Research on Flexible Graphite Grounding Materials Based on Carbon Nanotubes Modified Technology and Its Application

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Abstract. Aiming at the existing poor corrosion resistance, difficult transportation and construction of metal grounding material in transmission line grounding grid, this paper designed and prepared flexible graphite grounding materials based on carbon nanotubes modified technology. The performance of new grounding materials was analyzed and electrical performance experiments were carried out. The final trial site application example showed that the material can meet the practical engineering applications.

Introduction

Lightning Stroke Tripping has been a major cause of system fault in power transmission line, the key of lightning protection lies in grounding, too large tower grounding resistance is the main cause of the line counterattack trip. Thus low resistance, long-term stability of transmission line tower grounding grid is an important guarantee to reduce the accident rate by lightning, keep the safe and stable operation of system power.

In this paper, a new type of grounding material - flexible graphite composite grounding material was prepared to solve the problem of transportation and construction difficulty, poor corrosion resistance, prone to theft and other issues of metal materials. This article briefly described the preparation of novel material, and performance characteristics of the grounding material. Then, the novel grounding material has been optimized based on carbon nanotube modification technology. Finally, flexible graphite grounding material based on carbon nanotubes modified technology was typically applied in one 220kV transmission lines in the mountains, which showed its practical application.

Flexible graphite grounding material properties

Preparation of flexible graphite adopted concentrated sulfuric acid as an interlayer insert, which mostly was eluted through washing and drying after completion of the reaction of graphite with an acid. So it is actually the residual graphite intercalation compounds. The most of interlayer inserts were gasified when rapidly heated the graphite intercalation compound, and formed a high pressure, the graphite particles were expanded along the C-axis direction, finally formed the flexible graphite.

Compared to the existing metal grounding materials, flexible graphite grounding material has more excellent characteristics: good electrical conductivity and impulse current withstand characteristic, by actual measurement, the resistivity of the grounding material is $3.25 \times 10^{-5} \Omega \cdot m$, if combined with conductive fibers whose resistivity can be reduced $10^{-6} \Omega \cdot m$ level; reliable corrosion resistance, corrosion resistance is far superior to metal grounding material under the conditions of acid, alkali, salt and other soil, using in conjunction with a reducing agent will not cause corrosion of grounding devices, which can reduce the cost of whole life cycle of the grounding device; stable mechanical structural, flexible features of the grounding material makes good bending and torsional performance, which can meet the actual needs of the grounding construction; good thermal stability; convenient transportation and construction, and high soil fit; prevent theft and vandalism, the
secondary use of graphite composite grounding material has low-value, which can effectively prevent human theft and sabotage.

Optimization of flexible graphite grounding materials

Flexible graphite grounding materials modified by carbon nanotubes. Flexible graphite material can solve the problem that corrosion resistance of metal grounding material of transmission line is poor, but it is still with some drawbacks, like low mechanical strength, low conductivity, etc. So flexible graphite material needs some modifications. While carbon nanotubes is good at conductivity, and it’s aspect ratio and mechanical strength are high. If carbon nanotubes can be dispersed into flexible graphite evenly, assembling the two substances which are different in structure but similar in working principle, taking advantage of their synergy, highly conductive carbon nanotubes can help electrons between graphene sheets transporting, a substantial increase would have been in the conductivity of flexible graphite. What’s more, small size effect of carbon nanotubes can increase the mechanical strength of the flexible graphite.

Since the flexible graphite prepared process needed oxidation by acid, the graphite structure was partially destroyed and contained part of the oxygen-containing functional groups, which led to a larger decrease in its conductivity, so adopted hydrazine hydrate as a reducing agent to reduced graphene oxide and removed the oxygen-containing functional groups of flexible graphite sheets, so that it can be transformed into a good conductive graphite after the complete reduction of insulating graphite oxide. Principle of flexible graphite modified by carbon nanotubes shown in Figure 1, in which GO is flexible graphite of oxidized state, GR is flexible graphite reduced by hydrazine.

![Figure 1](image1.png)

Figure 1. (a) Flexible graphite / carbon nanotube composites schematic. (b) Flexible graphite / carbon nanotubes TEM image

Performance Testing. Used four-terminal micro-resistance tester measuring the resistivity of graphite composite grounding material, the wiring shown in Figure 2.

![Figure 2](image2.png)

Figure 2. Wiring method of graphite composite grounding material resistance measurement.

Resistance measurement test. Used micro-resistance tester to measure DC resistance, and calculated the resistivity according to graphite grounding devices’ length and radius, the sample size: the diameter was 0.028m, length was 1m. According to the formula \( \rho = \frac{R}{\frac{1}{s}} \) to obtain the resistivity of grounding device, as shown below in table 1:
Table 1. DC resistance of grounding devices.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC resistance</td>
<td>0.635</td>
<td>0.0612</td>
<td>0.0601</td>
</tr>
<tr>
<td>Resistivity</td>
<td>0.000039</td>
<td>0.000038</td>
<td>0.000037</td>
</tr>
</tbody>
</table>

From the test results, the sample average resistance was 0.000038Ω•m, and the difference of the detection result was very small, which was in the range of entirely acceptable. According to the actual operating experience, grounding devices retained stable structure when applied more than 120 kA surge current, which meet the dissipation of lightning current and short-circuit fault current.

**Frequency current and inrush current withstand test.** Took six standard samples, three samples were applied 20A-frequency current for 10 times, each time for 10s, time interval was 30min; the other three samples were applied 8 / 20μs, 5kA inrush current for 10 times, time interval was 1min. Experimental results was shown as follows in table 2:

Table 2. Frequency current and inrush current withstand experiments data table.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency current withstand experiments</td>
<td>grounding resistivity before experiments [m.Ω]</td>
<td>0.000039</td>
<td>0.000038</td>
</tr>
<tr>
<td>Resistivity change rate[%]</td>
<td>2.6</td>
<td>0</td>
<td>2.7</td>
</tr>
<tr>
<td>Continue resistance[m.Ω]</td>
<td>1.4,1.4</td>
<td>1.6,1.2</td>
<td>1.2,2.7</td>
</tr>
<tr>
<td>Inrush current withstand experiments</td>
<td>grounding resistivity before experiments [m.Ω]</td>
<td>0.00004</td>
<td>0.000038</td>
</tr>
<tr>
<td>Resistivity change rate[%]</td>
<td>0</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Continue resistance[m.Ω]</td>
<td>1.2,1</td>
<td>0.9,1.3</td>
<td>1.2,6</td>
</tr>
</tbody>
</table>

So we could see from the table that the rate of change in resistance of samples are much smaller than the change rate of 20%, which indicated that the test sample frequency and impact of current withstand tests were qualified.
Modified grounding graphite composite material application

Finally, the graphite-based flexible grounding device was applied at a actual 220 kV transmission line tower grounding grid in a mountainous area, whose soil resistivity was about 102 Ω • m. Live pictures was shown in Figure 4.

![Flexible graphite grounding device construction site](image)

Figure 4. Flexible graphite grounding device construction site

Graphite grounding composite device was buried in the around base of the tower in actual construction. Construction adopted four flexible graphite grounding devices with length of 10m and diameter of Φ28mm according to the topographical features of the tower foundation. The horizontal portions of grounding devices were interconnected and the average buried depth of grounding grid was about 2m. Measured grounding resistance of four defectors after the tower base were backfilled, power frequency grounding resistance value was stable at 5.13 Ω, which met the relevant standards that power frequency grounding resistance can not exceed 10Ω under the soil resistivity for grounding grid.

Field application showed that carbon nanotubes modified flexible graphite grounding material can effectively prevent corrosion in extreme soil conditions, tower grounding grid grounding resistance could meet the standards, therefore, this new grounding material has actual engineering applications value and application prospects.

Conclusion

In this paper, a new flexible graphite grounding material was designed and prepared in order to solve the poor corrosion resistance of the metal grounding material in existing transmission lines, and optimized the material based on carbon nanotube modification technology. The material has strong corrosion resistance and good electrical conductivity, light weight easy to transport, good bending and torsional performance easy to construction, and the secondary use of value is vary low which may be effective in preventing theft and sabotage. Applying the material for transmission line grounding grid has great practical value, field application shows that the material can meet the requirements of the grounding grid.

Reference


