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Analysis and design of transmission pole – as an alternative to conventional lattice tower

K. Sathish Kumar [1], J. Selvanathan [2], P.Sarala [3]
[1]PG Student, Department of Civil Engineering, Prathyusha Engineering College
[2]Proporater, JS Tower Consult
[3]Assistant Professor, Department of Civil Engineering, Prathyusha Engineering College
E – Mail: sathish17.rm@gmail.com

***Abstract*— Conventionally for transmission line, lattice towers made of angles are used. For aesthetic reasons and to reduce space at the base, pole structures with polygonal shape, made out of steel plates are used. In this project it is proposed to analyse & design 132KV double circuit transmission pole structures. After designing & analysing the pole structure, the same configuration will be applied on lattice tower, inorder to compare the merits and demerits between lattice & pole. Industry popular PLS-POLE software is proposed to be used. ASCE 48-05 "Design of transmission pole structures" will be used to check the stress limits so as to design plate thickness of various segments of the pole.**

Base plate design & the connection of pole segments either by slip or flange joint also will be studied in this project. Foundations for transmission monopoles with anchor bolt arrangement or bottom segment inserted in block foundation also will be carried out. Finally limitations of transmission towers usage in terms of distance between poles, plate thickness, grade, plate length availability, fabrication and manufacturing are all will be discussed.

***Index Terms*— Transmission Pole, PLS-POLE Software**

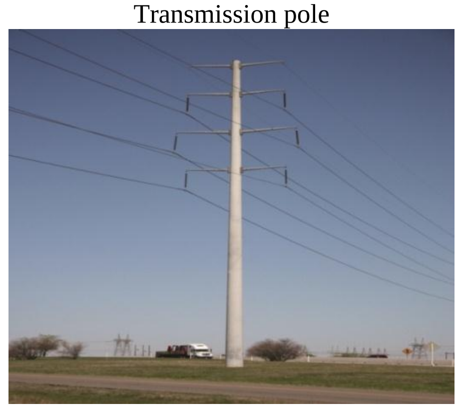
I. INTRODUCTION

Transmission structures support the phase conductors and shield wires of a transmission line. The structures commonly used on transmission lines are either lattice type or pole type. Lattice structures are usually composed of steel angle sections. Poles can be wood, steel, or concrete. Each structure type can also be self-supporting or guyed. Structures may have one of the three basic configurations: horizontal, vertical, or delta, depending on the arrangement of the phase conductors. Generally the transmission line Poles are classified into two major types viz. Tangent and Suspension type towers. It is also classified according to the number of circuits carried by them viz. Single, Double and Multiple Circuit towers.

Nowadays most of the transmission utilities are facing problems in laying the transmission lines in urban areas due to severe Right Of Way (ROW) problems. This is in view of non-availability of adequate land for installation of conventional lattice type towers. To overcome these practical difficulties, new concept of transmission lines on poles. Transmission poles made of wood, steel, or concrete are used on transmission lines at voltages up to 345-kV.

A transmission line tower comprises of cross arm members, conductors etc., Self-weight and Wind loads are the major criteria under which the tower was essentially designed. Situations such as Broken wire conditions, angle of deviation, icing loads, erection loads etc., are also taken into consideration. The members and connections are detailed by specified codal provisions.

Transmission pole



Wood poles can be economically used for relatively shorter spans and lower voltages whereas steel poles and concrete

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S. B. Author, Jr., was with Rice University, Houston, TX 77005 USA. He is now with the Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar.colostate.edu).

T. C. Author is with the Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA, on leave from the National Research Institute for Metals, Tsukuba, Japan (e-mail: author@nrim.go.jp).

poles have greater strength and are used for higher voltages. For areas where severe climatic loads are encountered, steel poles are often the most cost-effective choice. Steel poles have smaller plan dimension and are composed of only few pieces, compared to the lattice towers. The use of X-braces significantly increases the load carrying capacity of H-frame structures. At line angles or dead end conditions, guying is used to decrease pole deflections and to increase their transverse or longitudinal structural strength. Guys also help prevent uplift on H-frame structures. Large deflections would be a hindrance in stringing operations.

II. STUDIES ON TRANSMISSION POLE

Literature reviews for this project were collected based on the area of study required for this project, namely regarding the analytical, foundation, and failure criteria.

M. Ashraf, H.M. Ahmad and Z.A. Siddiqi (1993) studied on “power transmission poles”. An in-depth study into behaviour of high voltage transmission poles has been made covering their loading, analysis and design aspects. Due to large displacements produced, the secondary effects have to be accounted for in the solution of pole structure. Therefore, it becomes necessary to consider the geometric non-linearity while analysing a pole. For this purpose, “Tapered modelling technique” has been introduced by the authors. The finite element method, considered to be providing exact solution, is based on use of thin shell elements, requires a considerably large computer time and memory. Other available modelling techniques are based on frame elements, solutions of which are not found in good agreement with the exact solution unless nodes selected are appreciably high in number.

R. Balagopal and N. Prasad Rao (1992) studied on “Comparative studies on conventional monopole and microwave towers”. In urban areas with high density of population, great difficulties are experienced in finding land for installation of conventional lattice towers. Since the pole structures have smaller dimension and occupying lesser space for installation, they found to be a suitable alternate for lattice towers. Hence in the present study, self-supporting Microwave (Mw) lattice tower and telescopic steel tubular pole of 30m and 40m height is considered. The behaviour of these structures is studied under same wind speed, terrain category and antennae loading. The lattice tower made of steel angle sections is modeled by using beam elements and four noded plate element is used for modeling the shaft of the pole using NE NASTRAN software. Weight comparison is made. Simplified numerical model of the lattice tower and pole structure is developed based on model order reduction technique in MATLAB platform to compute the modal characteristics of these structures and subsequently compared with results of FE analysis.

N. Prasad Rao, R. Bala Gopal, et al (2012) conducted “Analytical and experimental studies on 400 and 132 kV steel transmission poles”. Self supporting lattice type towers are most commonly used for power transmission. It is very difficult to get land in urban areas for installation of conventional lattice towers for power transmission. Poles are suitable alternate supports to the conventional lattice towers. Test results from full scale testing conducted on 400 kV double circuit and 132 kV single circuit self supporting transmission line steel monopoles are compared with the analytical results in this study. The main shaft is hex decagonal in shape and with tapered cross section and the cross arms and ground wire peaks are of octagonal shape. The shaft is made of five segments and connected by telescoping splices.

Andres Torres (2013) presented “Transmission Poles Overview”. A general overview of different characteristics of transmission poles and general design considerations included in the ASCE Standard ASCE/SEI 48-11 Design of Steel Transmission Pole Structures is provided. Information related to pole geometry and typical single pole configurations is provided. Then, information about connection between sections and types of foundations typically used by transmission poles is provided. A section is dedicated to explain two of the most important elements, strength and deflection, that need to be considered in the design of transmission poles. Finally, two examples are given to illustrate the effect of limiting two variables, deflection and base diameter, in the design of transmission poles. Proper detailing and fabrication, full scale testing, quality assurance, quality control and assembly, and erection are also dealt. Communication between line designers and transmission poles designers is essential to develop the most cost-effective design for the specific characteristics of a project.

V. Narayanan (2013) performed “Study And Design of Monopoles for Power Transmission Lines”. The details of adoption of Monopoles for Power transmission Lines of 66kV-110KV-220kV towers in view of the urban population influx, throwing land for construction, impossibility is also explained in detail. Same arguments hold good in rural areas where agriculturists, due to already shrunk agriculture to reasons of no water, no power, and unwillingness to sell even at high prices. Due to the increased population, more mouths are to be fed, and it is not in the National interest to go in for large based towers in rural areas also losing agricultural law. For the present, Monopole seems to be an Optimum solution for all the above pestering difficulties.

D.Prasad, R. Kumaran et al (2016) presented “Emerging Solution For Line Compaction”. Various solutions for line compaction have been discussed. The four emerging technologies that support increased power transmission capacity for a given right of way (ROW) and clearance level has been dealt in detail. Use of high temperature low sag (HTLS) conductor, which has relatively low sag at high operating temperature is suggested to reduce the height of the tower. Sag-tension calculations were made at different temperature levels and comparison was made to indicate how the usage of HTLS can have an impact on line compaction. Insulated crossarms can restrict the inward and outward swinging of the insulator. Monopole structures, which have a very small footprint are suggested instead of broader lattice tower. Monopoles are more flexible and have improved stability against wind loads. Testing of monopole structure at different load conditions is also presented.

III. OBJECTIVES

- In urban areas with high density of population, great difficulties are experienced in finding land for installation of conventional lattice towers. Since the pole structures have smaller dimension and occupying lesser space for installation, they found to be a suitable alternate for lattice towers.
- To design the pole structure PLS-POLE Software is used.
- Base plate design & the connection of pole segments either by slip or flange joint also will be studied in the software.
- Foundations for transmission monopoles with anchor bolt arrangement or bottom segment inserted in block foundation also will be carried out.

IV. CALCULATIONS

Sag Tension

During erection of the overhead lines, the sags and tension to be allowed for various spans under the ambient conditions will also have to be properly evaluated, so that the line may give long and trouble free service. Sag tension are calculated using excel sheet. This is the first step involved in tower designing & analysing.

Sag tension should be evaluated or calculated in six conditions, So that every possible conditions are taken into considerations.

- Every day temperature (i.e. Normal temperature) with No Wind
- Every day temperature (i.e. Normal temperature) with Full Wind
- Minimum Temperature with No wind
- Minimum Temperature with Full wind
- Maximum Temperature with No wind
- Maximum Temperature with Full wind

The highest value of this six conditions will be taken as the sag tension value and it will be applied to the pole structure for analysis and other purpose.

For mallard conductor the sag value is 2.83m and the tension value is 51.1kN.

For GSW the sag value is 1.8m and the of tension value is 15.66kN.

Wire Load Calculation

Transmission pole are designed to withstand the following type of loads. These three load calculations should be calculated for two conditions. They are

1. *Transverse Loads*

Normal wire condition.

2. Broken wire condition.

Transverse Loads

Transverse loads are due to:

1. Wind on structure, conductor and insulator.
2. Deviation in the line.

Transverse load acts parallel to the longitudinal axis of the cross-arms.

After calculation,

Transverse NC – 9.91kN (for mallard conductor)
Transverse BWC – 6.0kN (for mallard conductor)
Transverse NC – 3.805kN (for GSW)
Transverse BWC – 2.169kN (for GSW)

Longitudinal Loads

Longitudinal load is due to unbalance tension in the conductor, produced either due to dead-ending of conductor on the structure or due to broken wire conditions. It acts along the direction of the line and the component at right angle to the longitudinal axis of the cross-arm is considered for design.

Longitudinal BWC – 35.63kN (for mallard conductor)
Longitudinal BWC – 15.11kN (for GSW)

4.2.3Vertical Loads

1. Self-weight of conductor, ground wire, insulator strings and accessories.

Vertical NC - 5.187kN (for mallard conductor)
Vertical NC - 1.48kN (for GSW)

2. Unbalanced vertical loads under broken wire condition.

Vertical BWC – 4.1kN (for mallard conductor)
Vertical BWC – 1.12kN (for GSW)

V. ABOUT SOFTWARE

PLS-POLE is a powerful and easy to use Microsoft Windows program for the analysis and design of structures made up of wood, laminated wood, steel, concrete and Fiber Reinforced Polymer (FRP) poles or modular aluminium masts. The program performs design checks of structures under user specified loads and can also calculate maximum allowable wind and weight spans. Virtually any transmission, substation or communications structure can be modeled, including poles, H-frames, A-Frames, and X-Frames. These models are rapidly built from components such as poles, arms, guys, braces, and insulators.

PLS-POLE is the result of nearly 25 years of evolution from our earliest structural analysis programs. It is the direct successor of our popular CPOLE, CFRAME, SPOLE, SFRAME, WPOLE, WFRAME and G-MAST programs. During our years supporting these programs we have continually refined our algorithms, user interface and program design. The result is PLS-POLE, a powerful and comprehensive design tool with unsurpassed reliability and ease of use.

VI. METHODS OF ANALYSIS

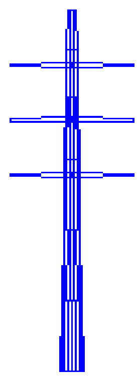
The response of a tubular structure subjected to factored design loads is generally nonlinear. Geometric nonlinearity (also called second-order effect) results from displacements that can be substantial. Material nonlinearity may occur in the behaviour of the steel material, with localized yielding taking place. Localized yielding may even take place at load levels less than design loads because of stresses induced during manufacturing.

Three states of behaviour can be described for a tubular structure: elastic state, inelastic or damage state and ultimate or collapse state. A structure is in the elastic state if it does not sustain permanent deformation under loading conditions. A structure is in the inelastic or damage state if it can safely carry the loads but sustains permanent deformation. Repair or replacement may be required depending on the extent of damage sustained. A structure is in the ultimate or collapse state when the loads cannot be supported. Geometric nonlinearities are present in all three states. Material nonlinearity becomes significant only in the damage or ultimate states. It is not significant in the elastic state.

The Structure Designer shall use established principles of structural analysis to determine the forces and moments caused by the factored design loads.

VII. MODELING

A Industry popular software PLS-POLE is used for modeling the tower. The below diagram shows the geometry of the pole. This is the basic or first to start a pole structure. This structure will be further developed to get a perfect structure.



Geometry of Pole Modeled in PLS-POLE

Further developing the structure by providing insulators etc., the calculated loads will be applied on the structure to research the analytical performance of the structure. The software will show the deflections and usage of the every member of the pole structures.

VII. CONCLUSION

In the future work, the proposed model will be then subjected to the calculated loads. The response of the tower to the applied loads will be taken and if necessary improvements will be made. The connections of the pole segments will also be analysed and studied. The base plate design and anchor bolts will be also done using the software.

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