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Review on Torsional Analysis and Design of Transmission Line Steel Tower

Raja Saraf[1], Dr. Rajeev Chandak[2]
Civil Engineering Department, Jabalpur Engineering College, JEC GOKALPUR Jabalpur Pin – 482011

Abstract: This paper presents a review of the state of the art and practice of transmission line tower design with specific attention to structure loading conditions. The structural planning and design process involves not just imagination and intellectual thinking, but also a thorough understanding of structural engineering science, as well as practical knowledge of modern design codes and bye laws, as well as a wealth of experience, intuition, and judgement. The goal of standards is to ensure and improve the safety of people and the environment. Tower is a steel structure developed by maintaining a delicate balance between economics and security.
Keywords: Transmission towers, Geometry of tower, Self-supporting tower, Configuration oftower, unit load, method of joint, deflection, design.

I. INTRODUCTION

Transmission towers are required for the distribution of power 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.

Transmission line towers account for almost 40% of the total cost of a transmission line. The choice of an optimal form, as well as the appropriate sort of bracing system, goes a long way toward producing a cost-effective transmission line tower 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. Electricity is now being used for rail transportation instead of fuel-powered engines due to lower costs. As a result, it is necessary to transfer the high voltage to the area in demand, which necessitates the installation of a transmission line tower to carry Extra High Voltage (EHV) [1-10].

India has a large population residing all over the country and the electricity supply need of this population creates requirement of large transmission and distribution system. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical support of transmission line represents a significant portion of the cost of the line and they play an important role in the reliable power transmission.

They are designed and constructed in wide variety of shapes, types, sizes, configuration and materials. The supporting structure types used in transmission line generally fall into one of the three categories: lattice, pole and guyed. The supports of high voltage transmission lines are normally steel lattice towers.

The cost of tower constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower.

The height of tower is fixed by the user and the structural designer has the task of designing the general configuration and member and joint details. In this paper, the sag tension calculation is carried for conductor and ground wire using parabolic equation. Then different loading format including normal condition, top conductor broken, earth wire broken condition is evaluated.The wind loading is calculated on the longitudinal face of the towers and then two dimensional analysis of the tower is carried outand accordingly the design is completed for different members [11-12].

II. PROBLEM STATEMENT

A 220 kV single circuit transmission line with suspension towers which is situated in wind zone II is selected for the study. Modelling, design and analysis is carried out on STAAD Pro. Software.

The advancement in electrical engineering shows need for supporting heavy conductors which led to existence of towers. Towers are tall structures, their height being much more than their lateral dimensions. These are space frames built with steel sections having generally an independent foundation under each leg. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration, member and the joint details (John D Holmes). A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view, the former decides the general shape of the tower in respect of its height and the length of its cross arms that carry electrical conductors (Visweswara Rao, G 1995). Hence, it has given rise to the relative tall structures such as towers. The purpose of transmission line towers is to support conductors carrying electrical power and one or two ground wires at suitable distance. In this study, a 132kV Transmission line tower is modelled using STADD Pro 2006. The towers are designed for wind zones V with constant base width.

III. DURING DESIGN OF TRANSMISSION TOWER

The base ground leeway of the most reduced conductor point over the ground level.

1) The length of the encasing string.
2) The least leeway to be kept up with among conductors and among conductor and pinnacle.
3) The area of a ground wire concerning peripheral transmitters.

The mid span freedom needed from contemplations of the unique conduct of the conductor and lightning insurance of the electrical cable. To decide the genuine transmission tower tallness by thinking about the above focuses, we have partitioned the complete stature of the pinnacle into four sections:

a) Minimum passable ground freedom (H1)
b) Maximum droop of the overhead conductor (H2)
c) Vertical dispersing between the top and base conductors (H3)
d) Vertical freedom between the ground wire and top conveyor (H4)

The higher the voltage of the transmission line, the higher the ground freedom and verticle separating will in general be. For example high voltage pinnacles will have a higher reasonable ground freedom and bigger verticle separating between the top and base conductors.

IV. 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 materials which are used as conductors for over head transmission lines should have the following electrical and physical properties.

1) It should have a high conductivity
2) It should have tensile strength.
3) It should have a high melting point and thermal stability.
4) It should be flexible to permit us to handle easily and to transport to the site easily.
5) It should be corrosion resistance.

V. LITERATURE SURVEY

1) Edgar, Sordo, T.-H., and Emilio (2017). "Structural behaviour of lattice transmission towers subjected to wind load": Hurricane Wilma hit Yucatan Peninsula in 2005, causing substantial damage to local electrical transmission towers. Based on the failure characteristics observed on such towers, an analytical study is performed to reproduce such failures and assess their vulnerability. Two latticed transmission towers are analysed under the action of 14 di erent wind velocity patterns corresponding to several national and international wind design codes. Displacement-controlled pushover analyses are performed to reproduce impending failure mechanism for considered wind patterns, and associated gradient wind speed is computed. Results illustrate that consistent cyclonic wind speed patterns lead to better estimates of failure mechanism and gradient wind values than traditional non-cyclonic patterns.

2) *Fengli Yang, Huixue Dang, Huawei Niu, Hongjie Zhang, and Zhu, B. (2016). "Wind tunnel tests on wind loads acting on an angled steel triangular transmission tower.":* Wind tunnel tests on scaled models of a triangular transmission tower body made by angled steel members were carried out. The drag coefficients of the total tower body or single frames at nine different test cases were obtained. The experimental results from wind tunnel tests were also mutually validated by computational fluid dynamics (CFD) analysis. The parameters for calculating wind loads on triangular tower bodies determined by wind tunnel tests were compared with the calculated values by some applicable design standards. For the regular triangular tower body with an equivalent solidity ratio for three lateral faces, the experimental curves of the skewed wind load factor Kθ approximately appear like W shape and symmetrical to the axis of θ=60°. Kθ is decreased to the minimum value when the wind incidence angle is 40° or 80°. When the solidity ratio of face A is different from the other two faces, the symmetry axis of the skewed wind load factor Kθ is shifted to θ=50°. Kθ is decreased to the minimum value when the wind incidence angle is 30° or 70°. The varying trend of Kθ, especially for the wind incidence angle corresponding to the minimum Kθ value in British standard, are quite different from the experimental results. Based on a combination of the drag coefficient of single frames and the shielding effect factor, a calculation method for the effective projected areas of triangular tower bodies was proposed. Especially for the wind incidence angle θ of 0° or 120°, the calculated values of the effective projected areas agree well with the experimental values obtained from the total tower-body models.
3) *Julie E Mills, "Experimental study on multi panel retrofitted steel transmission towers":* Due to the increasing demands on power supply and telecommunication services, existing transmission towers are frequently being required to carry extra loads above their initial design limits. A range of methods have therefore been used to increase the capacity of existing towers by retrofitting them in some way. This paper addresses steel lattice transmission towers with main leg members retrofitted by steel angles through bolted double steel angle connectors, a method that is widely used in practice but to date with little experimental research to support it. Three unreinforced tower models and four groups of retrofitted tower models with and without preloading have been tested in the structural laboratories at the University of South Australia. The experimental results verify the effectiveness of the retrofitting method. Load sharing analysis shows that axial loads can be effectively transferred between original tower members and reinforcing members through the bolted-splice system. Preloading reduces the load sharing in reinforcing members in the early loading stage but does not have significant influence on the ultimate strength of the whole structure.
4) *B. Bharath Kumar Reddy, "A Study on Analysis of Transmission Line Tower and Design of Foundation":* The Transmission line towers are one of the important life line structures in the distribution of power from the source to the various places for several purposes. The tower is designed for the wind zone V carrying 132 KV DC. Tower is modeled using constant parameters such as height, bracing system, angle sections, base widths, wind zone, common clearances, span, conductor and ground wire specifications. The loads are calculated using IS: 802(1995). After completing the analysis, the study is done with respect to deflections, stresses, axial forces, slenderness effect, critical sections and weight of tower. Using STAAD PRO v8i analysis and design of tower has been carried out as a three dimensional structure. Then, the tower members are designed.
5) *Sniawlangki T Chyrmang, "Analysis of Transmission Tower":* In this study, a typical type of transmission line towers (suspension tower) carrying 400kV double circuit conductors are modelled and analyzed using Staad.Pro V8i SS5 considering forces like wind load as per IS 802 (part I/Sec 1):1995, dead load of the structure and earthquake load as per IS 1893(part 1):2015. The height of transmission tower is 50m which includes the ground clearance and base width is 10m. The towers are designed into two wind zones i.e. 2 and 6 and it is located in the seismic region Zones i.e. II and V. K and X bracing systems are considered. From the whole analysis, it is found that X bracing is safer in cost as compare to K bracing. Comparison between the bracing systems, Wind zones and Seismic zones of the Towers is done.
6) *Anshu Kumar Pal, "Comparative Analysis of Transmission Tower Using XX and XBX Bracing Systems in Different Wind Zones":* An electrical power transmission line tower has now become indispensable requirement for the proper and safe transportation of high voltage electricity in our day-to-day life since it constitute 25 to 45 percent of capital cost of the power transmission line project. As the cost of the tower include parameters like labor, transportation, erection, etc. which are constant, major focus should be given in optimizing steel quantity for achieving the economical design without compromising the required strength of tower. In this analyzation, a quintessential 220 KV suspension type, square based self-supporting transmission tower having double circuit is taken for scrutinization. Two bracing systems viz. XX and XBX are being compared in all the six wind zones of India using seven different load conditions as per IS 802 (Part-1 / Sec-I):1995. The structural behavior of tower for both bracing systems are modelled and analyzed in STAAD Pro V8i software. The denouement of XBX – bracing system was concluded to be more economical in comparison with XX – bracing system in all wind zones of India.

7) *Jonathan Z. Liang, "Performance of Power Transmission Tower in PMA under Simulated Earthquake Ground Motion":* Transmission towers play an important role in the operation of a reliable electrical power system that is considered as a lifeline system. The performance requirement of fully operational under damage-limitation earthquake is assigned to lifeline system in many current seismic codes to provide protection in the immediate post-earthquake period. Many studies and post earthquake investigations have revealed that the material and geometric non-linearity have a major effect on the ultimate strength of towers and the tower collapse is due to either spread of plasticity or premature buckling. Hence, transmission towers designed by equivalent static analysis method should be examined to check their performance under dynamic loading conditions. In this paper, a study of the performance of transmission tower under damage-limitation earthquake and rare earthquake derived from the seismic hazard analysis of Perth Metropolitan Area (PMA) is carried out. The results are compared with code provisions and recommendations for the design of transmission towers.
8) *Rangoli K. Jiwankar," Comparison of Wind Codes for Transmission Tower":* The transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of the support structure. Mechanical supports of transmission line represent a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in the wide variety of shapes, types, sizes, configurations, and materials. In general, most towers may be idealized as statically determinate and analyzed for wind forces as per IS 875 part 3:1987. Revised code IS 875 is introduced in 2015. In revised code IS 875: Part 3-2015, loading and design parameters are changed. In this paper, the comparison of code IS 875: Part 2-1987 and EN 1991-1-4:2005 will be carried out.
9) *T. Abhiram Reddy, K. Murali, Chekravarty, P. Anil Sagar "Analysis and Economical Design of Transmission Line Towers of Different Configurations Subjected to Wind Load":* Transmission Line Towers represent approximately 28 to 42 percent of the cost of the transmission line. The growing demand for electrical energy can be met more economically through developing exceptional mild weight configurations of transmission line towers. I the present work, an attempt have been made to make the transmission line price effective through converting the geometry (form) and behavior (type) of transmission line structure. The main objective of our study is to design a 220 KV single Circuit Transmission Line carrying rectangular Base Self supporting Towers, which optimize the present geometry, such a suspension towers is replaced by Triangular Base Self supporting Tower. Then, the structural behavior of existing tower is studied with the aid of developing rectangular Base Guyed Mast. Excel programs are developed together with AutoCAD for configuring towers and calculating loading. By using STAAD.pro, evaluation of each of those 3 towers has been executed in a three dimensional systems. Then, the tower members are designed as ISA angle sections. For optimizing any member phase, the whole wind load computations must be repeated, simultaneously the analysis and again the design. Hence, three successive iterations had been carried out earlier arriving at the inexpensive designs of square base and triangular base self supporting towers and the square form guyed mast. Then all the3 towers are compared and analyzed.
10) *Alasdair Brewer, "Dynamic Wind Load Modelling of High Overhead Transmission Line Towers":* This thesis serves to contribute to the ongoing and developing research on the application of dynamic loads to Overhead Transmission line modelling processes. Special focus was on tall overhead transmission line towers. Tall transmission towers usually occur at critical points of a distribution line with most design currently carried out using static loading which is assumed to provide a conservative result. Dynamic load modelling expands the knowledge of the designer as to the true response of a structure under such conditions thereby enabling more informed design. In this thesis a literature review and background to tall transmission towers around the world is presented first. Secondly, the theoretical background and subsequent generation of spatially correlated wind time series which are applied across the height of the tower along with a method for calculating the allowable uplift force of a foundation based on vertical displacement. Thirdly, two finite element models of a Swedish tall transmission tower to model equivalent static and dynamic loads with the latter model also used to find natural frequencies and modal shapes of the tower. The main results show a reduction of 10% in maximum uplift force for the studied tower when modelled with dynamic loads that included static forces for the conductors. A theoretical reduction of up to 18% was obtained when conductor loads were excluded and static and dynamic response of the tower alone studied and compared. Generally, it is demonstrated that a more complete understanding of the tower´s behaviour is achieved through the dynamic process enabling more efficient design.

VI. CONCLUSION

The Geometry parameters of the tower can efficiently be treated as design Variables and considerable. It can be substituted between the transmission line of wide based tower where narrow width is required for certain specified distance. also restricted area (due to non-availability of land), more supply of electric energy with available resources and for continuous supply without any interruption in the transmission line, will demand the use of high altitude narrow based steel lattice transmission tower.

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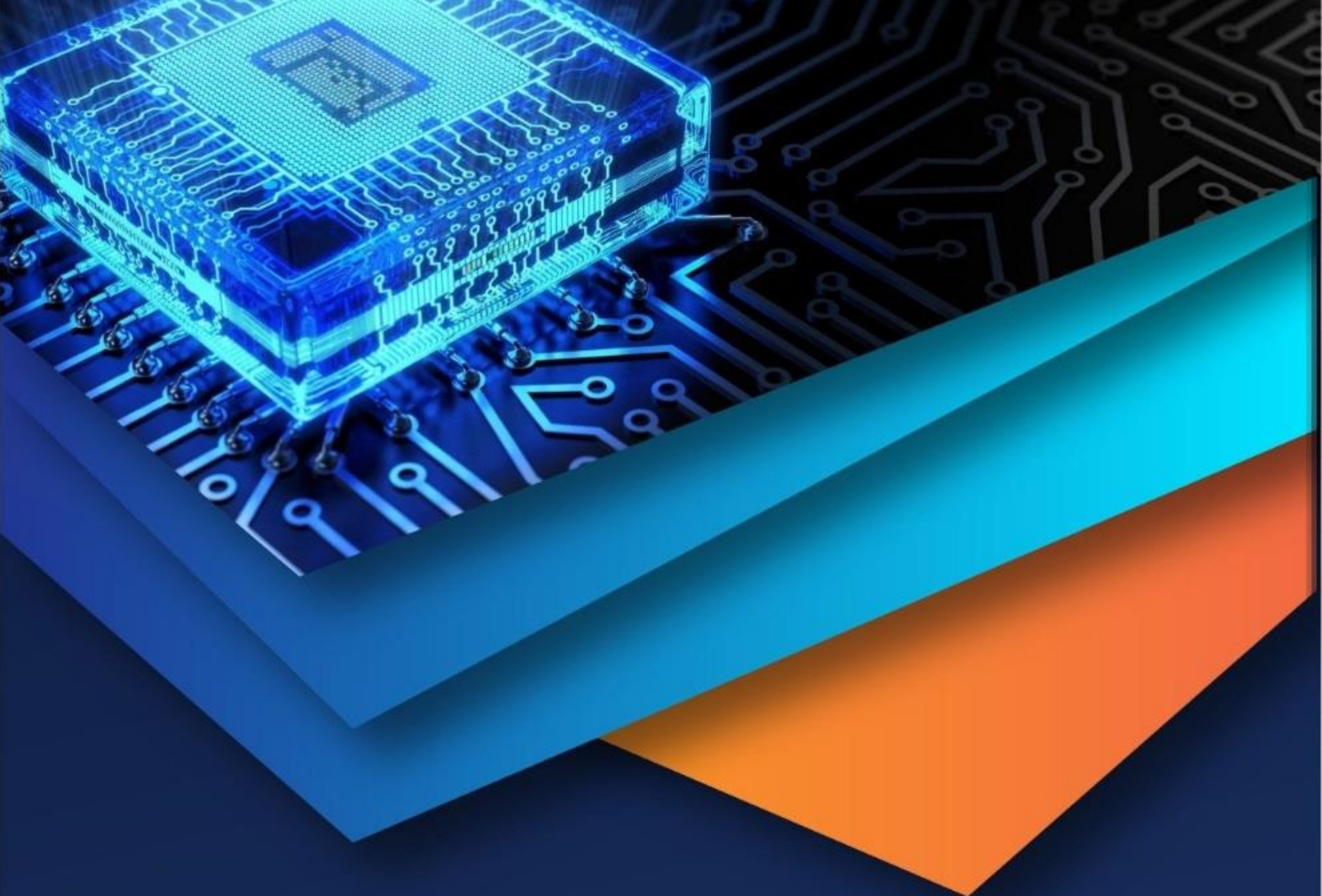

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