Analyze The Directional Effect Of The Wind On The Transmission Line Tower

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doi: 10.48047/ecb/2023.12.si6.133

Abstract- The primary goal of this final year project is to analyze the directional effect of the wind on the transmission line tower STAAD Pro software. The whole procedure will encompass manual load calculations as well as the comprehensive examination of the entire structure using STAAD Pro. The composition of the towers will be assessed based on specific criteria and requirements. The project will involve analyzing multiple 2D and 3D frames subjected to various load combinations. Special attention will also be given to analyzing offshore steel piers under different load scenarios. Once the analysis is complete, the structure will be thoroughly studied, and moment and shear force values will be generated. These values will be depicted in diagrams, aiding in visualizing the processing sequence. Furthermore, the deflection of different members under given load combinations will be evaluated. In essence, the project entails constructing transmission towers by meticulously analyzing the forces acting on the structural elements and understanding their properties. It is worth noting that the cost of a transmission tower can vary significantly, ranging from a quarter to half of the total expense, depending on the tower's design. Key elements in this project include analyzers, transmission wheels, load assessment, cost considerations, and wind effects.

I. INTRODUCTION

India possesses a vast population distributed throughout the nation, necessitating an extensive distribution system to meet their electricity demands. When it comes to the support structures employed in transmission lines, they can generally be categorized into three types: lattice frameworks, poles, and animal grazers, particularly cows. EHV tailgates typically form a lattice tower. Minara.co costs about a quarter of the cost of electric cables, so the minimal layer design will save. When designing the structure, you must first simulate it, and this analysis is done in this paper for a shaft 45-meter-high and 20meterwide. In coastal areas, the biggest burden is stormy winds. Wind blades are very special and protect the structure. It can. To make this paper more informative, parts of the framework are explained using different sources, Alu, several research articles on the same topic are reviewed and relevant information is obtained from them. Transmission shaft and undercarriage information from Google, and undercarriage and undercarriage images from Google Images. The image of the harvest power stamp used in Love Me is shown as a serious pro. In the same model at Stud Pro, Le showed a different wind pattern from a different direction than X.-X. Z. and -Z are also shown to act at low levels. Each type of tower roof is exposed to different conditions, so the complete table from Std. The Pro software shows what these exposure conditions and intervals mean. Finally, there is a proof of the output of ear analysis.

The provided graph demonstrates that the values for all the towers are within acceptable limits, indicating that the tower is not at risk of failure. This diagram [1] * Analysis and Design of Three and Four Leg 220KV Steel Vertical Transmission Line: Y.M. A tremendous study by Google and AS Salunkhe. In addition, effect of the wind at various positions depicted by a table. Research [5] also mentions the role of different members of the bridge pier and which is considerably higher in priority in terms of stability. Binary is just as important. The method of restoring the transmission tower column is discussed.

II. LITERATURE REVIEW

In our research, we conducted a thorough analysis of transmission towers under wind loads in coastal regions. Our focus was on the behavior of 3-legged and 4-legged towers, including their foundations, under these loads. We also compared the analysis results from different codes for the same tower.

The paper referenced, titled "Analysis and Design of 220 kV Transmission Line," highlights the complexity of manually analyzing statically indeterminate structures like transmission line towers. It suggests that computer analysis methods, such as using software like STAAD Pro or Ansys, offer precise solutions for the three-dimensional performance of these structures.

The study concludes that the adopted method of analysis, considering linear behavior and two-dimensional approaches, provides satisfactory results. However, it emphasizes the need for further verification using advanced software. According to the design concerns, all sections considered were found to be safe under worst-case conditions.

Overall, our study aims to provide valuable insights to design engineers, particularly those new to the field, by offering a better understanding of transmission tower behaviors and the analysis and design methods based on Indian Standard Codes of practice.

The second paper examines the limitations associated with foundation deformation in conventional Ultra-High Voltage (UHV) transmission shafts. The study analyzes various load scenarios, including 90-degree wind working load, 60-degree wind load, 10 mm ice load, and installation load case. The primary focus is on foundation settlement, adhesion, and displacement under the 60-degree wind load, which is identified as a critical factor for controlling foundation deformation.

In a comparative study titled "Comparison of China's new code with other standards for wind load prediction" by Jiang and Deng, the wind load definition in China's new code was compared with ASCE Standards, IEC60826, BS8100, and 500 kW transmission lines. It was found that China's new code had a smaller payback period and a lower aspect ratio compared to ASCE and IEC60826 standards. Additionally, the height factor for category B in China's new code was similar to IEC60826, greater than ASCE, and smaller than BS8100. For towers exceeding 60 meters in height, the wind load impacting conductors and ground cables was higher in China's new code due to the increased bottom-to-top response factor.

Therefore, China's new code was deemed conservative for tall towers. However, for towers below 60 meters, the wind load prediction in China's new code aligned closely with other standards, leading to more reliable and safe designs.

Another study by Gugal and Salunkhe, titled "Analysis and Design of Three and Four-Leg 400KV Steel Transmission Line Stand: A Comparative Study," compared the performance of three-leg and four-leg tower designs. It was observed that the three-leg towers exhibited advantages over four-leg towers, including a 77.81% increase in the load-bearing capacity of the vertical support component, a 60% increase in moment for the three-foot pier, and a 27.4% increase in deflection of the triangular stud compared to the square stud. Furthermore, the use of a three-legged model resulted in a 21.2% steel weight reduction compared to the four-legged type, highlighting its efficiency in terms of material usage.

The application of Fiber Reinforced Polymer (FRP) structural profiles in transmission line piers was investigated in a study mentioned in reference [6].

The study involved a comprehensive analytical and experimental program focusing on linear-elastic response. The results indicated that FRP structural parts could effectively replace rolled steel corner sections in transmission line towers, provided appropriate connection methods were utilized. The findings emphasized the potential for building transmission line towers with multiple FRP structural components, showcasing the advantages of this alternative material.

Furthermore, an optimization study discussed in reference [8] aimed to optimize the structure of a transmission line shaft for a 132KV double motor circuit. Different tower configurations and materials were considered as variable parameters. Geometry optimization of the tower, in terms of member force, indicated that a tower configuration with 3 panels and a base width of 6.05 m was geometrically safe. The analysis revealed that a tower with a 45° angle and K-span, with a density of 7833.41 kg/m3, achieved the greatest reduction in weight. The use of a narrow base steel truss structure was found to play a vital role in reducing wind load and ensuring structural integrity, especially at greater heights compared to other tower types. The study emphasized the significance of the bottom member in carrying axial forces and its potential impact on the structural integrity of the tower.

Transmission line towers are designed in various types, such as panel structure and pipe pole structure lattice structure. The panel structure towers consist of multiple steel structural components that are joined or welded together. These towers, also known as self-supporting or freestanding towers, can be constructed using steel, aluminum, or galvanized steel materials. On the other hand, pipe pole structure towers are constructed with hollow steel columns, which can be manufactured as a single large piece or multiple smaller pieces that fit together.

The transmission tower is comprised of several important parts. The cage of the ear transmitter forms the lower section of the tower where the transmission lines are connected. Cross arms of the transmitter ear are horizontal arms that carry the current conductors, and their number depends on the number of circuits in the transmission line. The top of the transmission shaft refers to the upper section of the tower that supports the transmission lines. Additionally, there is the transducer housing cage, which provides housing for equipment and devices related to the transmission lines.

The tower bracket denotes the area between the tower body and the top section. The main vertical part of the transmission tower is known as the trap. The crosssectional shape of the tower cage is typically square, and its specific shape depends on the height of the transmission line.

At the top of the tower, the upper cross arm is utilized for attaching the ground wire, suspension clamps, and tension clamps for the transmission lines. It also serves to provide vertical orientation.

In conclusion, transmission line towers consist of various components, including the cage of the ear transmitter, cross arms, top of the transmission shaft, transducer housing cage, tower bracket, and upper cross arm. These components play integral roles in supporting and connecting the transmission lines, ensuring the proper functioning of the power transmission system.

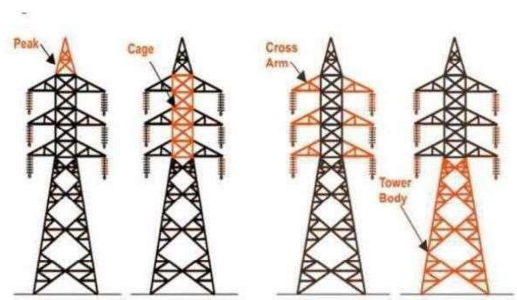

Fig 1- Tower Structure and its components

Fig 2- Depiction of Transmission Tower

III. ANALYSIS OF TRANSMISSION TOWER

It has a height of 45 meters and a width of 20 meters. It is situated in Category 1 terrain with Exposure Condition B. In Figure 3, the analysis is focused on determining the required steel strength based on the tower's height and width. It has been concluded that in order to enhance the safety factor, the yield value of the steel used in the anchor ring should be high. Therefore, a recommended yield value of 500,000 KN per square meter is advised.

Figure 4 pertains to the voltage values observed on the side arm cable of the transmission axle, specifically at the end of the side knob. This analysis takes into consideration various types of transmission lines. It is noted that under extreme conditions, the skin typically experiences a tensile value of 90KN.

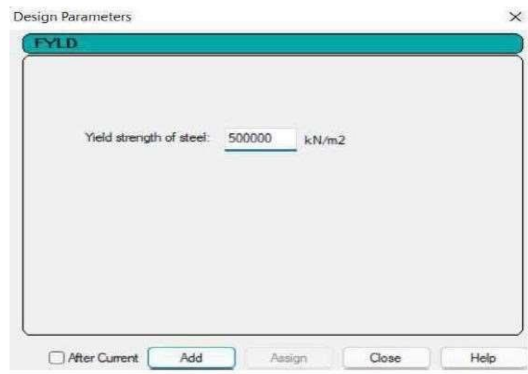

Fig 3-Yield Strength of Steel

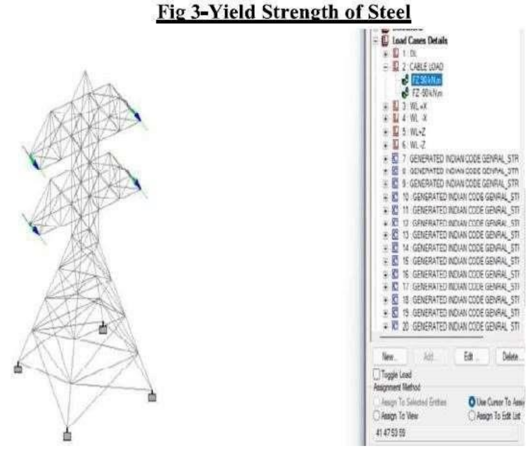

Fig 4-Cable Tension Loads

As part of the wind analysis, it was discovered that the transmission tower experiences wind loading from four distinct directions. These wind directions directly influence the values of deflection and bending moment at the tower. The wind loadings are identified as follows: Figure 4(a) represents wind loading in the WL+X direction, Figure 4(b) represents wind loading in the WLX direction, Figure 4(c) represents wind loading in the WL+Z direction, and Figure 4(d) represents wind loading in the WL-Z direction.

Considering these various wind directions and their corresponding wind loadings is crucial in accurately evaluating the structural response of the transmission tower.

The deflection and bending moment values can be significantly affected by the wind forces acting on the tower from different directions. By analyzing and accounting for these wind effects, the tower's stability and structural integritcan be properly assessed and ensured.

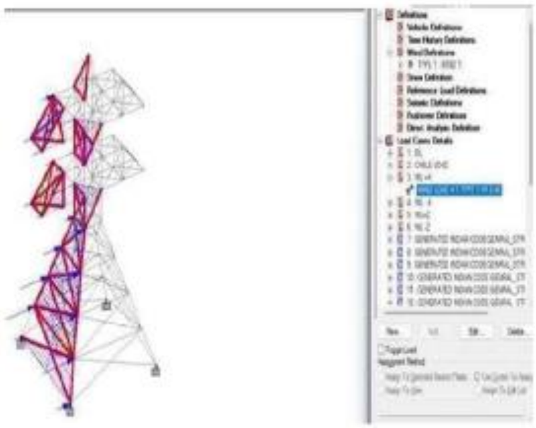

Fig 4(a)- Wind load(+X direction)

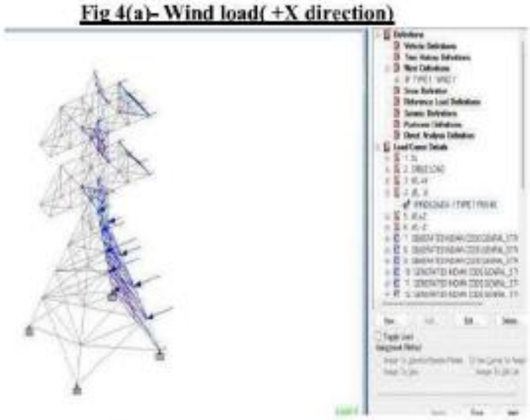

Fig 4(b)- Wind load(-X direction)

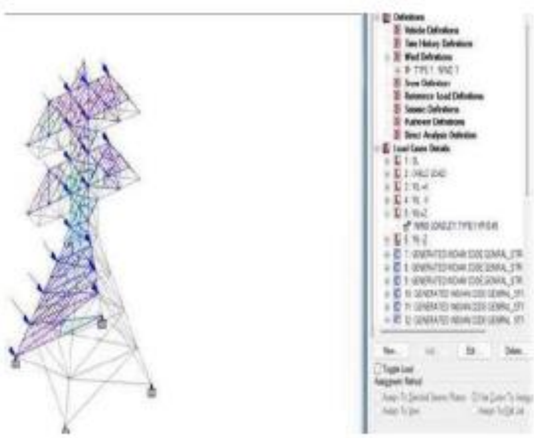

Fig 4(c)-Wind load (+Z direction)

Table 1 Wind Category Description

The EXPOSURE classifications for transmission towers are:

EXPOSURE A: This classification applies when the maximum dimensions of the tower, either horizontally or vertically, are less than 20 meters. It indicates that the tower is exposed to relatively smaller dimensions in its surroundings.

EXPOSURE B: Towers falling under this classification have maximum dimensions ranging from 20 to 50 meters. It signifies that the tower is located in an environment where larger dimensions, within this specified range, may be present in the surrounding area.

EXPOSURE C: This classification is assigned to towers with maximum dimensions greater than 50 meters. It suggests that the tower is situated in an area where substantial dimensions, exceeding the specified threshold, are present in the immediate vicinity.

These EXPOSURE classifications are essential in assessing the potential impact of the surrounding dimensions on the structural integrity of transmission towers. By considering the specific EXPOSURE category, appropriate design measures can be implemented to ensure the tower's stability and resilience in accordance with the dimensions of its environment.

Tables 1 and 2 (CATEGORY & EXPOSURE) In the context of the provided information, Table 1 represents the CATEGORY classification, which denotes the elevation of obstructions, while Table 2 represents the EXPOSURE classification, which denotes the height of the entity being analyzed.

Considering that the transmission tower is situated in a coastal area, it suggests that the terrain is likely to be flat and the environment open. As a result, the obstruction's elevation in the vicinity of the tower is expected to be relatively low, leading to a CATEGORY 1 classification.

Furthermore, the transmission tower itself has an elevation of 45 meters. Based on this height, the tower falls under EXPOSURE B in terms of analysis. This classification accounts for the tower's specific height in relation to wind load considerations and design factors. To summarize, the transmission tower is categorized as CATEGORY 1 due to the expected low elevation of obstructions in the plain and open coastal terrain. Simultaneously, the tower's own elevation of 45 meters places it in EXPOSURE B for the analysis, considering its specific height in relation to wind effects and design considerations in coastal areas.

Table 2-Exposure conditions

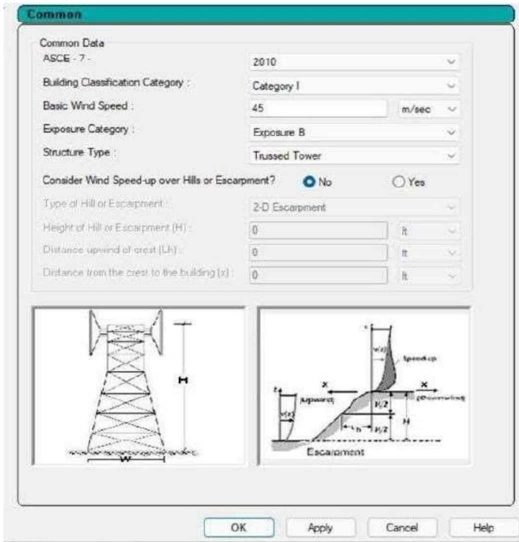

Fig 5-Tower Stipulations

Fig 5 It comprises of the approximations from Fig. 4 as well as the tower details.

Table 3 After all analysis is completed, deflection values for pile dead load, wind load, all load combinations in all directions, and cable load.

L/C	Length m	Max x mm	Dist m	Max y mm	Dist m	Max z mm	Dist m	Max mm	Dist m
1 DL	16.000	-0.001	8.000	-372.747	8.000	0.000	0.417	372.747	8.000
2 CABLE LO	16.000	-0.001	12.000	0.000	0.000	0.000	0.000	0.001	12.000
3 WL +X	16.000	-0.001	10.667	-0.042	4.000	0.004	0.250	0.042	4.000
4 WL -X	16.000	-0.001	12.000	-0.058	12.000	0.010	0.750	0.059	12.000
5 WL+Z	16.000	-0.001	8.000	-0.011	12.000	0.062	0.500	0.062	8.000
6 WL -Z	16.000	0.001	13.333	0.012	4.000	-0.066	0.500	0.066	8.000
7 GENERATE	16.000	0.001	9.333	-559.121	8.000	0.000	0.667	559.121	8.000
8 GENERATE	16.000	-0.002	12.000	-447.316	8.000	0.006	0.250	447.316	8.000
9 GENERATE	16.000	-0.001	8.000	-447.317	8.000	0.013	0.750	447.317	8.000
10 GENERAT	16.000	0.001	13.333	-447.304	8.000	0.075	0.500	447.304	8.000
11 GENERAT	16.000	0.001	13.333	-447.289	8.000	-0.079	0.500	447.289	8.000
12 GENERAT	16.000	-0.001	14.667	-447.278	8.000	-0.005	0.250	447.278	8.000
13 GENERAT	16.000	0.001	13.333	-447.276	8.000	-0.012	0.750	447.276	8.000
14 GENERAT	16.000	-0.001	12.000	-447.290	8.000	-0.074	0.500	447.290	8.000
15 GENERAT	16.000	-0.001	12.000	-447.305	8.000	0.079	0.500	447.305	8.000
16 GENERAT	16.000	-0.001	12.000	-447.297	8.000	0.000	0.500	447.297	8.000
17 GENERAT	16.000	0.001	14.667	-559.145	8.000	0.006	0.250	559.145	8.000
18 GENERAT	16.000	-0.001	12.000	-559.146	8.000	0.016	0.750	559.146	8.000
19 GENERAT	16.000	-0.001	14.667	-559.130	8.000	0.093	0.500	559.130	8.000
20 GENERAT	16.000	-0.002	14.667	-559.110	8.000	-0.099	0.500	559.110	8.000
21 GENERAT	16.000	-0.001	12.000	-559.097	8.000	-0.007	0.250	559.097	8.000
22 GENERAT	16.000	0.001	14.667	-559.095	8.000	-0.015	0.750	559.095	8.000
23 GENERAT	16.000	-0.000	13.333	-559.112	8.000	-0.093	0.500	559.112	8.000
24 GENERAT	16.000	-0.000	14.667	-559.131	8.000	0.099	0.500	559.131	8.000
25 GENERAT	16.000	-0.001	12.000	-335.472	8.000	0.000	0.583	335.472	8.000

Table 3–Result of Analysis

Cases		Relative direction to wind	Limited values in transverse direction(mm)	Limited values in longitudinal direction(mm)
Settlement	90-degree wind	Down wind	165	112
	90-degree wind	Against wind	68	112
	60-degree wind	Down wind	169	134
	60-degree wind	Against wind	65	80
	Accreted ice	/	129	116
	Installation	/	131	116
Inclination	90-degree wind	Down wind	1578	1703
	90-degree wind	Against wind	1705	1703
	60-degree wind	Down wind	1312	1274
	60-degree wind	Against wind	1661	1811
	Accreted ice	/	1750	1784
	Installation	/	1763	1806

Table 4- With respect to the different angles the effect of the wind on the tower.

With the help of this table the table number 4 is derived, it shows the wind striking at different angles of the tower and thus the position and inclination values for the corresponding wind angles. Wind chills can reach 60 degrees.

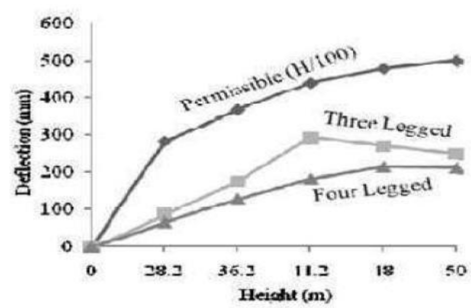

Fig 6– Height v/s Deflection graph

In the context of utilizing studs for jumping, there are two types to consider: three and four legged studs. Notably, when examining a graph, it was observed that the quadruped (four-legged) studs exhibited less deviation compared to the three-legged studs. This suggests that the four-legged studs provide more consistent results in terms of cost-effectiveness during jumping. While additional specific data and context would enhance the analysis, the current evidence indicates an advantage for four-legged studs in reducing cost-related variations.

IV. RESULTS AND DISCUSSION

The transmission tower described is an impressive structure with a height of 45 meters and a square base measuring 20 meters on each side. It features two side arms on each side, designed to provide support and accommodate necessary equipment and cables. The tower is constructed using high-quality steel with a yield strength of 500,000 kilonewtons per square meter (KN/m2), ensuring its strength and durability.

The cable tension applied to the nodes of the side arms, as depicted in figure3,has a magnitude of 90 kilo newton in both global +Z and -Z directions. Wind loads were applied in all four directions, as shown in Figure 4: WL +X for wind load in the positive X-direction, WL -X for wind load in the negative X-direction, WL +Z for wind load in the positive Z-direction, and WL -Z for wind load in the negative Z-direction. The wind load properties were determined based on the tower's location near coastal areas.

The tower was classified under Category 1, representing open terrain with minimal obstructions and surrounding objects typically below 1.5m in height. Considering the higher wind speeds near coastal areas, a wind speed of 45 m/s was selected. The tower's height of 45m falls within Exposure B, which is suitable for structures up to that height. Given that the tower is of a trussed structure type, it was designed accordingly.

To assess the tower's performance, deflection was evaluated. A table in Figure 6 presents the deflection values along all axes resulting from various load combinations. Figure 7 displays a table showing the foundation deflection caused by wind load on the transmission tower. Although the displacement values were relatively small, noticeable deflections occurred in both the transverse and longitudinal directions, contributing to enhanced resistance against foundation deflection.

The permissible deflection limit was determined based on the tower height. Figure 8 depicts a graph indicating the allowable deflection using the formula (H/100), where H represents the tower height in millimeters. With a tower height of 45,000mm, the permissible deflection was established at 450mm. Additionally, the graph highlights that three-legged towers generally experience intense deflections with regards to four-legged towers.

V. OUTCOME

The analysis of the transition wave following postprocessing revealed a correlation between wave deviation and high wind speeds near the coastal area. As a result, it was determined that the shear strength of the structure experienced a slight increase, leading to a corresponding increase in bending moment. To ensure the structure's ability to withstand these wind-induced moments, it is important to design it accordingly. To address the increased bending moment, the foundation and structural elements should be reinforced appropriately. This may involve using stronger materials or incorporating additional support structures as needed. Additionally, the stability of the transmission ear is influenced by its length-to-width ratio. In this case, a ratio of 2.25 has been chosen, aiming to minimize it as much as possible. This design choice helps to reduce shear forces, bending moments, and deflection, ultimately improving the overall stability and performance of the structure.

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