.000119	10121.2
8	0.000122	11231.1
9	0.000126	12340.9
10	0.000129	13450.8
11	0.000132	14560.6
12	0.000135	15670.5
13	0.000137	16780.3
14	0.00014	17890.2
15	0.000142	19000

##### Exposure Factor - 0.5



**Fig. 5. Assigning of exposure factor**

### 3.3 Dead Load Analysis:

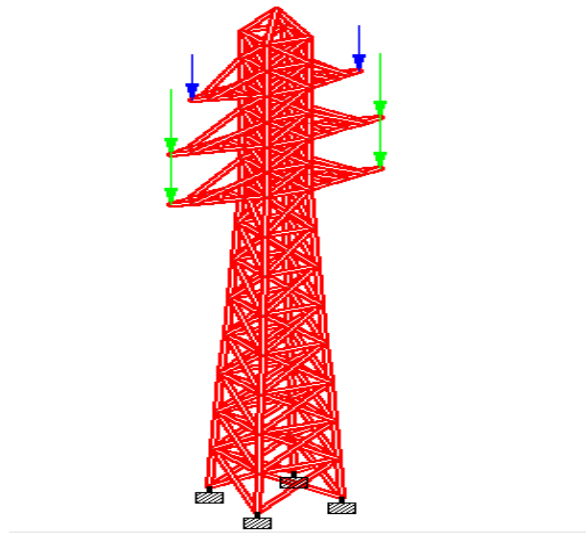


Fig. 6. Assigned Dead Load

Table 4. Dead Load Values

Self-Load Factor	KN
220kV wing	KN
440kV wing	K KN

### 3.4 Live load Analysis

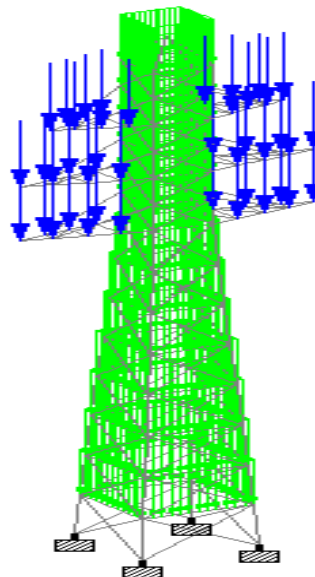


Fig. 7. Assigned Live Load

Table 5. Live Load Values

Loads on Wings	1.5KN
Uniform force on other members	0.75KN/m

### 3.5 Effect of Wind

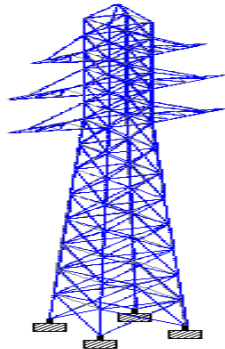


Fig. 8. Assigning Wind load at X+ direction

## 4. STEEL DESIGN

CODE: - IS 802: 1995 PART I

FYLD (yield strength of steel) – 250 N/mm<sup>2</sup>

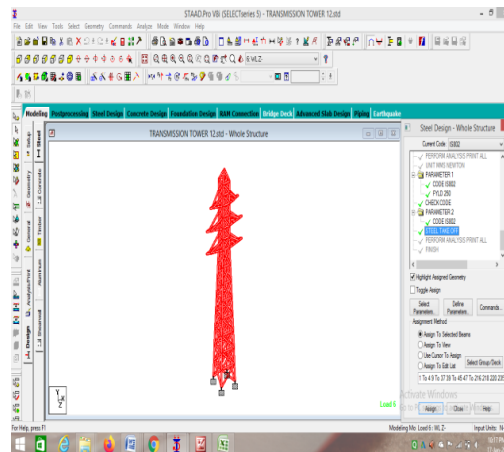


Fig. 9. Assigning steel Take off

## 5. FINAL ANALYSIS & RESULTS

### 5.1 Shear Force & Bending Moment analysis for beam no 140:

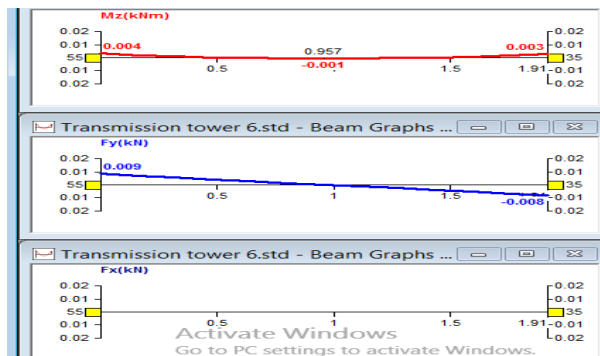


Fig. 10. Graph of load and moment variation

## 5.2 Stress Variation

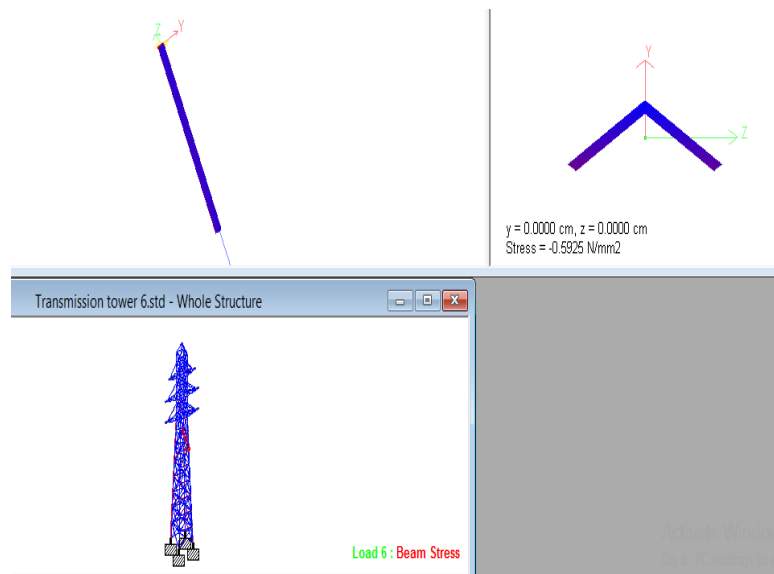


Fig. 11. Stress Diagram

## 5.3 Brief Details of Few Accepted Members

Table 6. List of passing members

1 ST ISA75X75X8	(INDIAN SECTIONS)		
PASS TENSION	0.006	13	
1657.90 T	0.00	0.00	0.00
2 ST ISA100X100X8	(INDIAN SECTIONS)		
PASS COMPRESSION	0.012	7	
4525.23 C	0.00	0.00	0.00
3 ST ISA75X75X8	(INDIAN SECTIONS)		
PASS TENSION	0.006	12	
1756.79 T	0.00	0.00	0.00
4 ST ISA75X75X8	(INDIAN SECTIONS)		
PASS TENSION	0.019	7	
5454.03 T	0.00	0.00	0.00
9 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.042	7	
18588.51 C	0.00	0.00	0.00
10 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.043	7	
18916.62 C	0.00	0.00	0.00
11 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.023	7	
10258.14 C	0.00	0.00	0.00
12 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.043	7	
18749.50 C	0.00	0.00	0.00
17 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.033	7	
14412.75 C	0.00	0.00	0.00
18 ST ISA100X100X10	(INDIAN SECTIONS)		
PASS COMPRESSION	0.033	7	



### 5.4 Calculation of Quantity of Steel

**Table 7. Steel Take-off**

Steel take-off		
Profile	Length	Weight(NEWT)
ST ISA75X75X8	278231.06	24365.866
ST ISA100X100X8	67907.80	8033.627
ST ISA100X100X10	74083.25	10869.885
<b>Total =</b>	<b>43269.379</b>	

### 5.5 Total Reactive Load-case Details

**Table 8. Summary of reactive load**

Total reaction load (KN-m) summary (Loading 5)						
Summation force-X =	0.00					
Summation force-Y =	0.00					
Summation force-Z =	-4.14					
Summation of moments around the origin-						
MX=	-43.07	MY=	-0.01	MZ=	0.00	
Maximum displacements (Cm /radians) (loading 5)						
MAXIMUMS AT NODE						
X =	-1.28088E-03	1				
Y =	1.34028E-02	31				
Z =	3.52137E-01	1				
RX=	0.00000E+00	0				
RY=	0.00000E+00	0				
RZ=	0.00000E+00	0				
External and Internal joint load summary KN/m						
JT	EXT FX/	EXT FY/	EXT FZ/	EXT MX/	EXT MY/	EXT MZ/
	INT FX	INT FY	INT FZ	INT MX	INT MY	INT MZ
SUPPORT=1						
2	0.00	0.00	0.03	0.00	0.00	0.00
1.59	-10.71	1.00	0.00	0.00	0.00	111111
3	0.00	0.00	0.03	0.00	0.00	0.00
-1.59	10.71	1.00	0.00	0.00	0.00	111111
4	0.00	0.00	0.03	0.00	0.00	0.00
1.59	10.83	1.01	0.00	0.00	0.00	111111
5	0.00	0.00	0.03	0.00	0.00	0.00
-1.59	-10.83	1.01	0.00	0.00	0.00	111111

### 5.6 Applied Load Case Details

**Table 9. Summary of applied loads**

Total applied load (kN -m) summary (loading 6)	
Summation force-X =	0.00
Summation force-Y =	0.00
Summation force-Z =	-4.14
Summation of moments around the origin-	
MX=	-43.07
MY=	-0.01
MZ=	0.00

## 6. CONCLUSION

Based on the design and analysis done on the tower we have concluded as follows:

- 1) The configuration of the tower's construction is critical to its performance, especially when eccentric loading is present.
- 2) The vertical members carry the tower's loads more prominently than the horizontal and diagonal elements. The members supporting the cables at higher elevations are likely to have a greater impact on the tower structure's behaviour.
- 3) All of the specified members with their given sections passed tension and compression, according to the software's results. As a result, we can say that all members are meant to be safe.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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