Simulation Analysis on Force Characteristics of Transmission Tower by Foundation Settlement

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ABSTRACT. In order to study the foundation foundation settlement under the most unfavorable conditions for the comparative analysis of the internal force development and deformation of the transmission tower and its jack-up electric tower, combined with the finite element structural analysis software Midas, a 110kv transmission tower and its jack-up tower are carried out. Modeling and comparative analysis. In this paper, the corresponding laws are summarized, and suggestions for the design of the jack-up electric tower under the action of foundation displacement are proposed for designers' reference.

1. Introduction
With the continuous development of China's economy, the power consumption in various regions has been increasing year by year. Transmission lines are more and more appearing in areas with poor geological conditions [1]. As a new type of adjustable electric tower, whether the internal force development and deformation of the structure of the jacking tower is different from that of the ordinary tower under the action of settlement, and whether there are structural defects in the design compared with the ordinary tower is still lack of systematic research. In recent years, transmission tower safety assessment has been widely studied [2-6]. Based on the research, this paper mainly chooses the most unfavorable settlement as the main research object. Taking a transmission line project of transmission tower as the background, with the aid of the finite element software MIDAS, the safety assessment model of transmission tower is established, and the effect of foundation displacement is calculated and analyzed. Based on the stress condition of transmission tower and jacking tower, the relationship between foundation displacement and safety reliability of transmission tower and jacking tower is given. According to the stress characteristics of transmission tower and jacking tower under different foundation displacement, the design scheme of jacking tower under foundation displacement is proposed for reference of designers.

2. Finite element model
2.1. Model parameter
The existing SD1 of a 110 kV transmission line is a self-supporting Double Circuit Tower. The tower has a height of 36 m, a height of 46 m, a width of 6.130 m, a narrow side of 4.550 m, a conductor model of lgj-240, a ground wire model of gj-50, a tower leg of Q345 angle steel, a skew material and a transverse bar of Q235 angle steel, a design wind speed of 35 m/s, and no icing. In this paper, the tower model does not consider the tower material node connection, and its finite element calculation model is shown in Figure 1. The power transmission tower of the same type is adopted for the jacking tower, and the jacking foot support is 3M high. The vertical layout under the original support is shown in Figure 2.
2.2. Constraint condition
In the finite element model, the tower leg support is consolidated. By applying vertical or horizontal displacement to the support node, the uneven settlement, inclination and root opening change of the transmission tower caused by the actual foundation and foundation displacement are simulated. Tower foundation support number is shown in Figure 3.

3. Numerical calculation method
3.1. Failure criteria
The transmission tower is generally a high-order statically indeterminate structure composed of angle steel. The pull rod in the tower is generally strength failure, the compression rod is mostly instability failure, and the allowable stress of the tower member is the yield strength of the material. When the axial tensile stress of the pull rod reaches the allowable stress, the pull rod will be subject to plastic deformation. At this time, the internal force of the section will reach the yield strength of the material, but the pull rod still has certain strength, so it can continue to participate in the calculation. When the plastic deformation of the straight pull rod reaches the preset value, it can be considered that the structure is damaged. For the compression rod, when the axial compressive stress exceeds the allowable stress of the rod, the rod will lose its stability, but the rod will lose its stability There is post buckling bearing
capacity after instability, and the unstable members still contribute to the overall stiffness of the tower [7].

The displacement of the base support of the tower leg causes the deformation and additional stress of the whole tower. It can be seen from the references that the geometric nonlinearity of the transmission tower is not obvious, and it can be seen from the references that the internal force of the members does not change much before and after considering the $P - \Delta$ effect. Therefore, geometric nonlinearity is not considered in the analysis of this paper, and the strength design value of tower material is taken as the failure criterion of tower material, that is, when the maximum stress of tower material exceeds its strength design value, the tower material is considered as failure.

In this paper, when the Midas software is used to study the failure mode of the tower, the gradual increment method is adopted, that is, when calculating the displacement and other reactions of the structure with each increment of load applied, the structure is considered to be linear and the stiffness matrix of the structure is constant. In essence, it is a piecewise linear polyline instead of a nonlinear curve.

3.2. working condition analysis

The settlement of the foundation is mainly studied under the following conditions (X-direction is along the line direction, Y-direction is perpendicular to the line direction, z-direction is vertical and upward is positive direction)

- (1) single support sinking.
- (2) the two supports of Y-direction AB sink at the same time.
- (3) the two supports of BC in X direction sink at the same time.
- (4) ABC three support sinking.

4. Calculation and analysis

The calculation and analysis show that the upper part of the tower body is little affected by the settlement of the foundation support, and the displacement and internal force are mainly concentrated on the tower legs, inclined materials and diaphragm members near the bottom, and the lower structure is the first to fail. Therefore, the failure mode of the bottom material is mainly considered.

4.1. Working condition (1) single support sinking

The calculation and analysis show that with the settlement of support C, the tower legs C and a are under tension, and the tower legs B and D are under pressure. For every 5mm settlement of single support C, the stress combination value of tower leg D increases by 16.69% of the maximum stress design value. When the support C settles to 30mm, the tower leg d first reaches the maximum design stress (380MPa) and fails. The deformation of the bottom of the original transmission tower under condition 1 is shown in Figure 5.

With the settlement of support C, the tower leg C and tower leg a are under tension, and the tower leg B and tower leg D are under pressure. For every 5mm settlement of single support C, the stress combination value of tower leg D increases by 3.12% of the maximum stress design value. When the support C settles to 162mm, the tower leg d first reaches the maximum design stress (380MPa) and fails. The deformation of the bottom of the original transmission tower under condition 1 is shown in Figure 6.
4.2. Working condition (2) and working condition (3) two bearings sink at the same time

Under working condition (2) and working condition (3), the two bearings sink. With the increase of the settlement, the maximum overall deformation of the transmission tower always occurs at the top of the tower, and the displacement of the tower top increases rapidly to form a tilt trend. The maximum displacement of the tower top increases 506.31mm with the settlement of 50 mm of AB bearing, The maximum displacement of the original transmission tower increases 377.29mm with the settlement of BC bearing of 50mm. The maximum displacement of the top of the tower increases by 603.3mm with the settlement of 50 mm of the AB support, and 447.81mm with the settlement of 50 mm of the BC support. In case (2) and case (3), before the internal force reaches the ultimate bearing capacity, the transmission tower loses stability first.
4.3. Working condition (4) ABC three support sinking
The calculation and analysis show that with the settlement of the original transmission tower with the combination of support ABC, tower leg C and tower leg a are under tension, and tower leg B and tower leg D are under pressure. For every 10 mm settlement of single support C, the stress combination value of tower leg D increases by 19.43% of the maximum stress design value. When the support C settles to 41mm, the tower leg d first reaches the maximum design stress (380MPa) and fails. The deformation of the bottom of the original transmission tower under condition 4 is shown in Figure 13. With the combined settlement of support ABC, the tower leg C and a are under tension, and the tower leg B and D are under pressure. For every 10 mm settlement of single support C, the stress combination value of tower leg D increases 22.66% of the maximum stress design value. When the support C settles to 43mm, the tower leg d first reaches the maximum design stress (380MPa) and fails. The deformation of the bottom of the tower under the original transmission tower under condition 4 is shown in Figure 14.
5. Conclusion
Based on software analysis and result comparison, the following conclusions can be drawn:

• Single support settlement is the most unfavorable condition, which is most likely to cause tower leg material failure and cause structural damage. Under its action, the damage settlement of the jacking tower is far greater than that of the original transmission tower. The transmission tower designed according to the original transmission tower design standard can improve the bearing capacity and stability of the structure after jacking.

• The settlement of double supports will lead to the rapid increase of tower top displacement, which is most likely to cause instability. The height of the tower after the top lifting increases. Compared with the original transmission tower, the tower top displacement slightly increases.

• Under the action of uneven settlement, the tower leg always reaches the yield strength of the material first. The deformation of tower top is much larger than other positions.

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