

## CORPULENT ANALYSIS OF SEISMIC AND THERMAL STRESS ON STABILITY AND SERVICEABILITY EVALUATION OF POWER TRANSMISSION

### TOWER USING FEA

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### ABSTRACT

Tall tower constructions' structural integrity and safety are of the utmost concern in areas vulnerable to seismic activity and thermal fluctuations. In this paper, a tower structure's response to seismic pressures and temperature effects is thoroughly examined. The study makes use of cutting-edge engineering techniques and simulations to assess the tower's performance and stability under these dynamic external stresses. This investigation's primary method of analysis is seismic, with a particular emphasis on how the tower will respond to earthquakes. The report describes the procedures followed in accordance with seismic design guidelines. It goes over the numerous inputs and criteria that were taken into account when simulating the tower's response to ground motion. In order to precisely forecast how the tower will react to seismic and thermal stresses, the analysis makes use of sophisticated computational methods like finite element analysis (FEA). The results are presented and explained, offering a thorough understanding of the tower's behavior. These data include stress distributions, displacements, and mode shapes.

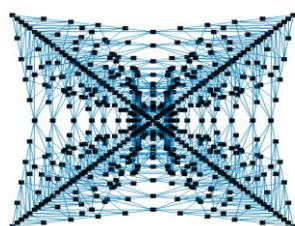
**Keywords:** ANSYS; Finite Element Analysis (FEA); Power Transmission Tower; Thermal Stress Variation; Seismic Force.

### I. INTRODUCTION

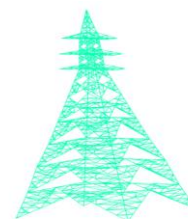
Transmission towers, which frequently soar to great heights above the ground, are essential to the distribution of electricity. It is critical to ensure the towers' structural stability and safety, particularly in areas that are vulnerable to earthquakes and temperature fluctuations. In-depth discussion of seismic and thermal analysis for transmission towers is given in this essay, along with an explanation of the approaches and their importance in the structural engineering community.

Tall tower buildings must be safe and structurally sound when located in areas that are prone to earthquakes and temperature fluctuations. The thorough examination of a tower structure and its reaction to thermal and seismic forces are the main topics of this research.

The stability and performance of the tower under these dynamic external stresses are assessed by the study using sophisticated engineering techniques and simulations. An important part of this research is seismic analysis, which focuses on evaluating the tower's response to seismic activity. The study describes the approaches that were followed in accordance with earthquake design standards and rules. It talks about the different variables and aspects taken into account when simulating the tower's reaction to ground motion.



(a)Top View



(b)Lateral View

**Figure 1.** Layout of structure

In areas where there has been a history of seismic activity, seismic analysis is an essential part of assessing the structural stability of transmission towers. The purpose of this analysis is to comprehend how a tower reacts to earthquake-related ground motion. Seismic analysis involves a number of important variables and techniques, including:

**Material Behavior:** The coefficients of thermal expansion of the various materials used in the building of transmission towers vary. It is crucial to comprehend these characteristics in order to forecast how temperature variations would impact the tower.

**Contraction and Expansion Joints:** To account for thermal changes and avoid structural damage, transmission tower designers may include contraction and expansion joints.

**Stress and Deformation Assessment:** In order to guarantee the tower's long-term durability, thermal analysis evaluates the stress and deformation patterns brought on by temperature fluctuations.

Seismic and thermal assessments are integrated in the most thorough transmission tower examination. This addresses the fact that temperature variations and seismic activity can affect these structures. The combined influences on the structural behavior of the tower are considered at regions where these elements overlap.

The substantial effect that extreme weather has on transmission tower structural integrity is demonstrated by these scholarly investigations. Although the precise impacts of these meteorological occurrences might differ, they include:

- **Structural Failure:** Transmission towers that are not properly designed and constructed are vulnerable to collapsing when strong winds are present.
- **Component Damage:** Important transmission tower components including conductors, insulators, and guy wires are susceptible to damage from severe weather events, which can include strong winds, rain, and ice. Within the impacted areas, this damage may cause interruptions and power outages.
- **Corrosion:** Metallic components inside transmission towers may corrode due to the presence of moisture from rain and snow as well as salt-laden air. since of this corrosion, the towers are more vulnerable to destruction during extreme weather events since their structural integrity is weakened.
- **Seismic and Structural Responses:** In areas where temperature fluctuations and seismic activity are common, seismic and thermal analysis of transmission towers is an essential aspect of structural engineering. Transmission tower safety, integrity, and longevity are critical for the steady distribution of electrical power, and these assessments are necessary to guarantee these aspects. When constructing and maintaining transmission towers, engineers may make more informed judgments with the aid of the approaches covered in this essay, which include thermal behavior evaluation, finite element analysis, and seismic design codes. Engineers improve the resilience of our power infrastructure by carrying out thorough assessments that contribute to the safety and long-term stability of these vital installations.

#### **Objectives of the study:**

Understanding the nature of the strains on transmission towers resulting from seismic and thermal impacts is one of the main goals of the research of transmission tower stresses caused by these factors.

- Create techniques for estimating the strains placed on transmission towers.
- Create materials and design techniques to enhance transmission tower performance.
- Point up any possible flaws in transmission tower design.

The following research questions can be answered in the study of wind and heat impacts on transmission tower stresses:

- What kinds of strains are caused by these factors on transmission towers?
- How do the tower's design, the materials employed, and the surrounding environment affect the stresses brought on by wind and temperature effects?
- How can the strains brought on by temperature and wind influences be precisely calculated?
- What materials and design techniques may be applied to enhance transmission tower performance?
- Are there any possible flaws in the transmission tower design?

Examining the stresses that transmission towers encounter due to heat and seismic effects is a challenging and complex task. It is an essential responsibility to improve the security and dependability of power transmission.

The pressures resulting from wind and heat impacts on transmission towers may be examined using the following methods:

- Analytic techniques
- Test-driven techniques
- Algebraic techniques

Analytical approaches are based on mathematical models of the tower and its environment. Towers are put to the test in a controlled setting utilizing experimental methods. Numerical techniques model tower dynamics using computer simulations.

The specific objectives of the investigation will determine the preferred approach. Analytical approaches are often used to provide more information regarding the stresses on towers in general. Experimental methods are often used to verify the accuracy of analytical procedures and look into the effects of certain environmental conditions. Numerical approaches are widely used to assess the dynamic response of towers and the effects of fatigue and corrosion.

The issue of transmission tower stresses caused by temperature and seismic factors is still being researched. As new technologies are developed, new approaches are being developed to assess the pressures on these structures. To make sure that the towers are constructed to withstand expected forces and prevent breakdowns, this study is essential.

## II. METHODOLOGY

### GENERAL

Under seismic and thermal stresses, analyzing a power transmission tower is a challenging and intricate task. It is an essential responsibility to improve the security and dependability of power transmission.

The following challenges must be considered when evaluating the stresses on electrical transmission towers since the following issues may make the study more difficult:

Predicting the stresses on the towers is difficult because of the following:

- The towers are regularly subjected to dynamic loads;
- The materials used in the towers may be weaker because to corrosion and fatigue; and
- The environmental conditions may change substantially.

Notwithstanding these challenges, assessing the stresses placed on power transmission towers is an essential task that might improve power transmission's dependability and security.

### Seismic Stresses

When calculating seismic stresses resulting from earthquake loading in structural engineering, seismic design regulations, including the Indian Standard (IS) norms, must be adhered to. The seismic design code in India, IS 1893 (Part 1): 2016, offers the foundation for figuring out seismic stresses in structures. The main procedures in these computations, as per IS 1893, are summarized as follows:

The tower's form affects the drag coefficient, which is a dimensionless coefficient. The area of the tower that is perpendicular to the wind direction is known as the cross-sectional area of the tower. Air pressure and temperature have an impact on the density of the air, which is a constant. The wind speed is the wind speed at the tower's height. Clause 7.4.3.5 of IS 875 (Part 3) is cited.

Finding the Seismic Zone: Finding the seismic zone of the site where the construction is to be erected is the first stage. Zone II (low seismicity) through Zone V (high seismicity) are the several seismic zones that make up India. The region's historical seismic data served as the basis for this categorization.

Site-Specific Response Spectrum: The code offers response spectra for various seismic zones when the zone has been identified. The variations in ground motion accelerations over time are depicted by these spectra. In the event that more precise data becomes available, the algorithm also permits the development of site-specific response spectra.

Calculation of Design Base Shear (V): One of the most important parameters that indicates the highest seismic force that a structure can withstand is the design base shear. The following equation is utilized in its calculation:

$$V = A * S / R * I$$

Where:

'A' is the horizontal acceleration response spectrum value at the fundamental period of the structure.

'S' is the seismic zone factor.

'R' is the response reduction factor.

'I' is the importance factor.

**Distribution of Seismic Forces:** The design base shear must be dispersed across the structure's height after it has been established. Guidelines for this distribution are provided by IS 1893, which takes the structure's height and mass distribution into account.

**Designs and Seismic Stresses:** Seismic stresses are then obtained by dividing the predicted seismic forces by the relevant cross-sectional area of the structural elements. The permitted stresses for the building materials are then contrasted with these stresses.

**Detailed Design:** The seismic design process is briefly described in the phases above. To make sure the building can resist seismic forces, engineers must do a thorough study and design of the structure. In order to withstand seismic loads, suitable materials must be chosen, structural parts must be sized, and connections and foundations must be designed.

**Thermal Stresses**

The tower's expansion and contraction as it heats up and cools down result in thermal stresses. Using the following equation, the thermal stress on a power transmission tower is determined:

$$F_t = \alpha * E * \Delta T$$

where:

$F_t$  = force resulting from thermal stresses

$\alpha$  =proportional of thermal expansion

E =Young's modulus

$\Delta T$  = variation in temperature

Thermal stresses are produced by the tower's expansion and contraction as it heats up and cools down. The thermal stress on a power transmission tower is calculated using the following equation:

**Combined Wind and Thermal Stresses**

A power transmission tower's overall stress may be calculated by adding its thermal and wind loads together. The following equation is used to compute the overall amount of stress.:

$$F_t = F_w + F_t$$

**Design of Power Transmission Towers**

Wind and thermal strains are taken into account during the design of electricity transmission towers. The structure's design makes sure the tower can sustain the anticipated forces without collapsing.

The design process typically involves the following steps:

- Identify the expected wind and thermal stresses.
- Calculate the total stress on the tower.
- Select the materials for the tower.
- Calculate the dimensions of the tower.
- Verify that the tower is able to withstand the expected stresses.

**Table 1.** Structural Specification

	PARTICULARS	STRUCTURAL PROPERTIES
1.	Total height of tower, h	90m
2.	Flare height of the structure, hf	$(1/3) \times 90 = 30m$
3.	Top diameter of structure, D	3.5m
4.	Flare diameter of structure, Df	$1.6 \times 3.5 = 5.6m$

5.	IS code for steel structure	IS:6533-1989
6.	European code for steel structure	EN 1993-3-2

**Table 2:** Material properties considered in the study

Yield stress of steel	250 KN/m <sup>3</sup>
Modulus of Elasticity (E) of steel	2×10 <sup>5</sup> N/m <sup>2</sup>
Poisson's ratio	0.3
Strain in elastic range	0.2%

**Loads acting on the transmission tower**

Various loads are placed on transmission towers, such as:

**Dead load:** The weight of the tower itself, including the weight of the cables, insulators, and guy wires, is referred to as the dead load.

**Wind load:** The force of the wind on the tower is known as the wind load. Particularly in places with strong winds, such coastal regions, the wind load can be quite significant. Table 33, Section 7.4.3.5

**Ice load:** The weight of the ice that builds up on the tower is known as the ice load. Particularly in regions that have regular ice storms, the ice burden can be quite high.

**Earthquake load:** The magnitude of an earthquake's impact on a tower is known as the earthquake load. Transmission towers can sustain severe damage from earthquakes, particularly in seismically active locations.

**Lightning load:** The lightning load is the force of a lightning strike on the tower. Lightning strikes can cause damage to the tower's components, such as the conductors and insulators.

The loads acting on a transmission tower are complex and vary depending on the specific location of the tower. Transmission towers are designed to withstand these loads, but they can be damaged or even collapse if the loads are too high.

**Self-weight:** Self-weight of the tower is calculated as per IS 875(Part 1): 1987.

**Wind load**

Since towers are tall structures, wind action has an important effect on them. High rise structures must be evaluated for their ability to withstand wind loads as the lateral strength of tall buildings is determined by such loads. Wind load should be applied on the external surfaces of a stack. Wind is a primary load for self-supported steel stack or towers.

Wind load are designed as per IS 875(Part 3): 2015.

As per IS code 875(Part3)2015:

wherein,

$V_z$  = Design wind speed z in m/s.

$V_b$  = Basal wind speed (refer Annex. A, Clause 6.2, IS 875 Part 3;  $V_b$  at Lucknow= 50)

$k_1$  = Risk coefficient

$k_2$  = Structure size factor

$k_3$  = Factor of Topographical Variance

$k_4$  = Importance factor for cyclonic region Design wind pressure,

$$V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4$$

wherein,

$p_z$  = Design wind pressure (N/m<sup>2</sup>) at height z

$V_z$  = Design wind velocity in (m/s) at height z

[across wind force is not needed to be calculated, IS 875-2015(Part 3), Clause 10.3]

**Seismic load**

As a natural load, seismic load is an essential factor for towers. Normally, this load is dynamic in nature. For short periods of time, seismic force is predicted to be cyclic. It is important to examine the structural reaction to



ground motion when building earthquake resistant constructions. A structure is considered serviceable if it can perform the operational purposes for which it was designed.

IS 1893(Part 4): 2005.

The fundamental time period of vibration for structure-like structure is

$$T = C_T \sqrt{\frac{W_t h}{E_s A g}}$$

wherein,

$C_T$  = Slenderness coefficient

$W_t$  = Gross weight of the stack,

$A$  = Area of cross-section at the base of the tower

$h$  = Total height of the stack

$E_s$  = Modulus of elasticity

$g$  = Acceleration due to gravity

Horizontal seismic force  $Ah = (Z/2) \times (S_a/g) \times (I/R)$

wherein,

$Ah$  = Horizontal seismic coefficient

$Z$  = Zone factor given in IS 1893:2005 (Part 1), wind l

$I$  = Importance factor ref. IS 875:2015 (Part 3)

$R$  = Response reduction factor given in 1893:2005 (Part 4) S

$a/g$  = Spectral acceleration coefficient.

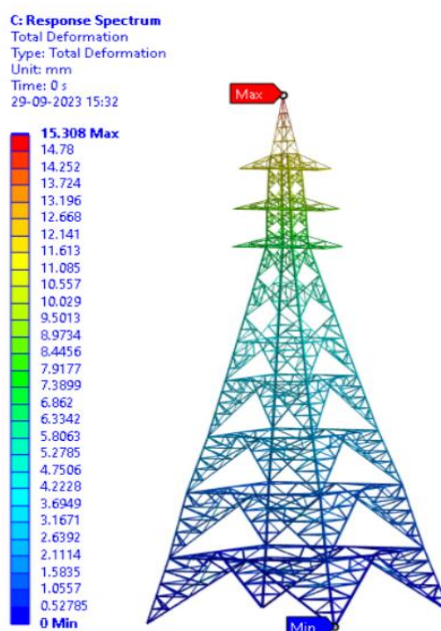
**Load Combinations**

Different load combinations have been considered while analyzing the structure as per IS 6533 (Part 2) 1989

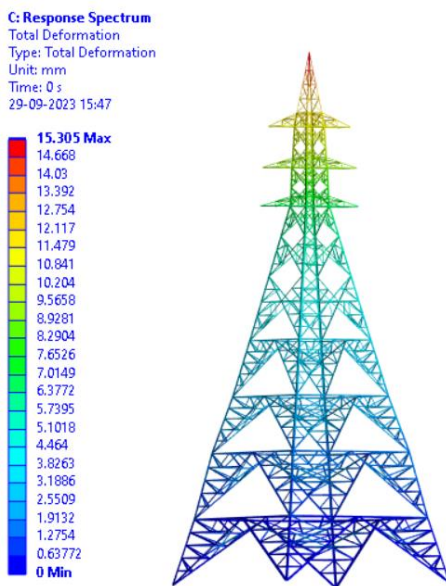
**III. RESULTS AND DISCUSSION**

For modeling purposes, the structure is regarded as free at the top and fixed at the bottom. Different load combinations are applied for wind and seismic loads, and the displacement at the top of the steel stack is recorded. Ansys software is used for modeling. The outcome allows for the observation of the transmission tower's behavior with respect to top displacement.

**Total deformation**



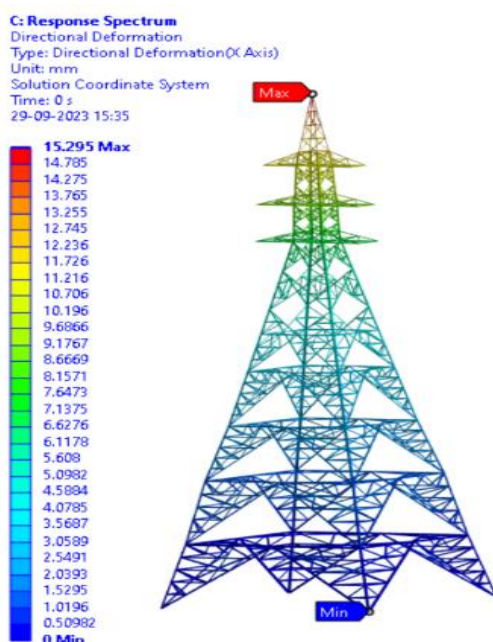
**Fig 2.** Total Deformation Diagram for standard loaded tower



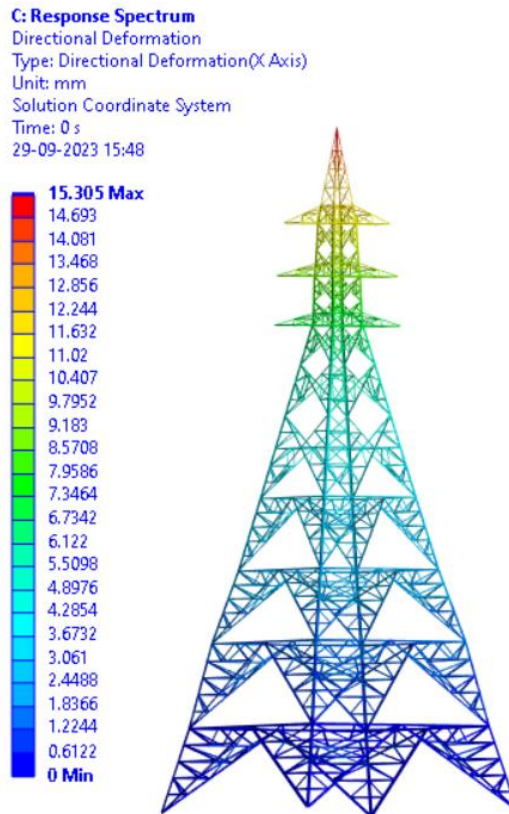
**Fig 3.** Total Deformation Diagram for thermally loaded tower

When the power transmission lattice tower structure is loaded with dead load, live load, and wind load in addition to thermal stresses, it deforms more overall than when it is supplied with the same loads but without thermal stresses. This is because heat stresses increase the structure's total load and lead to more deformation. The highest deformation in the first data set is 25.609 mm, whereas the maximum deformation in the second data set is just 1.103 mm. This demonstrates that the overall deformation is greatly decreased in the absence of thermal forces. Additionally, the first set of data had a larger average deformation (24.954 mm) than the second group (5.1887e-002 mm). This demonstrates once more how the total deformation is greatly decreased in the absence of thermal forces. Because they can greatly increase the overall deformation of the structure, thermal stresses must be taken into account when constructing power transmission lattice tower designs.

**Directional Velocity:**



**Fig 4.** Directional Velocity Diagram for standard loaded tower



**Fig 5.** Directional Velocity Diagram for thermally loaded tower

The image shows the response spectrum of a tower, with the directional velocity plotted on the y-axis and time on the x-axis. The directional velocity is the maximum velocity of the tower in any direction at a given time.

The directional velocity of the tower is 29.74 m/s at its peak. The velocity then decreases gradually until it reaches zero at around 15 seconds. This indicates that the tower experiences a sudden and large vibration at the beginning of the analysis, which then gradually subsides.

The directional velocity of the tower is also not constant in direction. It varies over time, with the maximum velocity in different directions at different times. This indicates that the tower is experiencing complex vibrations, with different parts of the tower vibrating at different frequencies.

Overall, the directional velocity of the tower is relatively high, indicating that the tower is experiencing significant vibrations. The vibrations are also complex, with different parts of the tower vibrating at different frequencies.

#### IV. CONCLUSION

Examining the stresses on electricity transmission towers is a crucial stage in the design process. This research ensures that the skyscraper is built to resist the expected stresses. Thermal loads and wind loads are the two primary types of stresses that are considered while designing electricity transmission towers. The combined wind and thermal loads are used to calculate the total stress on the tower. Afterwards, tests are conducted on the tower during the design stage to ensure that it can withstand the expected stresses.

The average deformation in the first data set is also higher than in the second, measuring 24.954 mm compared to 5.1887e-002 mm in the latter set. Just as the second dataset spans a much narrower range of values, from 123 N-mm at low to 10030 N-mm at high, the first dataset spans a wider range of values, from 1878.2 N-mm at minimum to 1.6228e+007 N-mm at maximum. The net torsional moment is calculated as the difference between the greatest and least bending moments. In the first set of data, the net torsional moment is 0.046 N-mm. In the second set of data, the net torsional moment is 0.727 N-mm.

The difference in total shear force at the conclusion of the time is taught to be 29N. The maximum axial force in the first set of data, however, is -2484.2 N, and it occurs at a time of 10 seconds, when we look at the net axial shear force. According to the second set of data, the maximum axial force, which is -90.783 N, happens at a time



of 10 seconds. Since the structural energy response plays a critical role in defining the structure's behavioral pattern, it is clear from the analysis that the strain energy is the energy stored in the structure as a result of its deformation. The damping energy is the amount of energy dissipated by the structure's dampers.

Artificial energy is the energy that has been contributed to the building by artificial factors, such as wind forces. It is clear from the data analysis above that the data set-1 with the thermal stresses causes greater strains than a normal loaded tower that does not account for thermal stresses.

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