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Accurate modeling of joint effects in lattice transmission towers

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ABSTRACT

Lattice Transmission towers are vital components of overhead transmission lines which play an important role in the operation of electrical power systems. Accurate prediction of the structural capacity of lattice towers under different failure modes is very important for accurate assessment of the reliability of transmission lines and power grids, and for design of efficient failure containment measures. Traditionally, lattice towers are analyzed as ideal trusses or frame-truss systems without explicitly considering loading eccentricities and slippage effects in bolted joints. Such effects are always observed in full-scale tower tests and introduce great differences in the ultimate bearing capacity and failure modes obtained from classical linear analysis models. In this paper experimental results available from full-scale prototype tests of a single-circuit 110 kV and a single-circuit 220 kV lattice transmission towers subjected to different load cases are presented and compared with those obtained from four series of numerical models that include joint eccentricity effects and different joint slippage models. The numerical simulation results confirm that joint slippage dramatically increases the deformation of the lattice towers, while its influence on load-bearing capacity will vary in different load cases according to the magnitude of vertical loading and the tower failure mode. Results from the pushover nonlinear static analysis of the towers considering both joint slippage and eccentricity are found in agreement with the experimental results. This type of analysis can be used to model joint effects in lattice towers.

1. Introduction

Lattice steel transmission towers are widely used all over the world as conductor supports in electric transmission grids. Classical lattice towers are self-supported and constructed of angle section L-shape members typically connected with bolted joints. In many instances, these bolted connections introduce eccentricities between the load transferred at the joints and the longitudinal principal axis of the member. Each tower comprises several joint configurations in terms of geometry, continuity, presence of gusset plates, bolt arrangements and load transfer eccentricity, which make these lattice structures difficult to be analyzed with accuracy using classical linear methods even when material nonlinearities are negligible. When loads are approaching the tower's capacity, however, both geometric and material nonlinearities have combined effects that cannot be traced with linear analysis. Most of the latticed towers presently in service around the world were designed using traditional stress calculations obtained from linear elastic ideal truss analysis, whereby members were assumed to be concentrically loaded and pin-connected. Tower designers have long recognized that the results of those ideal truss analysis models cannot match full-scale test results very well. Peterson [1] and Marjerrison [2] reported that during full-scale transmission lattice tower tests the analysis results would grossly underestimate the measured deflections, which might be as large as three times the theoretical linear elastic deflections. The discrepancy between the experimental results and the analytical solutions has traditionally been compensated by safety factors in member and connection design. However more analysis accuracy is necessary to assess realistic failure modes and tower capacity at ultimate loads. When the tower member deformations remain in their elastic range, the discrepancy between linear analysis models and actual tower response stems from two main sources: (1) Second-order effects caused by joint eccentricity (as shown for example in Fig. 1 where e_y, e_z are the respective eccentricity about local principal axes y and z), and (2) the occurrence of slippage effects in bolted joints (see Fig. 2), which leads to additional second-order effects.

Joint effects in lattice transmission towers have been studied for several decades and are now well-understood. Knight and

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