Study of Chronological Development and Design of Transmission Tower

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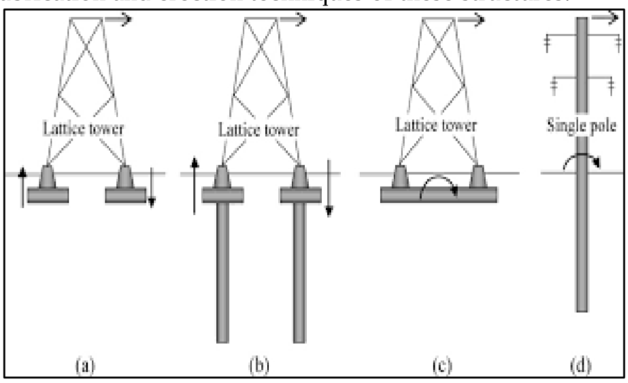
Abstract— The test procedure and structural behavior are discussed and compared to predictions from alternative methods of analysis. The prototype satisfied primary design objectives for behavior and could offer significant advantages relative to current design practice for power transmission structures. Currently, many resources exist to help designers accurately define and apply transverse loads to power transmission structures. However, there is less guidance available for longitudinal loads such as those applied by broken conductors. Current practice focuses on mitigating the effects of cascade events rather than stopping them altogether. An alternative approach for considering longitudinal loading is discussed that could prevent cascades through the use of the prototype structure that can sustain high loads while undergoing large longitudinal deflections. Such an approach could increase system reliability and security while reducing both initial and life-cycle costs of the power transmission infrastructure.

Keywords: Poles, Fuse Plates, Bolts, Welds, Auto-CAD, Ansys 13.0

I. Introduction

In this work, the analysis of poles is carried out by tapered model along with one of the standard packages based on finite element method. It is gratifying to note that the results obtained from developed tapered model are observed to be having close agreement with those of exact method. The lattice skeletal towers are being employed for transmission lines almost since the beginning of this industry. During the last two or three decades, the use of steel pole structures for this purpose is started and their use is increasing rapidly. With the growing demand, a considerable increase in the number of manufacturers with new configurations of poles and towers has occurred. They are also equipped with new design, fabrication and erection techniques of these structures.



II. Advantages

– Poles are subjected to lesser wind loads as compared to towers due to smaller aerodynamic coefficient, thus economizing their use.
– Poles, being a continuum type, offer more resistance to terrorist activities compared with those of towers.

Fig. 1: Analytical Models for Poles

A limited research work is carried out on the transmission poles/masts. Task committee on steel transmission pole structures, IS CODE Structural Division, has done a significant work on the subject matter. This report provides a uniform basis for the design and fabrication of steel pole structures. However, load deflection (P–Δ) analysis mentioning deflection limitation and compression capacity (buckling load) for non-prismatic members like tapered and elliptical polygonal poles etc. are not given in this report. Analysis aspects are introduced without reasonable details and are too brief to understand.

III. Analysis based on tapered model

This simplifies the analysis but keeping the acceptable level of accuracy. Another advantage of this modeling technique is its in-sensitivity for the number of nodes. Only loaded points, segment junctions and support points need to be considered in the analysis. It is further gratifying to note that the Tapered Model leads to conservative results compared with the exact solution. The analysis technique is based on the uniformly tapered polygonal tubular mast model whose differential equations have been developed along with their solution. This is the most accurate representation of steel pole structure among all other methodologies, with the exception of mast analysis based on finite element method. However, the exact solution requires considerably large computer memory, time and efforts.

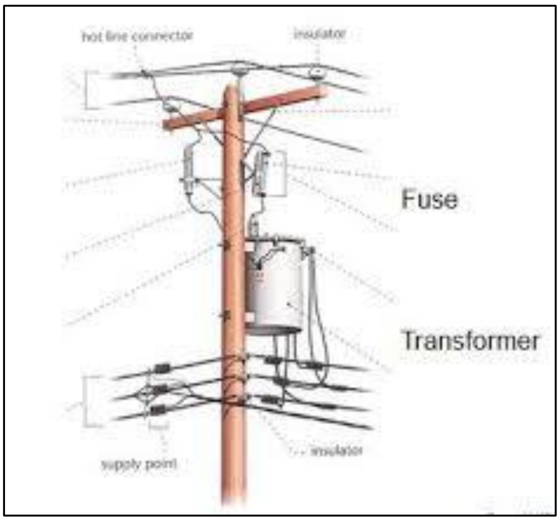
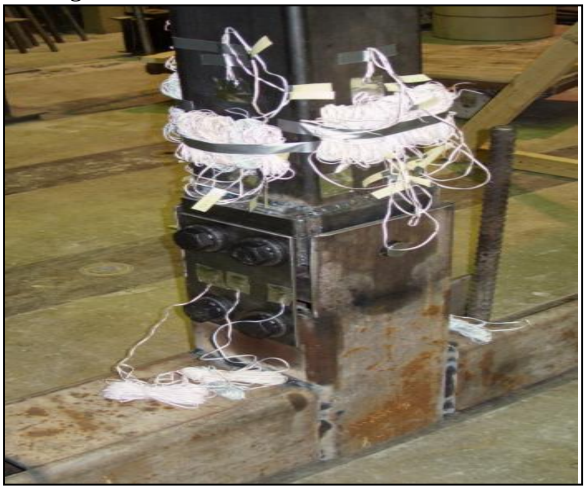


Fig. 2: Dimensions of the Selected 220 KV Twin Bundle Tangent Pole

One major deficiency is the fact that overhead power transmission systems as currently designed are susceptible to progressive or cascading collapse because failure of one structure or system component may well result in failure of successive structures through a lack of redundancy. Current codes and guidelines recognize this susceptibility and adopt empirical rules to mitigate the risk of such occurrences. The primary means of mitigating this risk is through the use of intermittent, expensive dead end structures to limit the magnitude of a cascade, thus leaving the lighter structures between dead ends vulnerable. Furthermore, because progressive collapse is often the result of secondary loads triggered by an initial component failure, this vulnerability is particularly difficult to quantify.

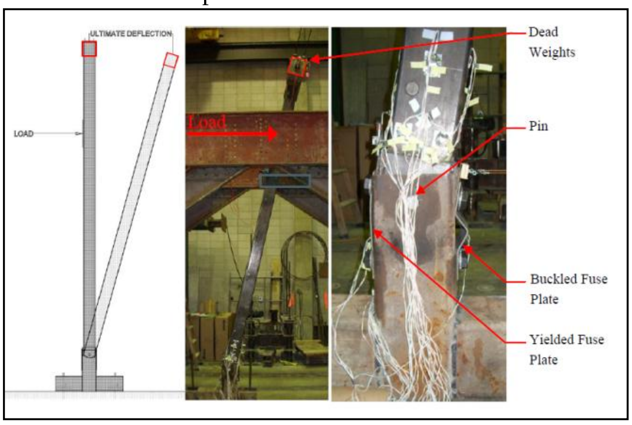
IV. PROTOTYPE SPECIMEN

As an alternative to the current practice of using dead-end structures to contain cascading collapses, the prototype power transmission structure discussed here is designed to achieve several objectives to prevent cascades at the point of origin. The primary objective is a high deflection capacity. Target behavior in this regard involves reaching 15–20% drift while sustaining at least 70% of peak lateral load resistance. This deflection capacity is required to allow adjacent structures along the line to share extreme loads. Secondary design objectives for structure behavior are high initial stiffness, constructability, and reparability. Another desirable, but less important, objective is the ability of the structure to provide self-restoring forces once the extreme loads are removed. The prototype structure envisioned is a modified monopole that can achieve these objectives through three important features. Presently there is no specific guide for deflection limits of structures leaving it up to the local utilities or design companies. For this reason, structures are designed with a broad range of stiffness values.



V. TEST SETUP

The tests were conducted by pushing the prototype structure with a displacement controlled actuator mounted at a height of 3.99 m while recording load and displacement data. Strain data was collected in the structural fuses and the lower portion of the HSS 203.2x203.2 (HSS 8x8) segment to monitor levels of stress and verify that no inelastic deformation occurred in the HSS. Load cells were placed on the post-tensioning rods to monitor and record the changes in post-tensioning forces during the test. Deflection was also measured at several heights along the test specimen. The ultimate displacement of the test specimen was estimated to be nearly twice this value. To achieve ultimate displacement a procedure of blocking the specimen and repositioning the actuator was applied. At full stroke the test specimen was braced in its deflected position, and the actuator was disconnected from the specimen and retracted. A block was then inserted between the load frame and actuator to effectively double the stroke. The actuator was then reconnected to the specimen and the test was resumed.



VI. Conclusion

A transmission line constructed with the proposed prototype poles could save initial construction costs by reducing the spacing of or eliminating dead-end structures, allowing lighter structure designs, and providing rapid, efficient means of construction. Significant savings could also be realized in the event of an extreme load because structures could be repaired quickly and economically rather than requiring replacement. Such a solution could be more sustainable in the long-term. Because testing has only been done on reduced scale structures, full-scale testing is needed to develop details, verify behavior, and quantify actual costs of implementation of this proposed design approach. The structural fuse plates and post-tensioning system effectively allow the designer to control the initial stiffness, peak lateral load, and ultimate load and deflection capacity. Designing transmission lines as a system of structures with carefully prescribed behavior, such as large deflection capacity, can introduce redundancy and thereby increase reliability. The prototype could be easily constructed by connecting the two segments of the prototype at the hinge, rotating the upper segment into place, and then connecting the post-tensioning and fuse plates. The base segment was detailed to allow post-tensioning to be performed from ground level. Both finite element analysis and simplified analytical calculations were able to predict behavior with reasonable accuracy. The ability of simplified analytical approach to predict behavior through ultimate failure of the structure implies that successful design could be accomplished without non-linear finite element analysis.

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