Application of Transmission Line Tower Foundation Protection in Power Engineering

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Abstract. The area of mountains, hills and plateaus in China accounts for about 69% of the total land area of the country. It is inevitable that the UHV and HV transmission lines under construction will be built in areas with complex geomorphic characteristics. This paper mainly describes the application of transmission line towers in practical projects, from geological survey, tower stability to foundation reinforcement solutions.

Keywords: power engineering, foundation slope stability, foundation protection.

1. Introduction

With the sustained and rapid development of the world economy, energy consumption and per capita energy consumption demand are showing a "double increase" trend. At the same time, since 2020, affected by the COVID-19, the world's three major energy production is in short supply. Promoting green transformation of energy structure and taking clean energy development as the guidance will also be the inevitable trend of future power demand [1].

In order to build an energy technology innovation system of "carbon peaking and carbon neutralization" and accelerate infrastructure construction, during the "Fourteenth Five Year Plan" period, the State Grid planned to build 38 ultra-high voltage lines of "twenty-four alternating and fourteen direct lines", with more than 30000 kilometers of lines, and the investment in smart grid construction continued to increase [2]. The construction of transmission lines, such as ultra-high voltage and high voltage transmission projects, is in full swing.

With the rapid development of electric power, it is inevitable that transmission lines will be built in high mountains, hills, plateaus and other regions with complex terrain and landform. At the same time, due to the impact of external environmental factors (environment, weather and transportation), it is more difficult to build tower foundations for electric power projects [3]. If disaster occurs to the tower foundation, it will not only increase the project cost, but also prolong the construction period, and even endanger people's lives and property safety. In order to ensure the stable operation of power transmission and transformation lines, the research on the stability of tower foundation pit and the prevention and control measures of support reinforcement has important practical engineering significance [4].

2. Problems in the design of transmission line tower foundation

Most of the tower sites along the route studied in this paper are located in hilly and mountainous areas, and the tower sites are prone to exposed foundation, backfill collapse and landslide. Landslide is a complex geological process. During the process of slope deformation to landslide formation, secondary landslide may also be accompanied, which may cause great hidden danger to foundation safety [5].

When transmission line towers and signal towers are built on hillsides, a large number of high slopes of transmission line towers appear, which makes the stability analysis of transmission line tower slopes much more complex than that of slopes not subject to external loads. The traditional

foundation load transfer laws and calculation methods are obviously difficult to apply to the treatment of transmission line tower slopes [6]. New technical models and methods are urgently needed.

There is no unified standard specification for reference in the design of transmission line tower foundation slope, which is mostly based on local conditions. There is no clear calculation method for determining the scope of slope instability and the scope of slope reinforcement under the action of tower foundation force of transmission lines. Designers often carry out slope reinforcement treatment according to previous work experience, which cannot meet the needs of practical projects.

The living environment factors are complex and diverse, the existing land resources are scarce, and the geological selection for the construction of transmission and transformation poles and towers is limited [7]. Comprehensive economic comparison and consideration should be made from the technical aspects such as construction, safety reinforcement, earthquake resistance, and ecological aspects such as human environment and ecological protection.

3. Design and analysis of transmission line tower foundation

3.1 Engineering geological foundation analysis

Comprehensive field survey and collection of basic engineering geological data of the area along the line, including meteorological conditions, topography, geological structure, hydrogeology, engineering geology and other environmental factors, to provide a basis for slope reinforcement.

3.2 Stability analysis of transmission line tower slope

On the basis of a comprehensive understanding of the geological and hydrological conditions of the transmission and transformation pole tower foundation project, the geological analysis and stereographic projection analysis methods are used to grasp the stability of the transmission line pole tower slope from a macro perspective to provide a scientific basis for the empirical design of the slope. Then, the limit equilibrium method is used to analyze the stability of the slope. Then, a reasonable data model is established for the transmission line pole tower slope through the finite element simulation method [8]. The stability of transmission line tower slope is analyzed from two aspects of safety factor and potential sliding surface, and the instability process of transmission line tower foundation slope is simulated. The stability of the transmission line tower foundation slope is evaluated by combining qualitative and quantitative methods, so as to provide a reliable basis for the subsequent reasonable prevention and control of the transmission line tower foundation slope. Stereographic projection is the most important analysis method.

3.3 Analysis on Reinforcement of Pole and Tower Retaining of Transmission Line

According to the support and reinforcement is a systematic engineering part, the slope engineering reinforcement technology shall be selected according to local conditions. According to the characteristics of transmission line tower foundation slope, the slope ratio design is considered from the engineering analogy method and engineering geological analysis method. According to the rock characteristics, hydrology, climate and other conditions, as well as the experience of common control measures in local slope engineering, the scope of application, advantages and disadvantages are comprehensively evaluated [9]. Common reinforcement methods include slope surface protection and greening, support and reinforcement works, etc.

On the site with relatively good engineering environment, the combination of Internet of Things technology and digital monitoring means can be selected to monitor the geological environment and reinforcement status of the slope, which has important design basis and support of project implementation data for subsequent maintenance and reinforcement model establishment.

4. Key technologies in the design of transmission and transformation towers

4.1 Stereographic projection method

In a rock slope, the development of rock mass joint fissures or the interaction between the distance between rock mass structural planes of the same group, the shape and surface characteristics of the slope excavation surface, etc., cause the instability or destruction of the rock wedge structural plane. Stereographic projection method is used to represent the relationship between lines and surfaces and their movement tracks. The geometric elements of rock mass in three-dimensional space are reflected on a projection plane through stereographic projection technology, showing the two parameters of dip and dip, determining the occurrence of the intersection lines of two surfaces, and judging the stability of the slope and the dynamic sliding of the structure.

4.2 Limit equilibrium method

The limit equilibrium method is based on the ratio of the shear strength of the rock and soil mass to the shear force acting on the potential failure surface in the rock and soil mass to obtain the safety factor of the slope. It mainly includes Swedish slice method, Bishop simplified method, Spencer method, etc. The limit equilibrium method has been used in engineering for a long time. The concept is simple and clear, and there are a lot of engineering cases and data references. At present, the limit equilibrium method is still the most commonly used method in slope stability analysis in the engineering community [10].

4.3 Reinforcement technology of transmission line tower support

When the transmission line tower is built in the mountain area, the mountain is often excavated during the construction, and the foundation construction will change the original structural plane of the rock mass, which will have a certain impact on the stability of the transmission line tower in the later period. Therefore, technical measures such as wind prevention and sand fixation, water retaining wall and shotcrete wall protection are taken to reinforce the foundation.

4.4 Protection and greening of transmission line tower slope

The slope surface protection is used to prevent the rock and soil mass on the slope surface from further weathering, peeling, shallow collapse, chipping and rain washing, so as to improve the stability and durability of the slope. Common methods in the project include dry masonry slope protection, plain spraying protection and gravity retaining wall.

5. Application of foundation slope protection

Taking the power transmission lines in the west of China as an example, since most of the western regions of China are in desert, flood gully and other unfavorable geology, in order to meet the needs of the western development of China, the power transmission lines cannot avoid unfavorable geology in the early stage of construction, so it is necessary to stabilize the slopes of the towers and foundations in the unfavorable geology during the excavation of the tower foundation and the later stage of stable operation.

5.1 Protection in desert area

In the desert geological section where the transmission line crosses, because there are quicksand and floating sand in the desert area, and there is gale weather all the year round, the soil layer will be exposed on the main column and bottom plate of the foundation if the foundation is not backfilled in time (Fig. a). Therefore, when building poles and towers in the desert area, it should be considered that after the foundation excavation, a layer of pebbles not less than 10cm thick should be placed on the bottom surface of the foundation to prevent uneven settlement of the foundation, and then the

foundation can be poured, After the foundation is backfilled, the tower base surface shall be protected from wind and sand.

The existing wind proof and sand fixation materials in western China often use hard materials such as reed poles as straw squares for wind proof and sand fixation, and the effect is obvious. When considering straw squares, the area of straw squares should be restricted in view of wind speed, windward face, tower heel, etc. If the straw squares are too large or small, they can not play the role of wind proof and sand fixation. Take this project as an example, because the tower is located on the top of the sand dune, Therefore, the grass square shall not be less than the sheltered area of 20m * 20m, and the reed pole buried underground shall not be less than 30cm (Fig. b).

Fig. 1: Foundation main column exposure

Fig. 2: Grass checkerboard for wind prevention and sand fixation

5.2 Protection in gully section

In China, the water area is rich and the land is wide, and the transmission line towers are affected by the landform, so it should be considered to avoid the gully and other sections scoured by water flow. When it is unavoidable, meteorological data of this section shall be collected in a timely manner. Generally speaking, the hydrological conditions of UHV transmission lines in China are 30 years except for 50 years. At this time, the hydrological conditions of this geological section shall not meet 30 or 50 years. It shall be considered whether there have been extreme hydrological conditions such as floods within 100 years. During the design process, flood control measures shall be considered for the tower and foundation in this geological section, The existing flood control measures in China include: retaining walls, flood control dams, drainage ditches, etc.

Figure 3: Water retaining wall

Figure 4: Flood control dam

6. Summary

This paper analyzes the stability and reinforcement of transmission line tower foundation from the aspect of engineering application, and puts forward solutions. In the future, depending on the new generation of information technology, the built transmission line tower foundation will be digitally monitored and the operation and maintenance model will be established to realize the predictable and preventable risks, accelerate the digitalization of power grid infrastructure and promote the construction of digital power grid.

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