Research on Resistance Reduction Method of Transmission Line Tower Epitaxial Grounding Based on Slope Soil Nailing Wall

Dawei Song, Ziping Liu, Yang Li, Xiying Liu, Zongjie Liu, and Muran Liu

Abstract Aiming at the problem of high grounding resistance of transmission line tower along the steep slope of the road, this paper proposes a method of reducing the resistance of the steel mesh in the soil nailing wall supported in the steep slope terrain, and builds the tower grounding grid and soil nailing wall along the steep slope terrain. The model compares and analyzes the changes of grounding parameters such as grounding resistance and step voltage before and after connecting the soil nailing wall, and analyzes the influence of the number of connecting wires, connection position, connection material and tower grounding grid position on the grounding resistance of the tower grounding grid. The simulation results show that the resistance reduction effect of the soil nailing wall on the tower grounding grid can reach 19.3–73.4%, and the maximum step voltage of the soil surface where the grounding grid is located is not more than 6 kV, which verifies the feasibility of the soil nailing wall scattered current resistance reduction method. The more the number of connecting wires, the smaller the low resistance, but the resistance reduction efficiency reaches 56.3% when the number of connecting wires is 4, which tends to be saturated. The more dispersed the connection position, the smaller the tower grounding resistance; the resistance reduction efficiency of the connecting wires using the new graphite composite material is 9.04% higher than that of the galvanized steel. The grounding grid is set on the slope and can have lower grounding resistance.

Keywords Grounding resistance · Transmission line · Soil nail wall

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1 Introduction

Transmission line pylon grounding grid is a basic lightning protection facility that affects the lightning resistance level of the line [1]. Under the condition, high soil resistivity is difficult to reach the standard. Therefore, it is a basic measure to reduce the ground resistance of tower grounding grid to prevent lightning flashover fault of transmission line. In practical projects, pylons and towers of transmission lines are often erected around public buildings such as highways, slopes and embankments. Due to the limitations of construction conditions such as landforms and public transportation roads, the design and construction of pylons and towers along roads still face the following problems: rolling terrain and complex terrain, poor soil conditions and high soil resistivity for pylons and towers construction; The construction area of the tower along the road is limited, which is not conducive to the laying of the ground grid or large ground electrode. After the pylon grounding grid runs for a long time, some problems such as corrosion and human damage occur to the local grounding electrode, and the pylon grounding grid along the road is not easy to be replaced and maintained frequently. Therefore, there is still a lack of effective construction scheme for tower grounding resistance reduction under the condition of limited epitaxial construction area along roads and embankment slopes [2].

In recent years, scholars at home and abroad have made a lot of research on the problem of high ground resistance of pole tower in mountainous areas. In order to improve the lightning resistance level of the line and reduce the grounding resistance of the tower grounding grid, literature [3] proposed to carry out the epitaxial way to reduce the grounding resistance on the basis of the tower grounding grid, and believed that the epitaxial lead itself also had different effects on the loose flow. Considering the influence of the area, direction and number of connecting wires on the drag reduction effect of the pole tower grounding grid, literature [4] proposes a method to reduce the drag of transmission line tower grounding by increasing the length, area and number of connecting wires of the auxiliary grounding grid. For the case of high soil resistivity, literature [5] believes that the resistance can be reduced by increasing the area of grounding grid, extensional grounding or deep well grounding, etc. Miao Haoming et al. verified the dispersion characteristics of grounding devices in different soil areas under the action of continuous impact by simulation calculation, and proposed the selection of grounding materials. Zhou Lixing et al. used the EMTP-ATP simulation software to calculate the impact characteristics of the grounding device of the tower in double-layer soil. The moment of lightning strike, the end of the grounding electrode would rapidly heat up and ionize the soil [6], and the spark discharge effect could reduce the impact grounding impedance of the tower grounding grid. Gao Xiaojing et al. calculated the ground dispersion characteristics of concrete pile foundation of tower and pole, and proposed a method to reduce the natural grounding resistance of pile foundation under the condition of limited construction area [7]. In addition, it is mentioned in literature [8] that reinforcement frame is adopted for soil nailing wall of slope protection under terrain conditions such as roads and embankments, which can play a role in fixing soil layer of slope and simulating landslide collapse construction. Considering that the pole and tower grounding resistance reduction of adjacent transmission lines under terrain conditions such as roads and embankments requires long distance extension, the slope protection soil nailing wall steel frame under terrain conditions such as roads and embankments can provide a scattering channel for the ground flow of adjacent pylons and towers, extend the tower grounding grid to the slope soil nailing wall steel frame, and achieve an effective increase in the area of the tower grounding grid and thus reduce the tower grounding resistance. This method can reduce the cost of tower grounding construction and avoid slope damage caused by large-scale equipment transportation construction. It has high engineering practical value.

Aiming at the problem of grounding resistance reduction of adjacent tower and tower under the condition of limited construction area such as road and river bank, this paper established a simulation model of grounding net and soil nail-wall under steep slope terrain, analyzed the influence law of grounding resistance reduction efficiency of tower and tower, such as the location of tower grounding net, the number of connecting wires and material parameters, and verified the feasibility of using road soil nail-wall for grounding resistance reduction of tower and tower. Relevant research conclusions can provide a feasible reference for the design and operation of power lines near slope protection land walls such as roads and embankments.

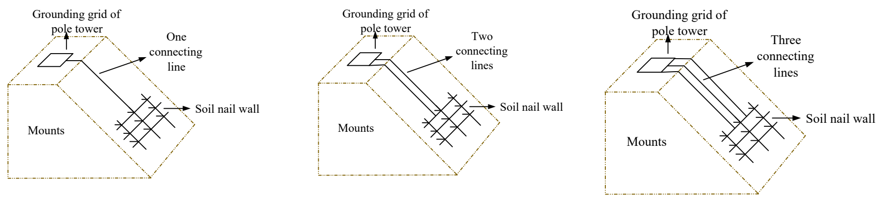
2 Analysis of the Influence of Different Factors on the Effect of Soil Nail Wall Assisted Resistance Reduction

2.1 Analysis of the Influence of the Number of Connection Lines

Soil nail wall as an epitaxial grounding grid, the number of connection lines between it and the pole tower grounding grid, will affect the size of the grounding resistance of the grounding grid. In order to investigate the influence of the number of connecting wires between soil nail wall and tower grounding grid on the grounding resistance, set the number of connecting wires as 1 ~ 5, respectively, and establish the transmission line tower epitaxial grounding resistance reduction model as shown in Fig. 1.

According to the different simulation calculation models shown in Fig. 1, the simulation calculations were carried out under the conditions of soil resistivity of 100 Ω-m, 300 Ω-m, 500 Ω-m, 700 Ω-m, and 900 Ω-m, respectively, and the results of the grounding resistance data of the pole tower grounding grid under the conditions of different numbers of connecting wires were obtained as shown in Fig. 2, and the conditions of soil resistivity of 100 Ω-m were used as an example to observe.

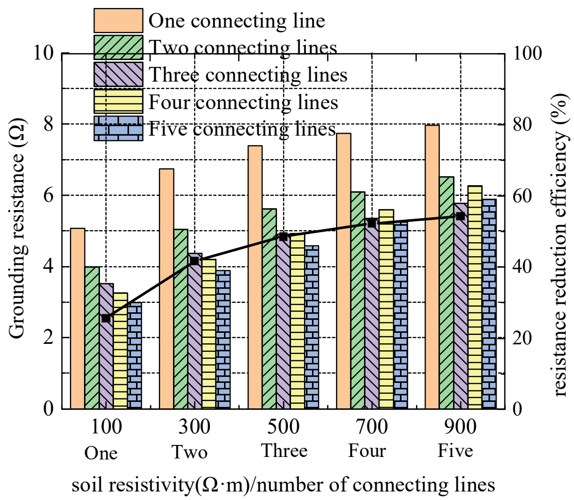
The simulation calculation results in Fig. 2 and show that increasing the connection lines between the grounding grid of the tower and the inner grid of the soil nail wall can enhance the resistance reduction effect of the inner grid of the soil nail wall



(a) One connection line (b) Two connecting wires (c) Three connecting wires (d) Four connecting wires (e) Five connecting wires

Fig. 1 Grounding grid model with different number of connection lines

Fig. 2 The relationship between grounding resistance and soil resistance, number of connecting conductor

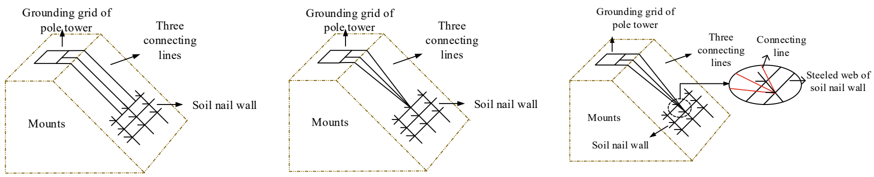


on the grounding grid of the tower, which can reach 25–55%. However, with the increase of soil resistivity, this positive correlation between "resistance reduction effect and the number of connecting wires" gradually weakened, and the number of 4 reached the saturation state, the shunt coefficient reached 54.32%, and the number of external leads continued to increase instead of making the grounding resistance reduced. Analysis is due to the influence of shielding effect, the more grounding conductors per unit area, the stronger the shielding effect, so that the effective dissipation area can be used is smaller. In the project if the use of soil nail wall grid or other auxiliary grounding grid for resistance reduction processing, the use of 1–2 grounding conductors to connect the soil nail wall and tower grounding grid.

2.2 Analysis of the Influence of Connection Position

The soil nail wall, as an extension of the grounding grid of the pole tower, is excited by the connection line, and the end of the connection line is the excitation point of the soil nail wall. Therefore, to investigate the influence of different excitation points on the grounding resistance, three connection lines are used to connect the edge of the inner grid of the soil nail wall, three centralized connections to the edge of the inner grid of the soil nail wall, and three centralized connections to the center of the inner grid of the soil nail wall, and the model shown in Fig. 3 is established.

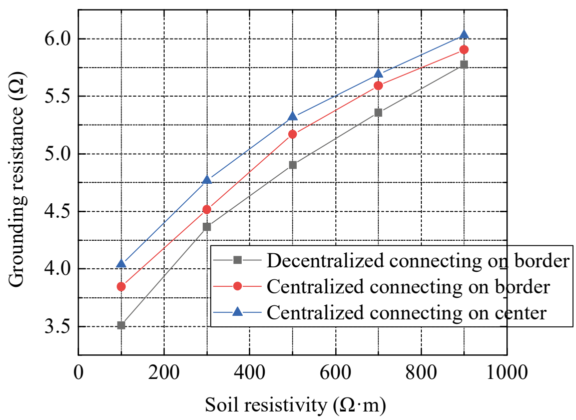
Simulations were performed for the three models in Fig. 3 under the soil resistivity conditions of 100, 300, 500, 700, and 900 Ω-m. Through simulation, the results of grounding resistance of the pole tower grounding grid under different connection positions are shown in Fig. 4.



(a) Dispersion connection border (b) Centralized connection border (c) Centralized connection center

Fig. 3 Grounding grid models with different connection positions

Fig. 4 The relationship between grounding resistance and connecting position



Comprehensive Fig. 4, simulation calculation results can be seen: comparing the connection line scattered connection soil nail wall and connection line concentrated in a point connection soil nail wall, in any soil resistivity conditions, the grounding resistance of the scattered connection are less than the grounding resistance of the tower grounding grid after two centralized connection methods under the same conditions. Therefore, in the actual project, when using multiple connecting wires to connect the grounding grid of the tower with the soil nail wall, each connecting wire should be dispersed. connection points and make each connection line keep a certain distance between them, reduce the conductor shielding effect, improve the grounding conductor's dissipation, and make the pole tower grounding resistance lower.

2.3 Analysis of the Influence of the Connection Lines Material

Galvanized steel due to its poor corrosion resistance, in the steep slope along the road and other terrain, it is difficult to ensure a long time of operation without damage [9–11]. As a metal less active copper and non-metallic material new graphite composites, with high corrosion resistance, excellent mechanical structure and good current dissipation, while avoiding rapid temperature rise, have become the optional material for today's grounding conductors.

In order to investigate the influence of different materials of connecting wires on the grounding resistance of the pole tower under the same conditions, the above three materials were chosen as the connecting wire materials, and the connection of soil nail wall and pole tower grounding grid with three connecting wires scattered connection was simulated under the soil resistivity conditions of different soil resistivity. Through simulation, the results of grounding resistance of the pole tower grounding grid under different connecting wire materials are shown in Fig. 5.

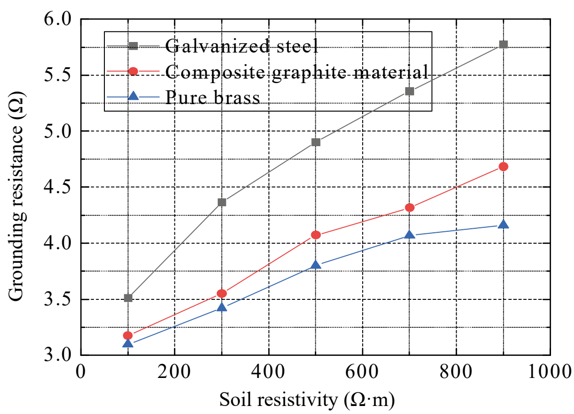


Fig. 5 The relationship between grounding resistance and connecting conductor material

Combined with the simulation calculation results in Fig. 5, it can be seen that under the same conditions, the connection wire made of copper and new graphite composite material is more conducive to the dissipation and resistance reduction of the pole tower grounding grid than the connection wire made of galvanized steel, in which the connection wire made of copper is lower than the grounding resistance of the pole tower grounding grid made of the connection wire made of new graphite composite material. However, the simulation results of the shunt coefficient show that the shunt coefficient of the new graphite composite grounding conductor can reach 62.01%, while copper is 57.44%, both higher than 53.13% of galvanized steel. The reason: the relative permeability of copper and new graphite composite materials is lower, the shielding effect is less, the current amplitude flowing into the grounding conductor is larger, and thus the shunt coefficient is high. And the new graphite composite grounding conductor shunt coefficient is greater than the copper counter-current coefficient, but the tower grounding resistance is greater, because the relative resistivity of the new graphite composite material is larger, much higher than copper, lightning flow at the connection line of the new graphite composite material is weaker than the copper material, while the effect of the soil nail wall to reach saturation, resulting in the use of the connection line with the new graphite composite material tower grounding grid The grounding resistance is slightly higher than that of copper. Therefore, new graphite composite material or copper can be used as the connecting wire material in actual projects.

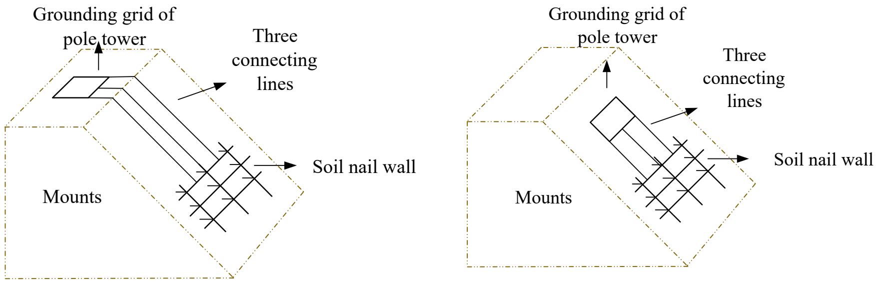
2.4 Analysis of the Influence of the Location of the Pole Tower Grounding Grid

In some steep slopes due to construction difficulty, distance and other reasons, the grounding grid of the pole tower will be buried at the slope of the steep slope. The grounding grid at the slope is different from the grounding grid at the top of the slope because of the position, inclination angle, distance, etc. Therefore, in order to investigate the influence of the tower position on the grounding resistance, the grounding grid at the top of the slope and the slope are set as shown in Fig. 6.

Under the soil resistivity conditions of 100, 300, 500, 700, and 900 Ω-m, the pole tower grounding grid at the two locations of the slope top and slope shown in Fig. 6 are simulated and calculated respectively. Through simulation, the grounding resistance results of the pole tower grounding grid under the conditions of two different locations are shown in Fig. 7.

Under the same conditions, the grounding resistance of the pole tower grounding grid located on the slope is lower than that of the pole tower grounding grid located at the top of the slope.

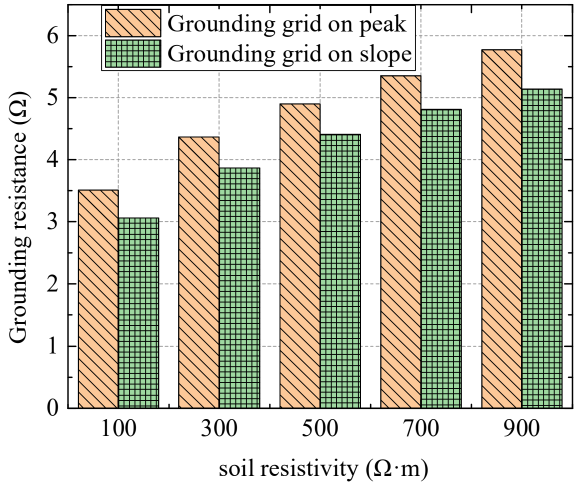
After calculation can be obtained, the position in the slope top, the pole tower grounding grid connection line shunt coefficient is 53.13%, is located in the slope when it reaches 63.32%, much higher than the slope top position. Analysis of the



(a) grounding grid at the top of the slope (b) grounding grid on the slope

Fig. 6 Model of the grounding grid of the pole tower at different locations

Fig. 7 The relationship between grounding resistance and position of grounding grid



reason: the slope of the tower grounding grid is closer to the soil nail wall, lightning flow more balanced dispersion to a wider area of the reinforcement grid of the soil nail wall; and the slope of the top of the tower grounding grid connection line is longer, part of the current in the conduction process of the connection line scattered flow makes lightning flow to the soil nail wall scattered flow is limited, making the shunt coefficient relatively small. Therefore, in the project, under the condition that construction conditions allow, the grounding grid can be set in the slope of the soil layer relatively close to the soil nail wall, in order to reduce the grounding resistance of the pole tower grounding grid.

3 Conclusion

This paper simulates and calculates the effect of soil nail wall on the grounding resistance and stride voltage of the pole tower grounding grid under steep slope conditions, and compares the effect of four factors, namely the number of connection wires, the connection position, the connection material and the location of the pole tower grounding grid, on the grounding resistance of the pole tower grounding grid. The following conclusions were obtained:

(1) Under the condition of steep slope, soil nail wall has obvious resistance reduction effect on the grounding grid of the pole tower, and the higher the resistance reduction ratio with the increase of soil resistivity. At the soil resistivity of 100 Ω-m, the resistance reduction ratio reaches 19.3%; at the soil resistivity of 900 Ω-m, the resistance reduction can reach 73.4%. Meanwhile, the simulation distribution of voltage across the step verifies the reasonableness of soil nail wall in terms of safety.

(2) compare and analyze the influence of each factor on the grounding resistance of the pole tower grounding grid, it can be learned that: the more the number of connecting wires of the soil nail wall and the pole tower grounding grid, the higher the resistance reduction effect, but the shunt coefficient saturates when the connecting wires reach 3–4, in the project generally use 3–4 can; the connecting wires adopt the connection method of dispersed connecting box to reduce resistance more obviously, the shunt coefficient is higher (53.13%); compared with Compared with the pole tower grounding grid set at the top of the steep slope, the grounding grid set at the slope has a lower grounding resistance.

(3) The new graphite composite material and copper can be a good material for connection wire because of the good corrosion and heat resistance of the new graphite composite material, although the resistance reduction efficiency is only 9–10% compared to galvanized steel as the connection wire material.

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