ISSN: 2710-0588

Study on the Applicability of Flexible Graphite Grounding Body and Grounding Module for 500kV Transmission Line in High Altitude Area

Jian Chen, Ke Liu, Yebin Huang, Yuefu Bei, and Aoxiang Wu

China Aneng Group Second Engineering Bureau Co, Xiamen 361021, China

Abstract

Sichuan-Tibet Railway Changdu-Linzhi section construction power supply project (Phase II) by Tibet Power Grid Co. 4900m), the mountain is treacherous, the foundation excavation is difficult (mostly rock foundation). Among them, 3 times across 35kV lines, 1 time across 220kV lines, 1 time across the Nujiang River, across the construction is more difficult. At present, China often use galvanized steel, galvanized copper and other traditional grounding materials, due to corrosion phenomenon caused by the increase in grounding resistance, affecting the frequency current, lightning current dispersion, but also cause local stride voltage and contact voltage does not meet the requirements of the regulations, generally in 8 years need to be replaced, which greatly increases the construction cost. In order to ensure the safe operation of power equipment and the safety of staff operation, stable and highly reliable grounding materials are needed. In recent years, flexible graphite material is widely used in grounding engineering, which has good electromagnetic characteristics and strong chemical stability, not easy to be eroded by the environment, and can operate in the grounding of power equipment in a long-term and stable manner. In this paper, the soil geological structure and typical line tower grounding resistance in Tibetan area are tested and analyzed, and the flexible graphite grounding material is applied to the grounding transformation of line tower in combination with local problems in Tibet, which can reduce the burial depth of grounding electrode, and compared with the solution of using traditional grounding material, it can reduce the cost and improve the project progress, and help the construction unit and construction unit to control the budget and construction period.

Keywords

High Altitude Areas; Flexible Graphite Grounding Body; Electrical Conductivity; Transmission and Substation Engineering.

1. Introduction

Sichuan-Tibet Railway Changdu-Linzhi section construction power supply project (Phase II) by Tibet Power Grid Co. 4900m), the mountain is treacherous, the foundation excavation is difficult (mostly rock foundation). Among them, 3 times across 35kV lines, 1 time across 220kV lines, 1 time across the Nujiang River, across the construction is more difficult[1]. Local nature protection is better, more wild animals, local herdsmen (Tibetan Khampa) are mostly, most people do not know Chinese, there are communication difficulties and other problems. Line across more and more difficult construction, outage window period is short. Among them, there are 3 times of crossing 35kV line, 1 time of 220kV line and 1 time of crossing Nujiang River[2], which makes the crossing construction difficult. In addition, the project is located in Guoqing Township and Tongka Township, Baxu County, Changdu City, Tibet, which has a high altitude and short construction period (May-October is the best construction period). The climate of Tibet is unique and complex due to the influence of topography, geomorphology and

ISSN: 2710-0588

atmospheric circulation. In general, the climate is characterized by cold and dry in the northwest and warm and humid in the southeast. Therefore, there are various types of climate from southeast to northwest, such as tropical, subtropical, plateau temperate, plateau sub-cold, and plateau cold. In the southeast of Tibet and the southern slope of the Himalayas, the climate changes vertically from tropical or subtropical climate to temperate, cold temperate and boreal climate due to the iterative rise in terrain and the gradual decline in temperature[3].

As the altitude increases, the air pressure decreases and the air density decreases, the oxygen content per cubic meter of air gradually decreases, which is equivalent to 73% of sea level at 3000 meters above sea level, 62%-65.4% at 4000 meters, 59% at 5000 meters, and less than 52% above 6000 meters.

Under the control of alternating westerly winds in winter and southwesterly monsoon in summer, the dry season and rainy season in Tibet are very obvious, generally from October to April of the following year is the dry season; from May to September is the rainy season, and the rainfall generally accounts for about 90% of the annual precipitation. Precipitation is also seriously uneven, with annual precipitation decreasing from 5,000 mm in the southeast lowlands to 50 mm in the northwest.

The climate of southern Tibet and northern Tibet is very different. The southern Tibetan valley is influenced by the warm and humid airflow of the Indian Ocean, with mild and rainy conditions, annual average temperature of 8℃, minimum monthly average temperature of -16℃ and maximum monthly average temperature of 16℃ or more. The northern Tibetan plateau is a typical continental climate, the annual average temperature is below 0℃, the freezing period is up to half a year, the highest July does not exceed 10℃, June to August is warmer, the rainy season is more night rain, winter and spring are more windy[4].

Tibet Autonomous Region Lightning Protection Center of Tibet 16 years of statistical analysis of lightning accidents, in recent years, Tibet lightning disasters are increasing year by year trend, and the loss is also increasing. From a geographical point of view, there are annual lightning disasters throughout the region, of which the number of Naqu and Changdu lightning disasters is relatively more. From the affected location, most of the lightning disasters occur in the open areas of agricultural and pastoral areas or isolated buildings without any lightning protection facilities. From the affected object, mainly involving personnel, construction (buildings), household appliances and electronic communication equipment, especially in agricultural and pastoral areas, lightning accidents account for a greater proportion, and mainly to casualties and livestock deaths[5].

2. Purpose and Significance of the Study Section Headings

High altitude areas have harsh geographical environment, poor soil quality, individual areas usually ordinary galvanized round steel grounding materials can not meet the construction needs, transmission and substation lines in the construction of grounding installation and is the key link, which is related to the normal operation of the entire project. In order to solve the problem of grounding conductivity of 500kV transmission and substation project in high altitude area, it is recommended to use flexible graphite grounding body and grounding module tool, flexible graphite grounding body has good conductivity, can withstand long-term erosion of acid, alkali and salt solution seawater, can be used safely in -200℃~800℃℃, convenient transportation and simple installation. This topic studies the practicality of flexible graphite grounding body and grounding module in 500KV line in plateau area, and then provides reference for future transmission and substation projects in plateau area[6].

ISSN: 2710-0588

3. Research Content, Research Methods and Technical Route of the Project

3.1. Grounding Type of Graphite-based Flexible Grounding Device

For different voltage levels of transmission lines, different soil resistivity, graphite-based flexible grounding device has different types. The basic type is: the four tower feet through the armored graphite lead wire, connected to the graphite-based flexible horizontal grounding body, and in the horizontal grounding body under the laying of the width of 300mm graphite-based flexible resistance reduction cloth[7].

According to the national standard, the frequency grounding resistance of the substation inlet section tower should not be higher than 10Ω, and the frequency grounding resistance of the distant area with high soil resistivity should not exceed 30Ω. therefore, in this paper, we mainly study the near area and the distant area tower grounding device with high soil resistivity. 220kV and below voltage level, 500kV and above voltage level transmission line tower grounding device type schematic diagram are shown in Figure 1 and Figure 2 show. Different types of grounding device size parameters are shown in Table 1.

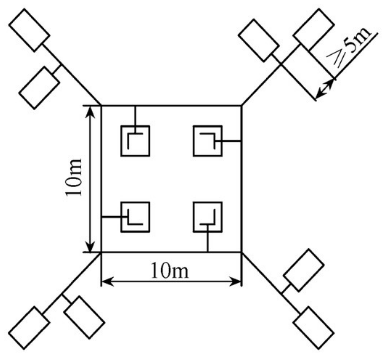

Figure 1. 220kV and below voltage level transmission line tower grounding device type

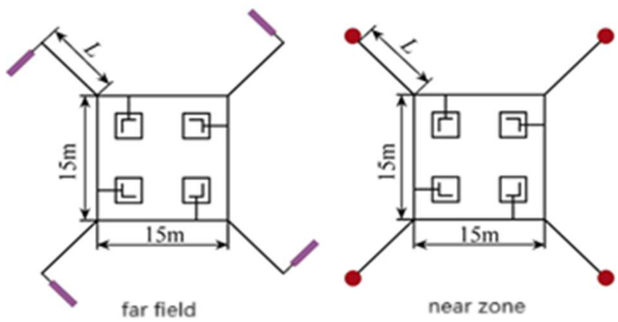

Figure 2. 500kV and above voltage level transmission line tower grounding device type

Table 1. Different types of grounding device size parameters

Voltage Rating	Location	Applicable soil resistivity/(Ω-m)	Horizontal grounding body cross section/(mm×mm)	Rays L/m	Graphite-based flexible barrier fabric length/m	Grounding module (grounding pole)/block (root)
220kv and below	Nearby Area	0~300	40×5	5	60	4
	Remote Area	1500~2000	40×5	40	200	16
500kv and above	Nearby Area	≦100	60×8	0	0	0
	Remote Area	2000~2500	60×8	35	200	4

ISSN: 2710-0588

In transmission lines with higher voltage levels, increase the cross-sectional area and length of the graphite grounding body to improve the current dissipation capacity of the grounding device. In areas with high soil resistivity, the grounding resistance requirements are met by extending the length of the ray and installing flexible plasma grounding electrodes or grounding modules at the end of the ray. Among them, the flexible plasma filled with environmentally friendly ions, in the application, the ion diffusion open can reduce the surrounding soil resistivity; grounding module through the spark spike to increase the local spark effect of the soil to reduce the grounding resistance.

3.2. Graphite-based Flexible Grounding Device Industrial Frequency Grounding Resistance Simulation

When the current passes through the grounding body, the graphite-based flexible grounding device is the center, and the flow is evenly dispersed to the surrounding soil, and the soil domain is set in the shape of a hemisphere. Engineering practice shows that when the size of the calculation area is greater than four times the size of the grounding electrode, the truncation error is negligible, so the soil domain in this paper is set to 10 times the size of the grounding device to ensure the accuracy of the calculation results.

According to the regulations, the grounding device is generally not less than the following burial depth: 0.8m in agricultural land and below the plowing depth; 0.6m in general areas; 0.3m in rocky areas where excavation is difficult and the soil resistivity is greater than 2000 Ωm. In this paper, the general burial depth is taken as 0.6m. According to these conditions and different types of graphite-based flexible grounding device, the simulation model of grounding resistance of graphite-based flexible grounding device is constructed as Figure 3 is shown.

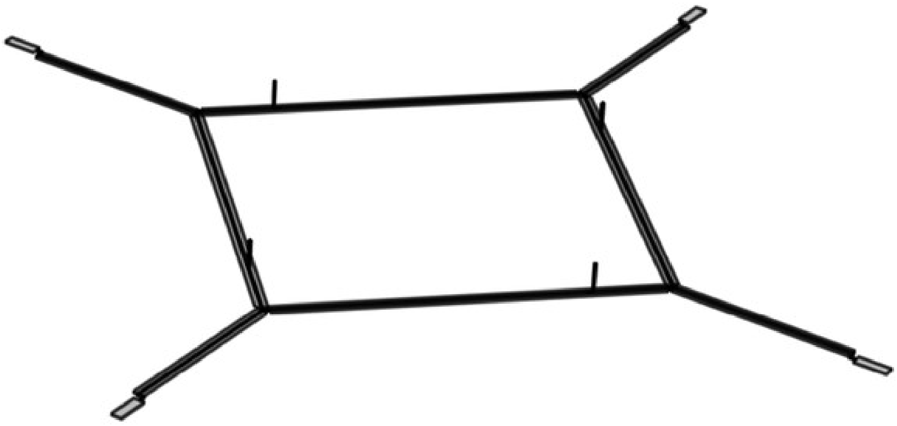

Figure 3. Graphite-based flexible grounding device grounding resistance simulation model

Because the frequency is low and single, while graphite is a weakly magnetic material and the inductive effect is not obvious the simulation calculation of the frequency grounding resistance can be solved by using the current field in the frequency domain.

When calculating the frequency grounding resistance, a current of amplitude 1A is injected from the upper end of the four lead wires of the grounding device, and the potential distribution of the graphite-based flexible grounding device of 220 kV transmission line towers is shown in Figure 4, and the potential distribution of the graphite-based flexible grounding device of 500 kV and above transmission line towers is shown in Figure 5. From the terminal voltage can be calculated from different types of grounding device frequency grounding resistance is shown in Table 2.

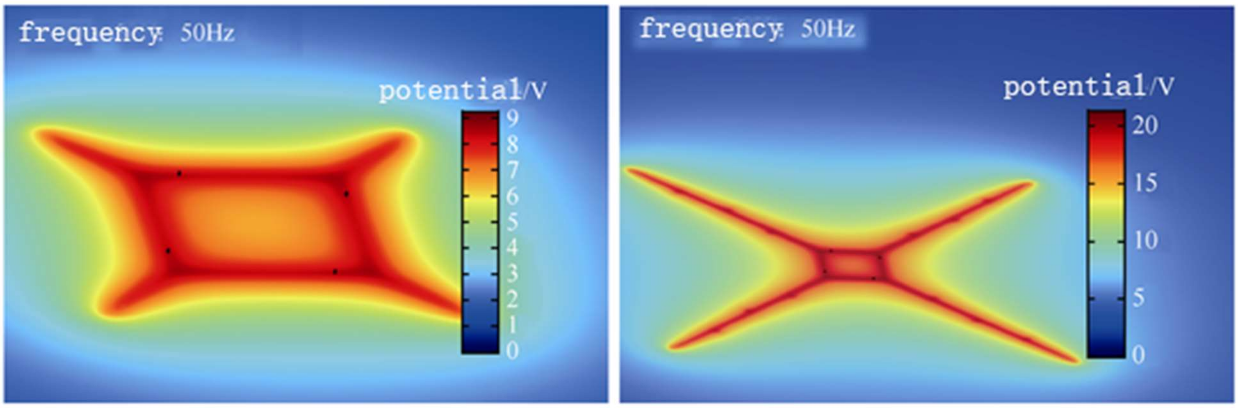

Figure 4. Potential distribution of graphite-based flexible grounding device for 220kV transmission line towers

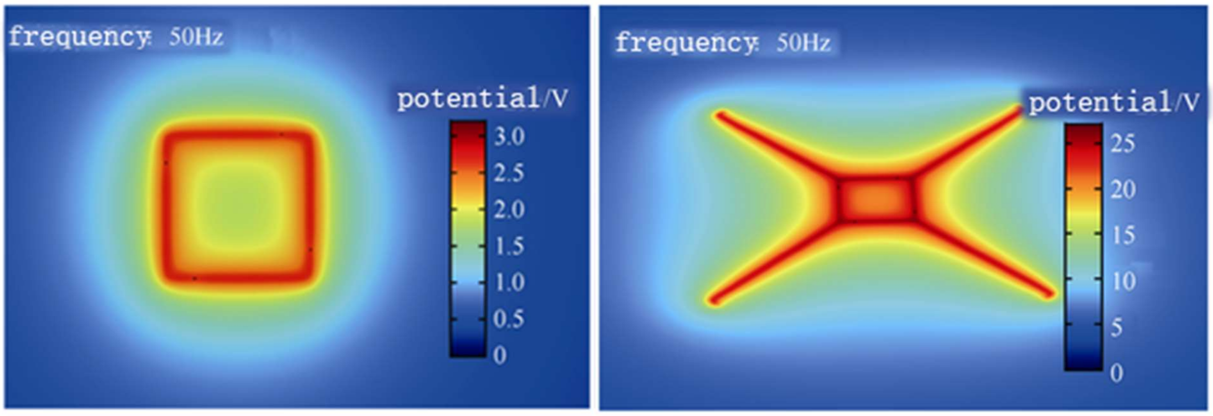

Figure 5. Potential distribution of graphite-based flexible grounding device for transmission line towers of 500kV and above

Table 2. Frequency grounding resistance of different types of grounding devices

Voltage Rating	Soil resistivity/(Ω-m)	Industrial frequency grounding resistance/Ω	
		Design value	Calculated values
220kv and below	≦300	≦10	9.256
	1500~2000	≦25	21.161
500kv and above	≦100	≦10	3.361
	2000~2500	≦30	27.634

3.3. Calculation of the Incoming Current During Single-phase Frequency Short Circuit and Lightning Strike

The same type of graphite-based flexible grounding device is used at the same soil resistivity for 220kV and below voltage level transmission lines, and the same type of grounding device is used at the same soil resistivity for 500kV and above voltage level transmission lines. Therefore, the current injected into the grounding device when single-phase frequency short circuit and lightning strikes the tower is calculated according to 220kV and 1000kV AC transmission lines, which is used as the terminal boundary condition for temperature rise calculation under high current.

According to the typical parameters of transmission lines in actual operation, the simulation model is built in ATP- EMTP, and the equivalent resistance is used to equate the grounding device. 220kV transmission line power station near-zone tower grounding resistance is set to 9.256Ω, and far-zone tower grounding resistance is set to 21.161Ω; 1000kV transmission line power station near-zone tower grounding resistance is set to 3.361Ω, and far-zone tower

ISSN: 2710-0588

grounding resistance is set to 27.634Ω. The grounding resistance of the tower is set to 27.634Ω. 2.6/50μs standard lightning current waveform is used for the original lightning strike tower, and the amplitude is calculated according to the probability of 40 years. 40 thunderstorm days per year, and the ground flash density is taken as 0.28 times/(km2 year).

Along the line uniformly selected 11 tower locations as fault points, respectively, in different locations set single-phase frequency grounding short circuit and lightning strikes the top of the tower. The near and far areas injected into the grounding device frequency current amplitude is shown in Table 3, the maximum possible lightning current through the grounding device of two voltage levels is shown in Table 4, according to the lightning current amplitude and waveform using double exponential function to simulate.

Table 3. Frequency current amplitude injected into the grounding device in the district and remote areas

Voltage level/kv	Maximum frequency short-circuit current amplitude to ground/kA	
220	1.728	0.295
1000	8.476	1.159

Table 4. Maximum lightning current injected into the grounding device

Voltage level/kV	Raw lightning current amplitude/kA	Lightning current amplitude injected into the grounding device/kA	Waveform/us
220	293.644	194.600	2.8/8.2
1000	307.137	214.320	3.5/11.0

4. Temperature rise Characteristics of Graphite-based Flexible Grounding Devices under High Currents

The duration of the short-circuit current and lightning current is short, and the heat transfer time between different media can be ignored compared with that. Therefore, when calculating the temperature rise of the grounding device under high current, the heat transfer process between different materials is not considered, and only the temperature rise caused by the material itself absorbing the energy of the frequency current is considered. The test shows that the graphite material temperature reaches about 300°C when it starts to smoke and the performance changes, so the temperature rise of graphite based flexible grounding device under high current cannot exceed 280°C (working at room temperature 20°C).

When calculating the temperature rise under a single frequency short-circuit current, the electromagnetic volume loss density P can be obtained by calculating the current field in the frequency domain, and the maximum temperature rise per unit volume of graphite material ΔV in the grounding device is:

$$\Delta T = \frac{P_{max} \times \Delta V \times \Delta t}{c_m \times \rho \times \Delta V} = \frac{P_{max} \times \Delta t}{c_m \times \rho} \tag{1}$$

Where: Pmax-maximum electromagnetic volume loss density of graphite material in the grounding device (W/m3).

Δt-Duration of short-circuit current of industrial frequency (s).

cm-graphite material specific heat capacity (J/(kg-°C)).

ρ-Density of graphite material (kg/m3).

The volumetric loss density distribution of the grounding device is calculated in COMSOL by using the amplitude of the frequency short-circuit grounding current in Table 3 as the terminal

ISSN: 2710-0588

current boundary conditions of the finite element simulation models of different types of grounding devices, respectively. volumetric loss density distribution of the graphite-based flexible grounding device of the near-zone pole tower of 220 kV transmission line under single-phase frequency short-circuit current is shown in Figure 6. Similarly, the maximum electromagnetic volume loss density of graphite material for different types of grounding devices can be calculated.

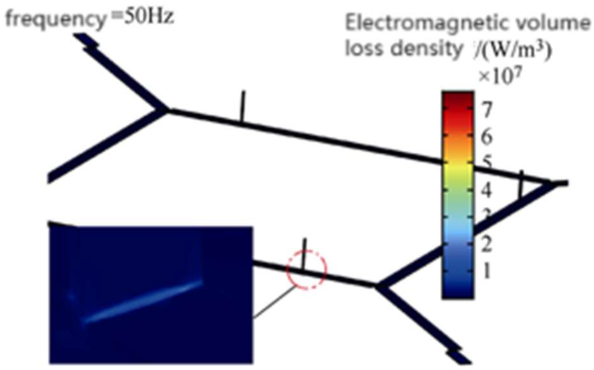

Figure 6. Volume loss density distribution

According to the measurement can be obtained from the graphite material density of 1060kg/m3, specific heat capacity of 710J / (kg °C), and the frequency short-circuit current in the pre-protection rejected after the duration of about 0.54s, can be calculated for different types of grounding device in the frequency short-circuit current temperature rise is shown in Table 5.

Table 5. Different types of grounding devices in the frequency short-circuit current temperature rise table

Voltage level/kV		Maximum electromagnetic volume loss density/(w/m^3)	Maximum temperature rise/°C
220	Nearby Area	7.639×10^7	54.811
	Remote Area	1.804×10^6	1.294
1000	Nearby Area	5.761×10^8	413.359
	Remote Area	1.263×10^7	9.062

When calculating the temperature rise under the lightning current, the inductive effect of the material cannot be ignored, and the multi-physical field coupled with the current field and magnetic field is needed to solve in the time domain. The armored graphite lead wire is shown in Figure 7. Segment ① has an outer layer with insulation and stainless steel armor, and segment ② has only graphite braid and stainless steel reinforced core plate. After the current passes through section ①, it starts to dissipate to the soil, but since the soil resistivity is much larger than the graphite material, the dissipation is very small, so it can be assumed that the current completely passes through the lead wire without dissipation, and only the temperature rise of the lead wire section ② when it passes through the complete lightning current needs to be assessed. In the simulation modeling only a section of the lead wire needs to be intercepted, and there is no need to build a complete grounding device.

Figure 7. Armored graphite lead wire

The lightning current is injected into the grounding device by the armored graphite lead wire of the four tower legs, and the shunt current of the four tower legs may be different when lightning strikes different positions on the top of the tower. According to the actual size of the tower structure, it will be equivalent to the resistance, inductance of the network, by the top of the tower at different locations to inject the amplitude of 300kA lightning current, four tower foot shunt as shown in Figure 8. As can be seen from Figure 8, the difference between the four tower feet shunt is very small, not more than 1%.

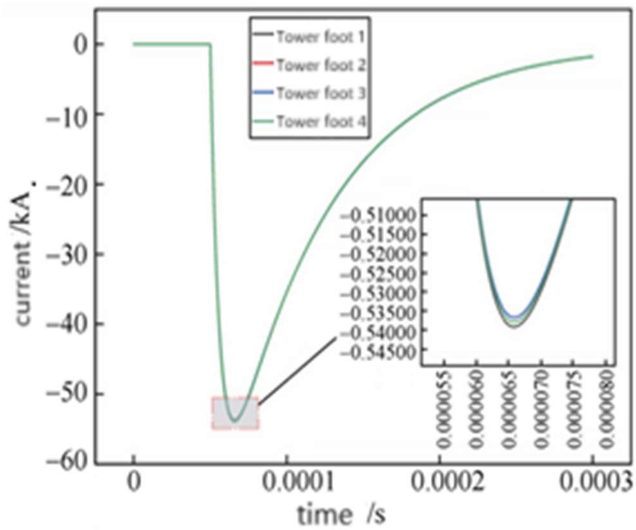

Figure 8. Shunt of the four tower legs

Therefore, taking 1/4 of the lightning current injected into the grounding device as the boundary condition for the terminal current of a single graphite lead wire, the temperature rise of the graphite material is:

$$\Delta T = \sum_{i=1}^{N} \frac{P_t \times \Delta t}{c_m \times \rho} = \frac{\Delta t}{c_m \times \rho} \sum_{i=1}^{N} P_i \tag{2}$$

where: Pt-volume loss density (W/m3) corresponding to the i-th time step of graphite material in graphite-based flexible grounding device.

N-Total time steps, N=t/△t,t is the lightning current duration (s).

△t-Time domain simulation time step (s).

The lightning current lasts for about 50 μs, so the simulation time is taken as 50 s with a time step of 0.1 μs. The electromagnetic volume loss density distribution of the lead wire with a cross-section of 40 mm × 6 mm at the moment of 3.1 μs is shown in Figure 9, and the maximum temperature rise of the two cross-section lead wires under the lightning current is shown in Table 6.

ISSN: 2710-0588

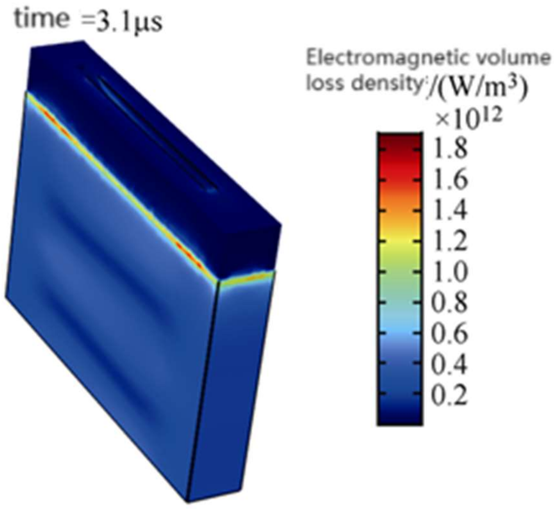

Figure 9. Electromagnetic volume loss density distribution

Table 6. Maximum temperature rise of two cross-sectional lead wires under lightning current

Graphite lead wire cross section/(mm×mm)	Maximum temperature rise/°C
40×6	21.818
60×8	10.630

5. Summary

Under the same voltage level, the graphite-based flexible grounding device applied to the high soil resistivity area can reduce the industrial frequency grounding resistance by extending the ray length and laying horizontal resistance-reducing cloth to make it reach the design requirements of the pole tower grounding resistance. In the ultra-high voltage transmission line, the temperature rise of the grounding device caused by the short circuit of the industrial frequency grounding is much larger than that caused by the lightning current, which is an important index to assess the performance of the grounding device. The graphite-based flexible grounding device applied in extra-high voltage transmission lines needs to increase the graphite cross-sectional area to reduce the current density, thus reducing the temperature rise under high current.

In this paper, the application of flexible graphite grounding material based on the retrofit is carried out for the problems of difficult construction of grounding networks such as distribution line towers, high soil resistivity, easy corrosion of traditional grounding bodies, and difficulty in meeting the specification requirements in Tibet. According to the soil address conditions in the area and the survey results of the grounding resistance of the typical address structure of the tower, the construction plan of the tower grounding network of "work frequency preservation and impact reduction" is proposed and evaluated by numerical analysis. The requirement of grounding resistance ≤4Ω after modification shows that the use of flexible graphite grounding material can effectively reduce the grounding resistance of Tibetan mountainous distribution line towers, achieve long-term stability of the tower ground network, improve the project progress by 30%, and reduce the construction cost by 20%, which has good application and promotion value.

References

[1] Dong Gang, Jiang Jian, Qian Shuaiwei, Jiang Zenghong, Wei Yihuan, Wang Chen, Yang Haifeng. Application of flexible graphite grounding electrode in the grounding transformation of 10 kV line

ISSN: 2710-0588

towers in Guilin area [J]. Modern Building Electricity,2020,11(10):41-44.DOI:10.16618/j.cnki. 1674-8417.2020.10.009.

[2] Chen H. Y., Jing H. C., Song T. J., Lv W. J., Wang Q. R.. Application of flexible graphite grounding electrode in mountain wind power projects[J]. Northeast Power Technology,2020,41(06):26-29+49.

[3] Zhang G. F., Huikang K., M. Kong Y., Guo J. Study on the applicability of graphite-based flexible grounding device in power transmission lines[J]. Electrical Technology,2021,22(10):93-97+103.

[4] Kong, Xiangmei, Zeng, Ting, Wu, Zhe, Liu, Chenggang, Xu, Liangzhao. Application of flexible graphite grounding body in transmission line grounding[J]. Electric World,2020,61(04):27-28.

[5] Lin, Tu-Fang, Zhang, Q-Xiong. Case practice of applying graphene composite grounding system to reduce grounding resistance[J]. Electrotechnology,2020(12):91-93+96.DOI:10.19768/j.cnki.dgjs. 2020.12.033.

[6] Zou Shengxing,Xi Xiaoqiang,Wan Xiaobo. Application of graphite cable flexible grounding electrode in power transmission lines[J]. Shandong Electric Power Technology,2020,47(05):41-45.

[7] Jiang Zili. Analysis of economic applicability of traditional grounding device and graphite grounding device[J]. Mass Electricity,2021,36(11):68-69.